HYGIENE AND ECOLOGY

Under the general editorship of Corresponding Member of National Academy of Medical Sciences (NAMS) of Ukraine, Professor *V. G. Bardov*

A textbook for students of higher medical institutions

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Taking into account the present-day achievements of human health and biosphere science the manual containts the theoretical backgrounds, methodology, goals and objectives, overarching environmental issues, structure and characteristics of the current state of the Earth's atmosphere, hydrosphere and lithosphere, study of the influence patterns of physical, chemical, biological and psychological factors on human health and public health, the use of established patterns to develop methods and systems for preventing the impact of negative gradations of these factors.

The manual consists of 38 topics, which include all sections of the academic programme and all main sections of the study discipline "General hygiene and human ecology": propedeutics of hygiene, human ecology, basics of the doctrine of the biosphere, global issues of biosphere pollution, influence patterns of natural and anthropogenic components of the biosphere on the human health and public health, main principles of municipal hygiene, nutrition hygiene, occupational hygiene, hygiene of children and adolescents, hygiene of health care facilities, radiation hygiene, hygiene in emergencies, military hygiene, tropical hygiene, personal hygiene, etc.

For students of higher medical institutions of the IV accreditation level, intern doctors, family doctors and practicing doctors.

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Preface

The World Health Organization released a list of top 10 threats to global health in 2019. Foremost among these threats are air pollution and climate change. 9 out of 10 people around the world breathe unclean air every day. According to the data of WHO, air pollution kills 7 million people every year by causing such diseases as cancer, cerebrovascular accident, heart and lung diseases.

Pollution of the atmosphere, hydrosphere and lithosphere, i.e. the Earth's biosphere, has become a global threat, which has turned a number of megacities into places of ecological catastrophe.

By the impact of the global greenhouse effect, there are such terrible phenomena as London Smog, Los Angeles Smog and Alaska Smog, acid rains, expanding area of desert "dead" zones on the planet, global water shortage, global climate-related disasters, gales and tornadoes, inundation, floods, heat waves, forest fires. The consequences are conflicts, wars and human migration, worldwide risk of massive flooding, widespread famine, extinction of many species of animals and plants.

These circumstances have stimulated the Ministry of Education and Science (MES) of Ukraine to pass a set of regulations on "ecologization" of teaching in all higher educational institutions of our State.

The course "Hygiene and ecology" in medical universities have always been intended for study of environmental impact on individual health and public health, and the use of established patterns to develop measures for the prevention of human diseases. Therefore, the latest scientific achievements in the field of hygiene, environmental ecology and human ecology were used to create this manual.

This manual was structured according to the master's degree academic programmes with majoring in 221 "Dentistry", 222 "Medicine" of higher educational institutions of Ukraine of IV accreditation level.

The manual "Hygiene and ecology" contains 38 topics in the form of educational content for lectures, practical classes, extramural studies and research work of students in the field of hygiene, environmental ecology and human ecology.

Corresponding Member of NAMS of Ukraine,
professor V. G. Bardov

List of common abbreviations

ADI	Acceptable daily intake
AII	Acute intestinal infection
AL	Allowable levels
AST	Advances in science and technology
BCS	Building Codes and Standards
BM	Basal metabolism
ChNPP	Chornobyl nuclear power plant
CP	Cogeneration plant
DDT	Dichlorodiphenyltrichloromethylmethane
DF	Daylight factor
EEVA	Equivalent equilibrium volume activity
EMF	Electromagnetic fields
EU	European Union
FAO	Food and Agriculture Organization
FE	Fuel elements
GMP	Good Manufacturing Practices
HCC	Halogen-containing compounds
HCF	Health care facilities
HCH	Hexachlorocyclohexane
IAEA	International Atomic Energy Agency
ICD-10	International Classification of Diseases, 10th revision
ICRP	International Commission on Radiation Protection
IMO	International Maritime Organization
IR	Ionizing radiation
IUCN	International Union for Conservation of Nature and Natural Resources
LC	Light coefficient
LWGR	Light water graphite-moderated reactor
LWR	Light water reactor
MAC	Maximum allowable concentration
MAD	Maximum allowable dose

MAL	Maximum allowable level
MED	Minimal erythema dose
MSW	Municipal solid waste
MTD	Morbidity with temporary disability
NCI	Nosocomial infection
NORM	Naturally occurring radioactive materials
NPP	Nuclear power plant
NRBU	Norms of Radiation Safety of Ukraine
PAH	Polycyclic aromatic hydrocarbons
PAR	Physical activity ratio
PCB	Polychlorinated biphenyl
PCC	Polychlorocamphene
PCP	Polychloroprene
PUFA	Polyunsaturated fatty acid
RAW	Radioactive waste
RL	Reference levels
RP	Radiation protection
RPh	Radiopharmaceutical
SBC	State Building Code
SES	Sanitary-epidemiological station
SF	Surfactants
S-SF	Synthetic surfactants
SIR	Sources of ionizing radiation
SP	Solid particles
SPZ	Sanitary protection zones
SSC	State Sanitary Code
STR	Scientific and technological revolution
TENORM	Technologically enhanced naturally occurring radioactive materials
TS	Technical specifications
TS(E)L	Tentatively safe (exposure) level
TPP	Thermal power plant
UHF	Ultrahigh frequency
UN	United Nations

UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNSCEAR	United Nations Scientific Committee on the Effects of Atomic Radiation
UV-	Ultraviolet
UVR	Ultraviolet radiation
VML	Mercury vapor lamp
WHO	World Health Organization
WMO	World Meteorological Organization
WTO	World Trade Organization
WWER	Water-water energetic reactor

1 CHAPTER PREVENTIVE MEDICINE. HYGIENE AS A SCIENCE. SANITATION

V. G. Bardov, S. T. Omelchuk, N. V. Merezhkina

1.1. Introduction to hygiene

Medical education lasts for 6 years, and then throughout their lives doctors fight to preserve and promote health as a core value of a human.

When mastering the vast majority of academic disciplines of medical university, students study some issues of disease prevention, but the main preventive discipline is hygiene.

Students study this subject during the fourth and fifth semesters at the departments of hygiene and ecology. At the end of each semester they undergo final unit testing or take an exam. The knowledge of hygiene has a special significance because it is graduate-level subject. At the end of the learning process, sixth-year students undergo "Krok-2" testing and take the state exam in human hygiene and ecology, public health and health care.

1.2. Organizational and methodological support for the study of hygiene and ecology

The university libraries have the following textbooks on the subject "Hygiene and Ecology" (Fig. 1.1 and Fig. 1.2):

1. Гігієна та екологія. Підручник / За редакцією В. Г. Бардова. — Вінниця : Нова Книга, 2006. — 720 с.
2. Профілактична медицина. Загальна гігієна з основами екології / І. І. Даценко, Р. Д. Габович. — Київ : Здоров'я, 2004. — 792 с.
3. Загальна гігієна. Пропедевтика гігієни / Є. Г. Гончарук, Ю. І. Кундієв, В. Г. Бардов та ін./ За ред. Є. Г. Гончарука. — К. : Вища школа, 1995. — 552 с.
4. Основи екології : підручник для студ. вищих навч. закладів / [В. Г. Бардов, В. І. Федоренко, Е. М. Білецька та ін.]; за ред. В. Г. Бардова, В. І. Федоренко. — Вінниця : Нова Книга, 2013. — 424 с.
5. Комунальна гігієна / Є. Г. Гончарук, В. Г. Бардов, С. І. Гаркавий та ін. / За ред. Є. Г. Гончарука. — К. : Здоров'я, 2003. — 726 с.
6. Гігієна праці / ред. Ю. І. Кундієв, О. П. Яворовський. — К. : Медицина, 2011. — 904 с.
7. Гігієна харчування з основами нутриціології, у двох книгах / За ред. В. І. Ципріяна. — К. : Медицина, 2007. — кн. 1 — 528 с., кн. 2 — 544 с.
8. Радіаційна гігієна / В. О. Мурашко, Д. С. Мечев, В. Г. Бардов та ін. — Вінниця : Нова Книга, 2013. — 376 с.
9. Гигиена и экология / Под общей ред. В. Г. Бардова. — Винница : Нова Книга, 2008. — 720 с.
10. Коммунальная гигиена / Е. И. Гончарук, В. Г. Бардов, С. И. Гаркавый и др. / Под ред. Е. И. Гончарука. — К. : Здоров'я, 2003. — 792 с.
11. Общая гигиена. Пропедевтика гигиены / Е. И. Гончарук, Ю. И. Кундиев, В. Г. Бардов и др. — К. : Вища школа, 2000. — 652 с.
12. Oxford textbook of Public Health / Under Roger Detels, James McEwen, Robert Beaglehole and Heizo Tanaka edition. — USA, Oxford. — Fourth edition, 2005. — 1955 p.
13. General Hygiene and Environmental Health / Under M. M. Nadvornyi edition. — Odessa, 2005. — 242 p.
14. Korobchanskiy V. A., Vorontsov M. P., Musulbas A. A. Hygiene and Ecology. — Kharkov, 2006. — 207 p.
15. Hygiene and ecology: textbook for students of higher medical educational establishments / Under the editorship of corresponding member of NAMS of Ukraine, prof. Bardov V. G. — Vinnytsia : Nova Knyha, 2009. — 688 p.
16. Medicine of emergency situations: textbook for students of higher medical institutions / V. V. Chaplyk, P. V. Oliynyk, S. T. Omelchuk, V. V. Humenyuk. — Vinnytsia : Nova Knyha, 2012. — 344 p.



Fig. 1.1. Ukrainian-language manuals (and few Russian-language comparables, ed. note)



Fig. 1.2. English-language manuals

17. Environmental Health. From global to local / Under Howard Frumkin edition. — Third edition. — San-Francisco, 2016. — P. 767.
18. General nutrition: Study guide for the 4th accreditation level Medical School Students / Edited by S. T. Omelchuk, O. V. Kuzminska. — Kyiv, 2016. — 146 p.
19. Hygiene and ecology: textbook for students of higher medical educational establishments / Under the editorship of corresponding member of NAMS of Ukraine, prof. Bardov V. G. — Vinnytsia : Nova Knyha, 2018. — 688 p.

You can use any of the manuals, but preference should be given to the manuals of recent years.

1.3. Health as an object of hygiene

The World Health Organization considers that caring for people's health is a core purpose among other social tasks. Health of the population — the main value of any country.

As defined by WHO (1946), **HEALTH** is a state of complete physical, mental and social well-being and not only the absence of disease or physical defects (Fig. 1.3).

Ukrainian scientists have given a more voluminous and nuanced definition (R. D. Gabovych): "Health is a normal and harmonious physical and mental development of a person, normal functioning of all body's organs and systems, ability to adaptation to an adverse effect in usual conditions of life and reproduction of healthy posterity, absence of diseases and tendencies to them, high physical and intellectual work capacity, which allows the person to perform the social functions".

Ukraine has a system of state measures to protect and improve the health of the population. These measures are applied by various services and institutions, but the key role is played by the public health service.

Caring for people's health is the most important task of medical science and practical healthcare. The solution of this task is achieved by implementing two sets of measures:

- prevention, i.e. health promotion and disease prevention;
- treatment or health recovery.

Both sets of measures to fight for the health of the population and an individual are carried out simultaneously. Preventive care is more effective, and therefore it is a priority in the activities of a healthcare practitioner of any profile.

1.4. Environment as an object of hygiene

The existence of a living organism, including human, is impossible without an environment. "Life is a way of existence of protein bodies, the essential moment of which is a constant metabolism with nature. Cessation of this metabolism means the end of life." F. Engels. The outstanding Russian physiologist I. M. Sechenov said that the existence of any organism is impossible without an environment, which supports it, and, therefore, the sci-

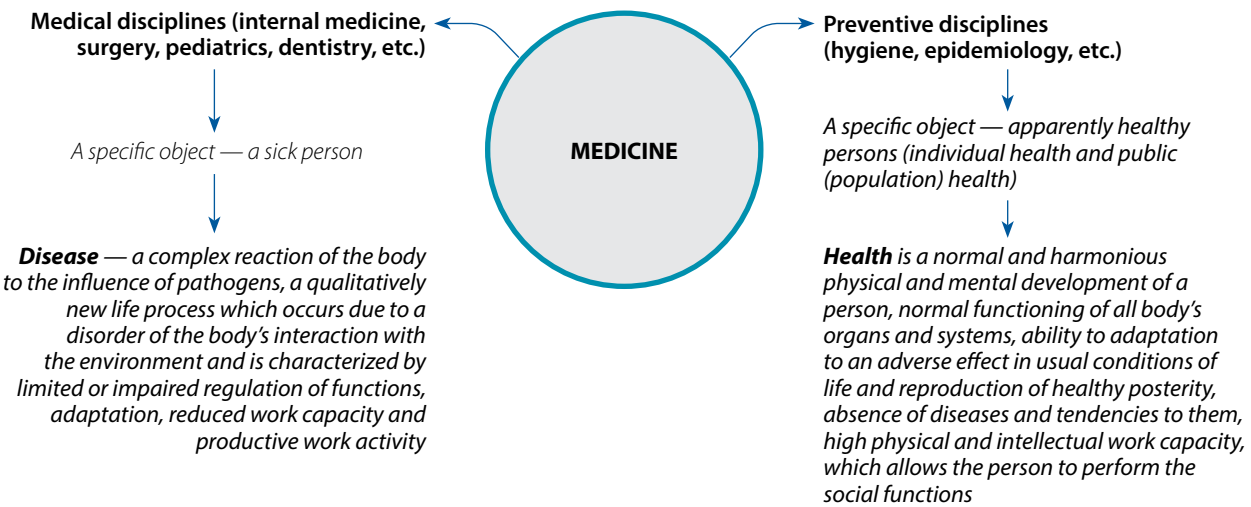


Fig. 1.3. Medical and preventive fields of medicine

entific definitions of the organism should include the surrounding environment.

In terms of science, the concept of "environment" includes everything that surrounds us, that directly or indirectly affects our lives and activities. In the broad sense, the environment includes our entire planet and outer space. The narrow and simplified sense of determining the environment involves only the biosphere. The environment affects the human body and therefore its health, so it is also an object of hygiene. In the following chapters, we will consider its effects in detail.

1.5. Preventive priorities in medicine

Since ancient times, humanity empirically has come to the following conclusion — prevention has a priority in medicine.

As far back as the 4th century B.C.E. "the father of medicine" Hippocrates taught: "The first task of a doctor is to take care of healthy people, therefore, they do not get sick". 2000 years BC in ancient China wealthy mandarins (bureaucrats) evaluated activities of a family physician in a simple manner: if everyone in a family is healthy, the doctor receives his fee; when someone in the family is ill, there is no fee.

Empirical preventive care ideas were cultivated in Ancient Egypt, Babylon, Greece and the Roman Empire: physical health cult, Spartans' way of life, construction of water supply systems-aqueducts, ancient baths-thermae for health promotion, quarantine for patients suffering from infectious disease, cremation of corpses to prevent epidemics, and many other preventive measures.

Practical conclusions of medicine gave grounds to prominent physicians of the past to express ideas about the priority of prevention. The outstanding surgeon M. I. Pirogov wrote: "I believe in hygiene. This is the genuine progress of our science. The future belongs to preventive medicine. This science, going alongside with curative medicine, will bring undeniable benefits to humanity". The great therapeutist S. P. Botkin said: "The first task of a doctor is to prevent a disease; if failed to do this — to treat the patient; in the case of incurable disease — to alleviate suffering". The famous Russian hygienist F. F. Erismann said: "The doctor must not only treat sick persons, but also prevent diseases. This is the ideal aspect of his vocation; this expresses the most effective and useful direction in his work".

PROPHYLAXIS (from the Greek. *prophylaktikos* — precautionary) — a broad system of state, medical and social measures focused on preserving and strengthening the health of the population, upbringing of the healthy young generation, increasing work capacity and people's longevity.

Prophylaxis is the main principle of public health care. One of the most important responsibilities of health workers is taking of measures for disease prevention in healthy people, and prevention of exacerbation, complication and relapse in sick persons.

In Ukraine, prevention means broad system of state, medical and social measures focused on preserving and strengthening the health of the population, the upbringing of the healthy young generation, increasing of work capacity and people's longevity (Fig. 1.4).

There are public and individual prophylaxes. Public prophylaxis is guaranteed by the state measures reflected in the Constitution and basic legislation concerning health protection. These measures guarantee the rights of people to labour, to housing, rest, education and treatment, pension — in other words, the possibility of harmonious development, both physical and intellectual, of preserving their health, ability to work and live without diseases.

Individual prophylaxis includes protection from overstrain of the nervous and other systems, and fight

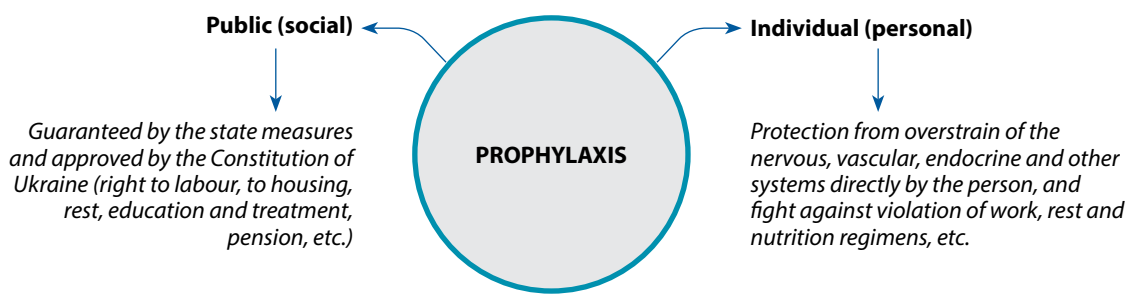


Fig. 1.4. Public and individual prophylaxis in medicine

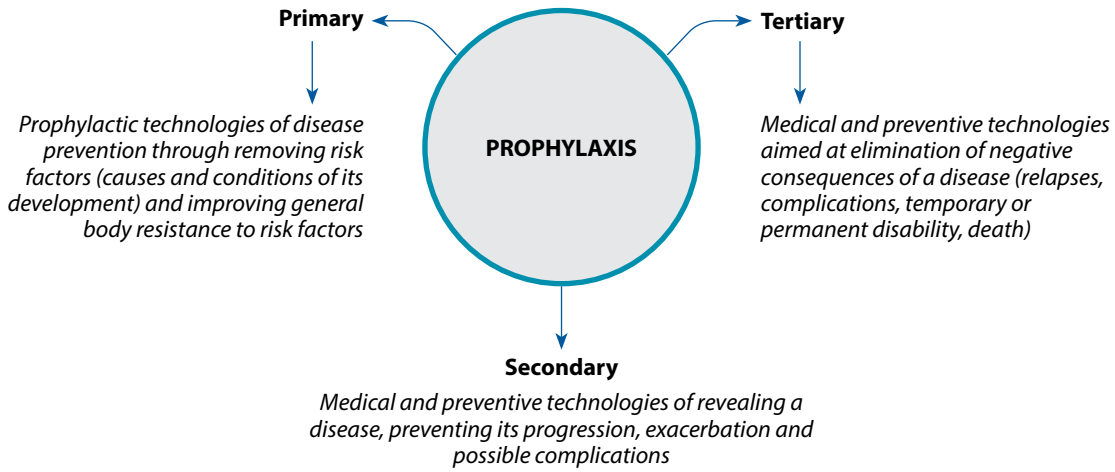


Fig. 1.5. Primary, secondary and tertiary prophylaxis in medicine

against violation of work, rest and nutrition regimens, hypodynamia, alcohol and smoking abuse.

Prophylaxis is divided into three types — primary, secondary and tertiary in accordance to the specific kinds of pathology (Fig. 1.5).

Primary prophylaxis includes prophylactic technologies of disease prevention through removing risk factors (causes and conditions of its development) and improving general body resistance to risk factors. Secondary prophylaxis includes medical and preventive technologies of revealing a disease, preventing its progression, exacerbation and possible complications. Tertiary prophylaxis includes medical and preventive technologies aimed at elimination of negative consequences of the disease (relapses, complications, temporary and permanent disability, death).

The level of population health is directly related to the level of implementation of preventive measures.

Experience proves a wise conclusion of the outstanding Russian therapeutist G. A. Zakharin: "The more experienced the practitioner, the better he understands the omnipotence of hygiene and a relative weakness of therapy. Only hygiene can triumph with the ailments of masses of the population".

1.6. Hygiene as a science. Purpose, tasks, content, methods, relationship with other sciences

Hygiene — the main prevention science in medicine. It summarizes all the data of theoretical and clinical disciplines in the field of prophylaxis, integrates knowledge about the complex impact of the environment on human health and formulates general principles and systems of preventive measures.

The word "HYGIENE" comes from the Greek *higieinos,* which means "one who brings health".

The origin of the name is connected with an ancient Greek legend. The god of Sun Apollo had a son, Asclepius (Aesculapius), who was a sickly child since birth. The father settled the sick Asclepius in the sunny Greek valley and provided him with doctors who cured him of all ailments. After recovering, Asclepius himself began to treat the inhabitants of the valley. His daughters assisted him: Hygieia and Panacea. Due to the fact, Hygieia was more concerned with the health improvement of healthy people and the prevention of diseases, her name was the basis for the name of the science"hygiene", which solves the problem of preventive care. Panacea treated patients. Therefore, her name was the basis for the name "panacea" in curative medicine.

There are different definitions of hygiene as a science.

The founder of hygiene in Ukraine F. F. Erismann (1901) wrote that hygiene is a science that, through "... experimental and statistical research, uses the truths acquired in these ways to improve public health". "If health is defined as a harmonious development of an organism and normal coexistence of all its organs, then the subject of the study of hygiene is all those conditions in its external environment which may affect the organism, disrupt its harmonious development or normal functions of its parts".

The creator of the Russian explanatory dictionary V. V. Dal (1898) defined the following: "Hygiene — the

art or knowledge to preserve health, to protect it from harm."

The Great Medical Encyclopedia of the USSR gives the following definitions of famous hygienists:

1. A. A. Letavet (1958): "Hygiene is a branch of medical science, which studies the impact of living conditions on human health, develops measures aimed at preventing the occurrence of diseases and creating conditions which ensure health maintenance".
2. F. G. Krotkov (1977): "Hygiene — a science which studies the impact of various environmental factors and production activities on human health, work capacity, life longevity and develops practical measures to improve the living and working conditions of human".

The following definition is currently accepted (R. D. Gabovych, 1983): "Hygiene — a science which studies the patterns of environmental impact on the human body and public health in order to give the grounds for hygienic standards, sanitary rules and sanitary measures, the implementation of which provides optimal living conditions, health promotion and disease prevention".

Summarizing the considered definitions, it may be said that **HYGIENE** is a branch of medical knowledge, the science of preserving and strengthening of public (collective) and individual (personal) health by means of preventive measures.

The purpose and tasks of hygiene

The outstanding English scholar E. A. Parks said, that hygiene as a science pursues a great and noble goal — to make the human body "the most perfect, life — the most powerful, dying — the slowest, and death — the most distant".

Tasks of hygiene

1. Studying the natural and anthropogenic environmental factors and social conditions affecting the health of a human.
2. Studying the patterns of the impact of environmental factors and conditions on the human body or the population.
3. Scientific substantiation and development of hygienic standards, rules and measures for rational use of environmental factors beneficial for human body as well as removing the harmful factors or limiting them to safe levels.
4. Practical implementation of developed hygienic recommendations, rules and standards in national economy and health care, controlling and improving their effectiveness.
5. Forecasting the sanitary situation for the near and distant future, taking into account plans of the national economy development, identification of relevant hygienic problems, which go beyond the predicted situation, scientific research of such problems.

The content of hygiene

The content of hygiene as a science is determined by the list of its main branches: social hygiene, municipal hygiene, occupational hygiene, hygiene of children and adolescents, hygiene of health care facilities, military hygiene, radiation hygiene, personal hygiene, marine hygiene, aviation hygiene, railway transport hygiene, sports hygiene, space hygiene, and gerohygiene.

Methods of hygiene

There are:

1. Specific methods of hygiene, which have distinguished hygiene into a certain scientific discipline.
2. Methods of hygienic research.

Specific methods of hygiene:

1. Epidemiological method.
2. Method of sanitary inspection and description.
3. Method of of hygienic experiment:
   - method of field experiment;
   - method of laboratory experiment.
4. Method of sanitary examination.

The epidemiological method aims to study the patterns of spreading noninfectious and infectious diseases depending on the influence of adverse environmental factors (chemical, physical, biological).

The method of sanitary inspection and description is dedicated to studying the environmental conditions on special maps or algorithms of sanitary inspection with mandatory quantitative and qualitative assessments using physical, chemical, biological and other methods of hygienic research.

The method of hygienic experiment is used in hygiene in the form of:

a) field experiment — for example, a study of the population health in real living conditions after the Chornobyl NPP accident;

b) method of laboratory experiment by means of laboratory modeling of processes on animals in the real environment with development of hygienic standards: MAL (Maximum allowable level) MAC (Maximum allowable concentration), TS(E)L (Tentatively safe (exposure) level), ADI (Acceptable daily intake), etc.

Methods of hygienic research (Fig. 1.6) are divided into:

- methods of environmental study;
- methods of studying the environmental effect on human body and health. These methods are considered in detail in practical classes and in independent studies.

Definitions of the topic

- **Inner environment** — the living environment of the organism, which is separated from the external environment by the stratum corneum (horny layer), mucosal epithelium of the respiratory, urogenital and digestive systems and secretory glands, as well as extero- and interoceptors and a set of tissues, including fluid (blood, lymph and tissue substance), which wash over the cells of the intercellular structure.
- **Internal environment** — the metabolic environment, in which it participates, provides nervous and humoral mechanisms of regulation and homeostasis.
- **External environment** — human habitat and production activity environment. It covers working, living, recreation and nutrition conditions (general for the population).
- **Outer environment** — a part of the environment, which is in direct contact with the epithelium of the skin and mucous membranes, affects all types of receptors, which perceive the world around each person on an individual basis.
- **Habitat** — a set of interrelated abiotic and biotic factors that are outside the body and determine its vital activities.
- **Occupational environment** — a part of the environment surrounding human, formed by natural and climatic conditions and occupational factors that affect human in the process of work activity.
- **Unaltered natural environment** — a part of the natural environment that is not changed due to direct or indirect human or social influence and characterized by the capacity of self-regulation without corrective human influence.
- **Modified natural environment** — the environment changed by the injudicious use of it by a per-

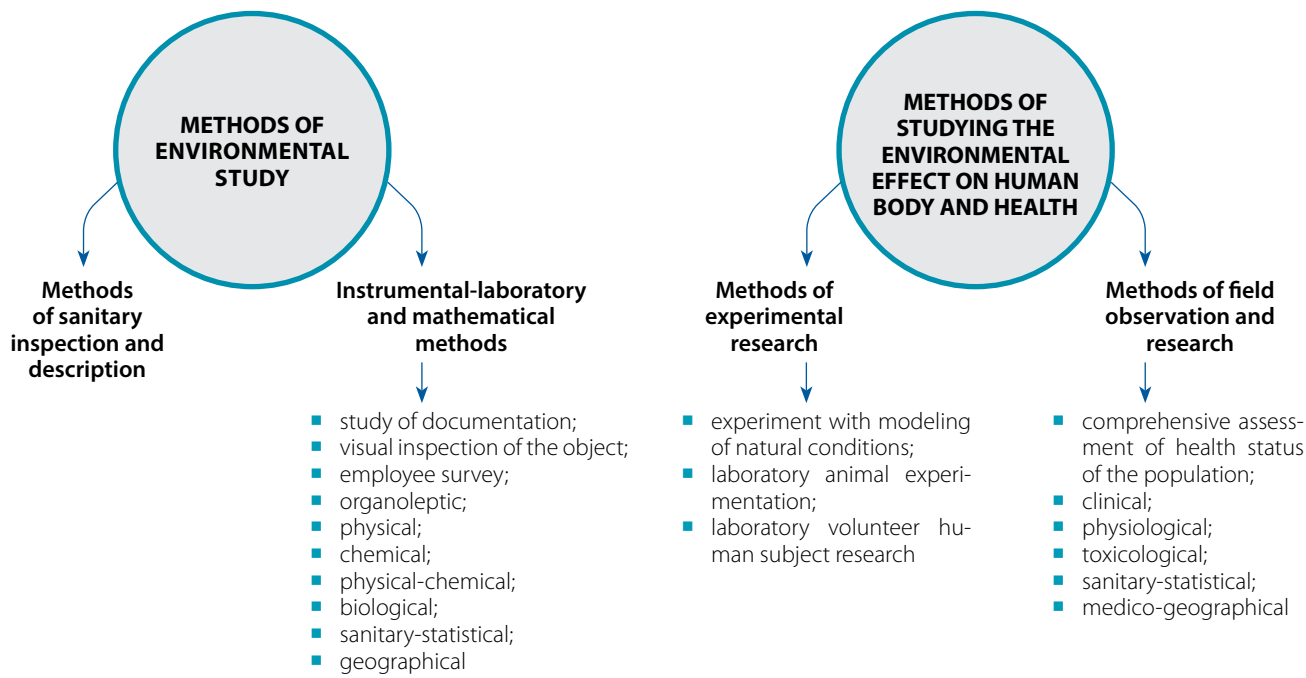


Fig. 1.6. Methods of hygienic research

son in the process of activity, as a result of which there is a negative impact on human health, its activity, living conditions.

Synonyms: *anthropogenic, anthropic, technogenic, denaturated environment.*

- **Artificial environment** — the environment created by human to temporarily maintain its life and activities in artificially created enclosed spaces (spacecraft compartment, interplanetary orbital station, submarine, caisson, etc.).
- **Social environment** — a part of the environment that determines the social, material, mental conditions of its formation, existence and activity: housing, living conditions, family, production, education, science, art, health care, sports, social security, etc.

When studying the impact of the environment on the human body or public health a precise conceptual construct (definition) is used in hygiene: inner environment, internal environment, external environment, outer environment, habitat, occupational environment, unaltered natural environment, modified natural environment, artificial environment, social environment.

The impact of the environment on the body and human health in hygiene is described in the general scheme (Table 1.1).

In 1984, the World Health Organization determined a share of the impact of environmental factors on public health in the form of risk factors:

1. A way of life — 49–53 %:
   - improper nutrition; stressful situations;
   - high levels of urbanization and population density;
   - unsatisfactory living conditions;
   - harmful working conditions;
   - low educational and cultural level;
   - unhealthy habits.
2. Environment — 18–21 % (up to 35 %):
   - rapid change in atmospheric conditions;
   - heliocosmic, magnetic radiation and radioactive emission; high concentration of manufacturing; unfavorable natural and anthropogenic processes; environmental pollution.
3. Genetic factors — 18–22 %:
   - predisposition to hereditary diseases.
4. Medical factors — 8–10 %:
   - lack and ineffectiveness of preventive measures; poor quality and belated medical aid.

Relationship of hygiene with other sciences

Hygiene is associated with almost all sciences (Fig. 1.7). This relationship is determined by the following circumstances.

Hygiene uses data from other sciences to describe the environment as one of its objects. Therefore, hygiene is related to astronomy, geography, geophysics, geology, climatology, meteorology, oceanology, radiology.

Hygiene uses data from other sciences about human and population health as an object of science. This determines the relationship of hygiene with anatomy, histology, embryology, physiology, biochemistry, biophysics, pathological anatomy, pathological physiology, gerontology.

Hygienic research uses methods of other sciences. It indicates the close connection of hygiene with physics, chemistry, biology, microbiology, mathematics, cybernetics.

The results of hygienic research are used for prevention and treatment practice in other sciences; it follows the connection between hygiene and other clinical sciences.

Hygienic standards and recommendations are used in research in all fields of science and in the implementation of all kinds of production activity, providing favorable conditions for education and upbringing, life,

Table 1.1. General scheme of environmental impact on the human body

The human body and health	Environmental factors	Conditions of	Socioeconomic status of
	• physical	Work Life Nutrition Upbringing Education Recreation Treatment	Society Family Human
	• chemical		
	• biological		
	• psychogenic		

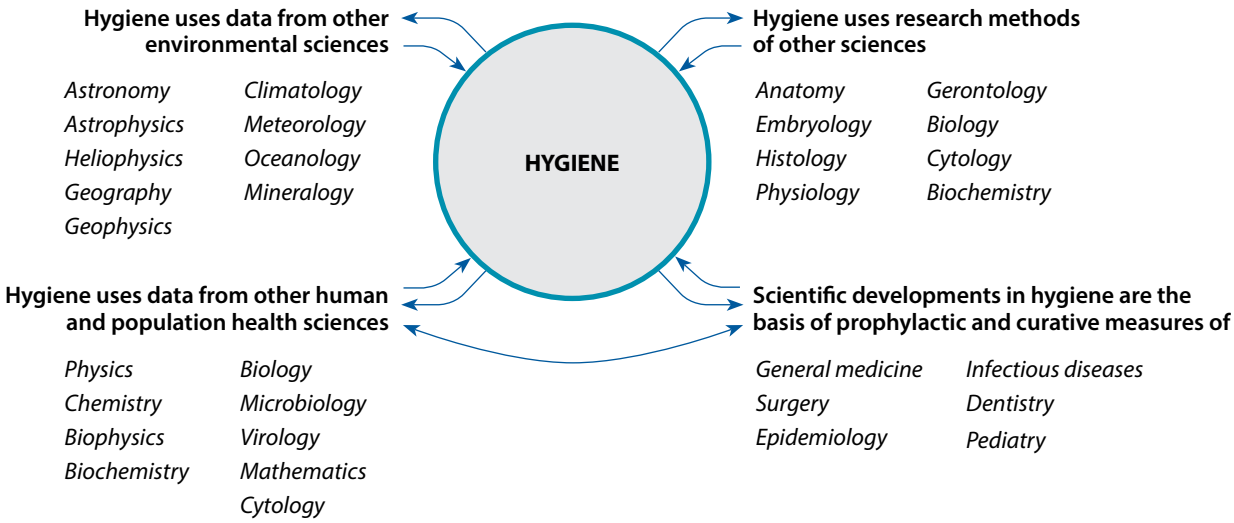


Fig. 1.7. Relationship of hygiene with other sciences

work, recreation and nutrition. This ensures the universal nature of the functional connection of hygiene with all branches of human knowledge.

1.7. Historical review on the development of hygiene

The development of hygiene as a science can be divided into the following main stages:

1. The period of empirical (pre-scientific) hygiene (Fig. 1.8).
2. The period of scientific-experimental hygiene (Fig. 1.9)

The first period roots down to extreme antiquity when at great cost based on life experience people created hygienic measures to save lives, preserve and promote health. These measures were aimed at preventing the spread of infectious diseases (keeping the body clean, isolating infectious patients, burying or cremation the corpses), consumption of safe plant and animal products, compliance with work, rest and sleep regimes, etc. Empirical hygiene was a system of practical skills that was reflected in household rules or religious precepts. During this period, there were constructed buildings that solved hygienic problems. These are aqueducts (water supply system), baths (thermae), sewers of Ancient Rome, Russian baths, Korsun water supply system of the 10th century, Novgorod water supply system and sewerage of the 11th century and so forth.

I. Empirical

Until the 10th century	Medical and sanitary practice in the form of folk hygiene (traditions and rituals aimed at health care)
10–17th centuries	Recording of traditional hygiene in written sources. The beginning of state, social and religious regulatory activity
The late 17th century — the early 18th century	Medical and topographic descriptions of the environment and its impact on human health
The latter half of the 18th century — the early 19th century	Formation of hygiene, dietetics and medical police as a subject of teaching, adoption of sanitary surveillance. Publishing of the first papers on hygiene
1810–1860s	Medical and geographical research (using statistical data) as a method of studying the impact of way of life and working conditions on human health

Fig. 1.8. The period of empirical (pre-scientific) development of hygiene

II. Scientific-experimental

1870–1920s	Experiment and systematic hygienic analysis are used to study the impact of environmental factors on health and its assessment. Independent hygienic departments are created. Hygienic thinking is formed in society
1930s — present	Differentiation and specialization of hygiene, formation of hygienic schools, introduction of precise hygienic regulations. A practical sanitary service has been formed.
1980s — present	System analysis, computerization of research. Continuous study of the state of the environment and its impact on public health, monitoring of hygienic health as an indicator of the environmental conditions

Fig. 1.9. The period of scientific-experimental development of hygiene

The development of capitalism in the late 18th century and the first half of the 19th century and, as a consequence, the growth of industrial centers, the substantial deterioration of the sanitary living conditions of workers, and the development of the natural sciences became the objective preconditions for the second stage of the development of hygiene — scientific-experimental period, which began in the middle of the 20th century.

The founders of this new scientific-experimental direction in hygiene were M. Pettenkofer and M. Rubner in Germany, E. Parks — in England, L. Levi — in France, and O. P. Dobroslavin and F. F. Erismann — in Russia.

O. P. Dobroslavin is the first professor of hygiene in Russia, founder of the St. Petersburg School of Hygiene. In 1871 he headed the first Department of Hygiene at the Medico-Surgical Academy, founded one of the first sanitary laboratories for the investigation of food, water, air and soil. In addition, he is the author of the manual on hygiene.

F. F. Erismann is the founder of the Moscow School of Hygiene. In 1892 he headed the Department of Hygiene of Moscow State University. In 1892 Erismann founded the Moscow Hygienic Society. In addition, he is the founder of school and occupational health hygiene and the author of the manual on hygiene.

The Department of Hygiene in Kyiv is one of the oldest hygienic departments in tsarist Russia. In 1863, the Academic Council of the Medical Faculty of St. Vladimir's University in Kyiv made the decision on its creation. That is, this department was the first among other educational institutions in Russia. The department was opened in 1871 for the training of medical specialists. The department was headed by privat-docent and soon Professor V. A. Subbotin.

Presently there is a network of hygienic institutes and departments in Ukraine. Subdisciplines have been developed into separate disciplines — nutrition hygiene, municipal hygiene, hygiene of children and adolescents, occupational hygiene, and so forth.

In 1922, the public sanitation service was established in accordance with a Decree of the USSR government. This public sanitation service had clearly defined tasks.

The development of hygienic science has contributed to the emergence of a number of scientific achievements, the appearance of outstanding scientists in various fields of hygiene. In the field of municipal hygiene — O. M. Sysin, Z. G. Frenkel, O. M. Marzieev, L. I. Medved, R. D. Gabovych, O. O. Minkh, E. G. Goncharuk, G. I. Sidorenko, M. G. Shandala; occupational (labour) hygiene — V. O. Levytskyi, O. O. Letavet, G. H. Shahbazian; hygiene of children and adolescents — N. A. Semashko, A. V. Malkov, G. N. Serdiukovska; military hygiene — V. A. Ulov, F. G. Krotkov and others.

Due to the prophylactic direction of hygiene science in Ukraine there have been the positive changes in public health: many infectious diseases have been eliminated (plague, cholera, smallpox, typhus, etc.), morbidity and mortality from many infectious diseases significantly reduced, overall mortality decreased more than three times, children's mortality — more than 10 times; life expectancy has more than doubled: from 32 years in 1913 to 71 years now; other health indicators have significantly improved.

However, things aren't that simple. The following subjects will address a large number of issues related to both environmental pollution and the promotion and preservation of individual and public health.

1.8. Sanitation. Types of sanitation

Sanitation (from the Latin word *sanitas* — health) — the practical use of standards, sanitary rules and recommendations developed by the hygienic science providing op-

timization of conditions of education, upbringing, everyday life, recreation and nutrition aimed at strengthening and preserving people's health.

The prominent Soviet hygienist G. V. Khlopin said: "If hygiene is the science of maintaining and strengthening health, then sanitation is a practical activity by which this can be achieved."

Sanitation is provided by sanitary and antiepidemic measures. Implementators of sanitary measures are the entire population of the country, government agencies, enterprises, institutions and organizations, agricultural enterprises, trade unions and other public organizations. Control over the implementation of sanitary and anti-epidemic measures is carried out by the Sanitary and Epidemiological Service, and now — by the State Service of Ukraine on Food Safety and Consumer Protection.

There are school, housing and municipal, industrial and food sanitation (Fig. 1.10).

School sanitation is a system of observance of sanitary norms, rules and hygienic requirements concerning physical development and state of health of children and adolescents, their daily regimen, organization of study, work, recreation, physical culture, as well as design, creation and operation of buildings, furniture, equipment in children's, preschool, school and adolescent institutions.

Housing and municipal sanitation provides measures for sanitary protection of atmospheric air, water and soil from pollution, carrying out rational, scientifically grounded planning, planting, building, sanitary municipal improvement and sanitary conditions of inhabited cities, residential buildings, as well as educational, culture and health care facilities, sports and physical education facilities etc.

Industrial sanitation is a complex of measures of observance of adherence to the standards of industrial environment which provide favorable working conditions and prevent the possibility of occupational diseases, ensure the development of sanitary and engineering means of combating unhealthy working conditions.

Food sanitation is a set of measures to comply with hygienic requirements in the design, construction and operation of food enterprises and institutions, materials and equipment for them, in the development of formulating and food technology, in the production, conservation, transportation, storage of food products, in carrying out measures to prevent nutritional diseases.

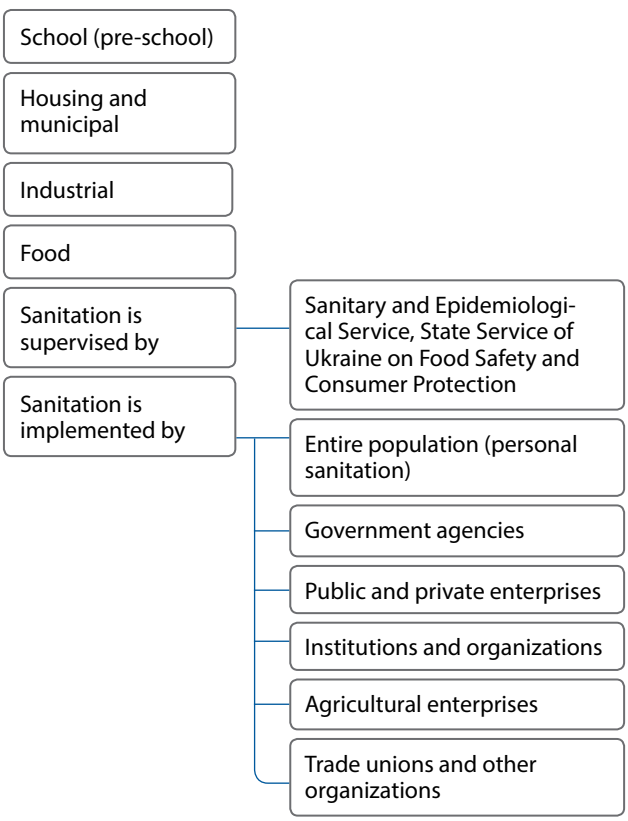


Fig. 1.10. Implementation and control over the implementation of sanitation

1.9. Sanitary and Epidemiological Service of Ukraine

The Sanitary and Epidemiological Service of Ukraine should control the compliance with sanitary measures. The Sanitary Epidemiological Service was established in 1922 by a Decree of the Council of People's Commissars "On Sanitary Institutions of the Republic". This service had a continuous improvement. From 1933 in the Ukrainian SSR, and from 1939 all over the USSR, sanitary-epidemiological stations (SES) were organized and recognized as the major institutions of the Sanitary and Epidemiological Service.

SES is a medical institution that carried out all types of sanitary and anti-epidemic activities in a district, city or region (or province). Sanitary-epidemiological stations were devising solutions of the relevant decision-making authorities on sanitary protection of the environment, measures to improve the conditions of education and upbringing, work, life and recreation of the population. SES managed sanitary and anti-epidemic activities of all health care facilities, conducted preventive and current state sanitary supervision, sanitary education of the population.

Let's consider in more detail the basic forms of activity of preventive and current state sanitary supervision.

Preventive state sanitary supervision is the control over observance of hygienic norms and sanitary rules in the process of designing and construction of projects.

Current state sanitary supervision is a systematic monitoring over the sanitary conditions of all facilities in the region during their operation. In the event of failure to comply with sanitary rules, SES employees could implement corresponding measures, up to the termination of people's activities, instituting administrative action or criminal liability against violators regardless of their official capacity.

It should be stressed once more that a sanitary-epidemiological station carried out primarily state supervision, i.e. competent control, and sanitary measures are carried out by enterprises and institutions themselves, including treatment and prevention. All sanitary-epidemiological stations had sanitary-hygienic departments, which employed state sanitary physicians in municipal hygiene, occupational hygiene, nutrition hygiene, hygiene of children and adolescents, radiation hygiene. Additionally, there were epidemiological departments with functioning bacteriological and virological laboratories.

In 2014, the functions of the Sanitary and Epidemiological Service of Ukraine were transferred to the State Service of Ukraine on Food Safety and Consumer Protection (Derzhprodspozhyvsluzhba).

1.10. Sanitary legislation in Ukraine

The most important component of social and personal prophylaxis is the appropriate legislative maintenance.

What is the sanitary legislation of Ukraine? This includes:

1. The Constitution of Ukraine.
2. Public health laws.
3. The Law "On provision of sanitary and epidemic safety of the population".
4. Laws and regulations of the government on protection of nature, air, water, soil.
5. State standards for quality of industrial products, alimentary products, pharmaceuticals.
6. State Sanitary Code (SSC), Building Codes and Standards (BCS).
7. Hygienic standards (MAC, MAL, MAD, etc.).

These components of sanitary legislation are mandatory for all enterprises and institutions in the country. Few countries in the world have such innovative sanitary legislation. Unfortunately, these regulations, as we shall see further, are not complied by everyone and in every instance.

1.11. The value of hygiene knowledge for doctors specializing in curative medicine

The vast majority of diseases are caused by the mistakes of individuals, primarily due to insufficient preventive activities of health officials. Preventive activities are based on knowledge of hygiene. The qualification profile of a medical doctor specializing in curative medicine legally confirms it. Knowledge of hygiene is necessary for many activities of a medical doctor.

Types of medical activities that require knowledge of hygiene:

1. Analysis of the population health in connection with living conditions.
2. Diagnostics, determination of etiology and pathogenesis of alimentary, occupational and infectious diseases.
3. Prescription of curative (in health care facilities) or preventive (in hazardous employment) nutrition, which promotes the excretion of harmful substances and increases the body's resistance to their action.
4. Professional orientation (matching of the health status to the profession chosen by the person), pre-employment medical examination.
5. Recommendations for day regimen, personal hygiene.
6. Prevention of nosocomial (hospital-acquired) infection.
7. Conducting sanitation and hygiene education for the population (in health care facilities), children's institutions (pediatrician), at an enterprise (doctor of the aid post of the medical unit), in a rural area (doctor of a rural medical unit), family doctor.

2 CHAPTER ECOLOGY AS A SCIENCE. BIOSPHERE

V. G. Bardov, S. T. Omelchuk, N. V. Merezhkina, S. I. Garkavyi, I. V. Serheta, V. I. Fedorenko

2.1. Ecology as a science

The term "**ecology**" derives from the Greek words "*oikos*" (home, dwelling, place of residence) and *logos* (science). The term "ecology" was originally proposed by the German scientist and biologist E. Haeckel in 1866. *Ecology* is a science that studies the organization and functioning of supraorganismal systems at different levels: species, populations, biocenoses (communities), ecosystems (biogeocenoses) and the biosphere.

From a present-day perspective, ***ecology*** is a complex integrated science that studies the state of the environment and the patterns of its impact on human in particular and society in general, as well as the peculiarities of environmental reverse reactions in response to human activities. Thus, ecology as a science which studies the organization of plant and animal life, the interaction of living organisms with the environment, their living conditions, lifestyle, etc.

For historical reasons, ecology is considered a constituent of biology. According to the American ecologist Yu. Odum (1975), ecology is the biology of the environment. Environmental ecology studies all types of ecosystems. Plant ecology studies the relationship of plant organisms to the environment. Animal ecology studies the dynamics and organization of the animal world. In addition, there are the human ecology and the microbial ecology.

The *subject matter of ecology* is an in-depth study of the basics of the structure and functioning of natural systems and human-created systems by means of quantitative assessment methods

The main tasks of ecology:

1. Study of the peculiarities of life organization in connection with the anthropogenic effect on natural systems.
2. Creation of scientific bases of rational exploitation of biological resources.
3. Forecasting nature changes, which occur due to the impact of human activities.
4. Human habitat preservation.

2.2. Human ecology. Tasks, global environmental problems, methods of ecology

At the present stage of ecology development, one of its most dynamic fields, incontrovertibly, should be recognized *human ecology*, which is a complex science that studies the relationship of a human and human society with the environment, develops scientific and methodological foundations for maintaining and strengthening health under constant influence of various environmental factors and social living conditions.

Taking this into account, the *object of human ecology study* is the system "human — environment", or anthropoecosystem. At the same time, the *main tasks of human ecology* as a disciplinary science should be considered as follows:

- study of the state of human health and establishing the features of dynamic changes in its main indices in the natural-historical, socio-economic, and physiological-hygienic aspects;
- study of the impact of certain environmental factors on the health and vital activity of distinct populations;
- study of the processes of preservation and restoration of health and social and labor potential of the population;
- forecasting the state of health of future generations;
- analysis of global and regional problems of human ecology;

- development of ways to improve the level of health, and social and occupational potential of distinct segments of the population;
- conducting of anthropo-ecological monitoring, i.e. the introduction of an effective system of monitoring changes in human life processes due to the effects of various environmental factors;
- medical-geographical mapping that reflects the territorial differentiation of population diseases associated with environmental deterioration;
- determination of scientifically well-founded values of maximum permissible human-made burdens on the human body, etc.

The current stage of development and formation of ecology is marked primarily by the fact that the problems of protection and preservation of the environment cause concern to the population of all countries and society as a whole. Global environmental problems are clearly identified and need to be adequately addressed, namely: environmental pollution, climate change prevention, the "greenhouse effect" and global warming, ozone layer depletion, "acid rain", photochemical smog, disposal considerations, degradation and erosion of soil, deforestation, depletion in numbers of different species of animals, etc.

Ecology as a complex science uses a broad range of methods that are specific to other basic sciences.

According to the content of *research*, there are natural (field) and experimental methods of ecological researches, as well as methods of modeling.

Natural (field) methods involve the study of populations of species and their communities in natural environment; provide an opportunity to determine the patterns of a complex of environmental factors impact on the organism or population, to clarify the general picture of development and vital activity of the species in specific conditions.

Experimental methods afford an opportunity to identify the causes and to establish the nature of the relationship and existence of individual species and individual ecosystems in natural and laboratory conditions, i.e. specially created, different from ordinary conditions.

Modeling methods provide reproduction in simulated laboratory systems on biological models, or on the basis of the application of statistical analysis methods and prediction of various processes inherent in the environment.

2.3. Biosphere and its structure

The biosphere (*bios* — life, *sphere* — layer) is the outer layer of the planet Earth in which all-living matter is concentrated. The founder of a contemporary view of the biosphere is the Russian natural scientist, academician V. I. Vernadskyi.

Biosphere components:

1. Living matter.
2. Biogenous matter.
3. Abiogenous (inorganic) matter.
4. Bioinorganic matter.

Based on the interaction of organisms with each other and with the environment, biogeocenoses or ecological systems are formed in the biosphere, i.e. specific systems of living and non-living components, interrelated by substance and energy exchange.

The biosphere is a system of immense complexity with constantly interacting and interconnected living and non-living components of nature. This system is in a state of dynamic equilibrium: living organisms are connected, and interact with each other.

The biosphere consists of:

1. Atmosphere.
2. Lithosphere.
3. Hydrosphere.

The biosphere has a great power. It includes a part of the lithosphere, i.e. the Earth's crust at the depth down to 10 km, a part of the atmosphere (up to 20–25 km) and the entire hydrosphere to the depth of 12 km (+ 0.5 km of the lithosphere below the bottom) (Fig. 2.1).

Movement (exchange) of substances in the biosphere:

1. Biological.
2. Geological.

The main components of the biosphere are air, water, numerous plant, animal, and microorganism species. All of them participate in the biological cycle of substances that takes place in the biosphere. Solar radiation plays an important role in these processes. Changes in any part of these components affect the entire biosphere. For example, intensive deforestation leads to weather and climate changes, the reducing of atmospheric precipitation, the reducing of surface and groundwater resources, soil erosion, changes in animal and plant species composition.

If the biological cycle of substances is not disturbed, the biosphere and the environment provide human with food, maintain the balance of the atmosphere, water and its purity, soil fertility and so on. The environment and the biosphere are the home of humanity.

A human appeared in the evolution process and he is a product of the environment and its integral part. The biological unity of the human and the environment lies in the fact that human is one of the chains of cycle of

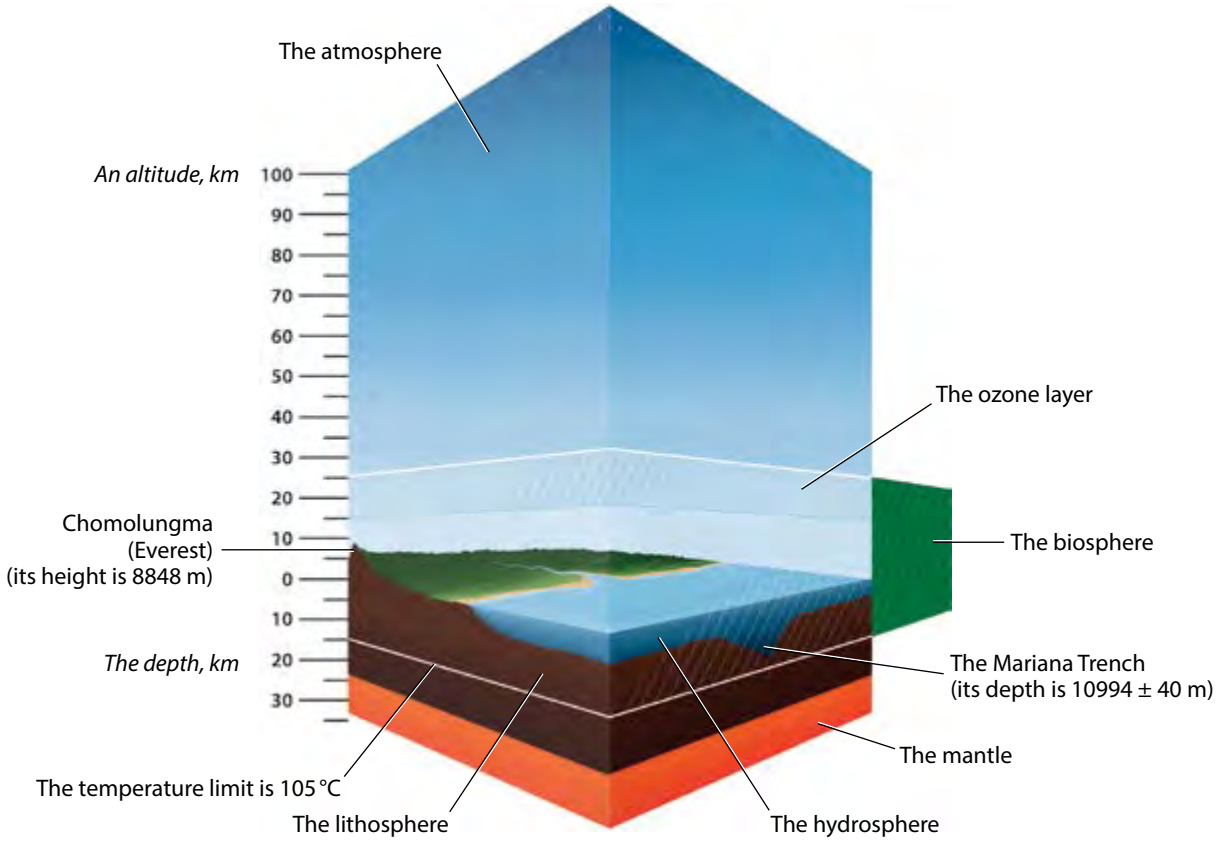


Fig. 2.1. Location of the biosphere in the hydrosphere, lithosphere and atmosphere of the Earth

substances. This indicates that the resources the human body takes from the natural habitat — such as air, water, food — are used by human in the life process and then (naturally, in a modified form) are removed and returned to the environment. Following that, they are broken down into constituent elements and re-enter the biological cycle of substances on the Earth.

The human, as a creature of the Earth's environment, has been adapted to life in its conditions in the process of his development and gradual evolution. Namely, human health and disease are thought of as the products of the human body's interaction with the environment.

In contrast to other species of living organisms, the human, guided by life experience, hygienic knowledge and opportunities that give him social, scientific and technological progress, at certain stages of his development began an aggressive adaptation of the environment to the physiological needs of his body. As a result, ther human has formed his living environment. This means exactly the environment in a broad sense. It includes, in particular, the space development.

2.4. Circulation of substances in the biosphere. Functions of the biosphere

The formation of living matter and its decomposition are two sides of a single process called the biological cycle of chemical elements. Life is the circulation of elements between the organism and the environment.

The processes of the circulation of substances in the biosphere are divided into large (geological) and small (biological) circulations.

The driving force of the large (geological) circulation is tectonic processes and solar energy. The small (biological) circulation of substances is related to the activity of living matter. Both circulations are interconnected and go on simultaneously. They form a single biogeochemical cycle: cyclic constant transformation of substances and change of energy flows with spatial mass transfer through the cumulative effect of biotic and abiotic transformations of matter.

Spatial movement (migration) of substances within geospheres. Main types:

1. Mechanical transfer (occurs without changing the chemical composition of substances).
2. Aqueous (solutes transfer in the form of ions or colloids). This is one of the most important types of movement of substances in the biosphere.
3. Air (movement of substances in the form of gases, dust or aerosols due to the wind currents).
4. Biogenic (movement occurs through the active participation of living organisms).
5. Technogenic (is a consequence of human economic activity).

Within a single biogeochemical cycle of the biosphere, the circulations of six elements are of the greatest importance: water, oxygen, carbon, nitrogen, phosphorus and sulfur (Fig. 2.2, Fig. 2.3, Fig. 2.4, Fig. 2.5, Fig. 2.6, Fig. 2.7).

Biogeochemical water cycle (Fig. 2.2). Water covers the Earth's surface. In one minute, the surface of the Earth's water reservoirs evaporates 1 billion tons of water through exposure of solar heat. Due to a steam condensation, there are cloud formation and atmospheric precipitation. Precipitation seeps into the soil; groundwater returns to the soil surface through the water springs. The atmosphere contains about $1.3–1.5 \times 10^{16}$ kg of water, the bulk of which is concentrated in the troposphere. The water circulation rate is very high: ocean water is renewed in 2 million years, groundwater — in a year, river water — in 12 days, water vapor in the atmosphere — in 10 days. Annually, approximately 1 % of the water in the form of precipitation is used in the processes of photosynthesis to create primary production of the biosphere. Humans already use about 2.5 % of total precipitation per year for domestic and industrial needs.

Biogeochemical oxygen cycle (Fig. 2.3). The natural producers of free molecular oxygen on the Earth are green plants that produce it in the process of photosynthesis. The atmosphere contains $1.2–2.0 \times 10^{15}$ tons of oxygen. Each year this stockpile is recharged by 70–100 billion tons due to photosynthesis of green plants, while 55 billion tons of oxygen are produced by forests. Oxygen is a vital component for the vast majority of living organisms. It ensures the implementation of oxidation reactions with released the energy necessary for the life of organisms. In nature, there is a constant cycle of this gas caused by balanced processes with atmospheric oxygen for respiration, oxidation processes and oxygen release in free form during photosynthesis. As per calculation, the complete cycle of oxygen in the biosphere is carried out in 2000 years.

Biogeochemical carbon cycle (Fig. 2.4). The mass of carbon in the biosphere exceeds 12.000 billion tons. The carbon cycling actually takes place between living matter and carbon dioxide (CO_2). In the process of photosynthesis carried out by plants, carbon dioxide and water are transformed into complex organic compounds by the energy of sunlight. Annually, green plants absorb 200 billion tons of carbon. The bulk of it returns to the atmosphere due to respiratory processes. Degradation of dead plant and animal organisms by fungi and microorganisms releases CO_2, which also returns to the atmosphere. The total carbon stock in the atmosphere is 711 billion tons. So-termed "carbonate system" of the World's

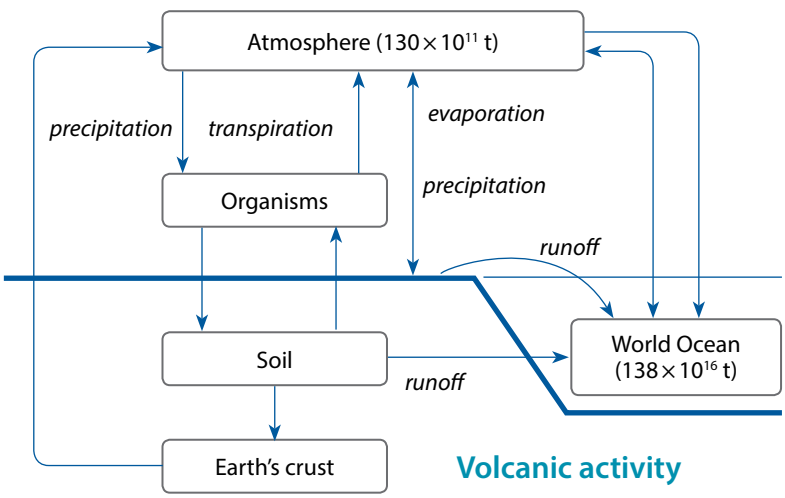


Fig. 2.2. Biogeochemical water cycle

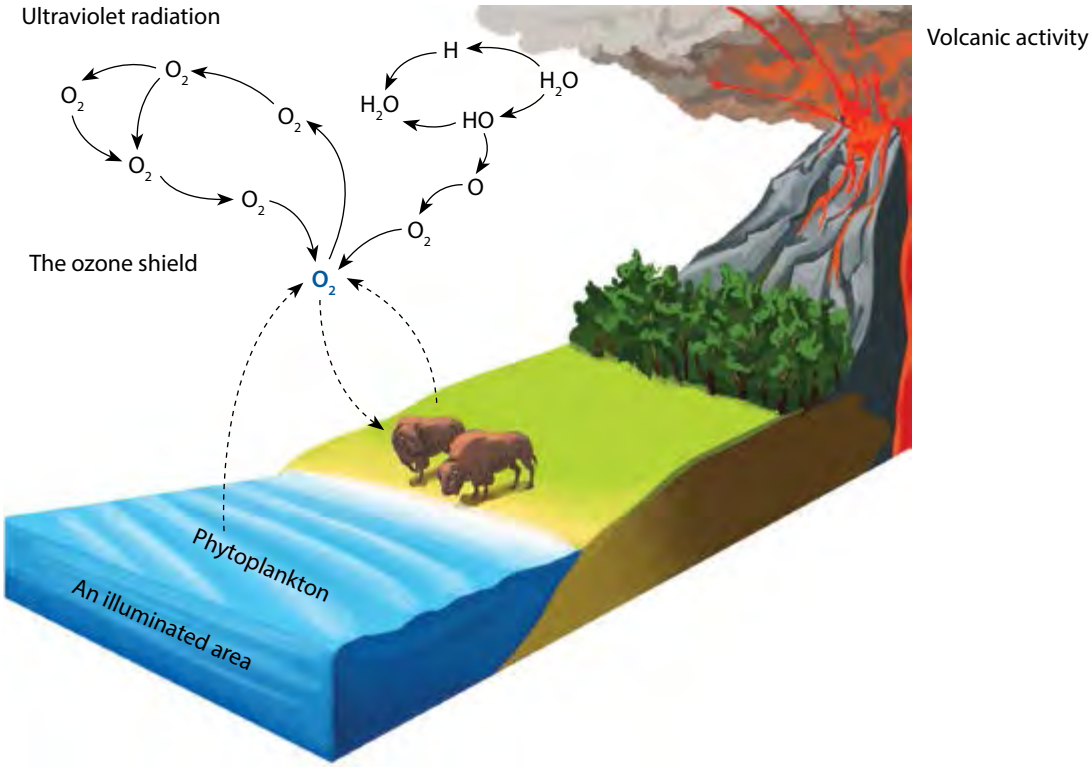


Fig. 2.3. Biogeochemical oxygen cycle

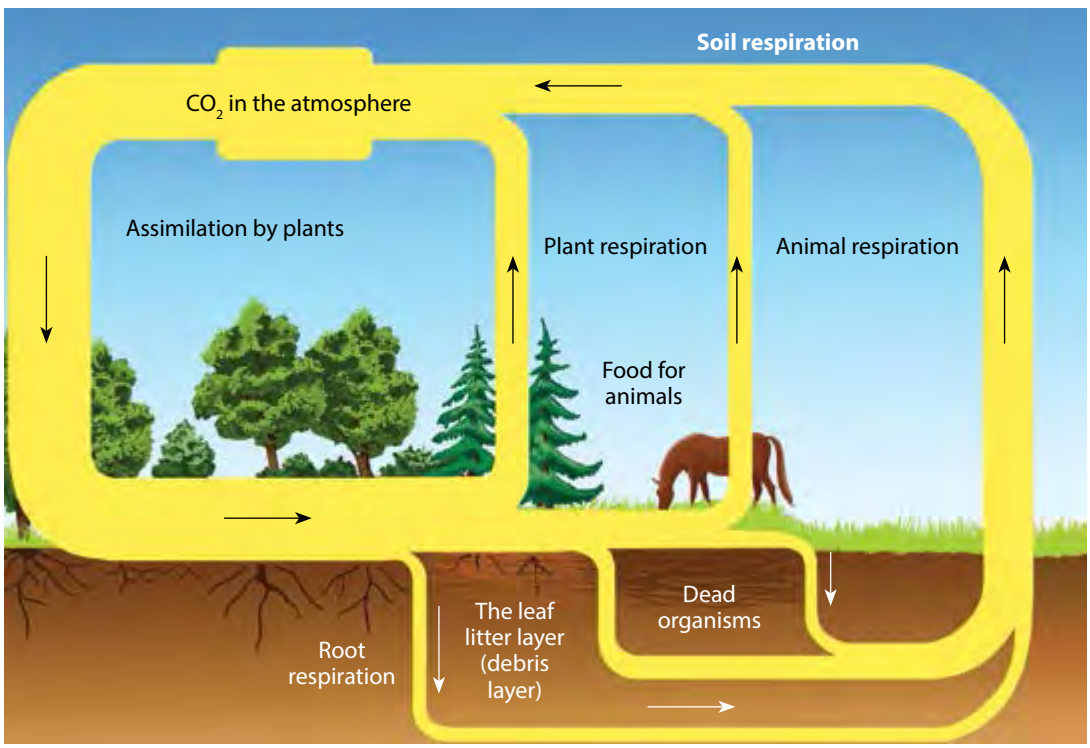


Fig. 2.4. Biogeochemical carbon cycle

Ocean contains even more carbon — 390 trillion tons. The carbonate system of the oceans consists of various living organisms — protozoa, algae, corals, mollusks, etc., which accumulate calcium carbonate in their bodies. The full carbon cycle of biosphere takes place over 300–1000 years.

Biogeochemical nitrogen cycle (Fig. 2.5). The atmosphere is the largest reservoir of nitrogen gas (3.9×10^{19} tons, or 78 % by volume). For most organisms, it is a neutral gas. Only for a large group of microorganisms nitrogen is a factor in life. Assimilating molecular nitrogen, such microorganisms after death provide the roots of higher plants with available forms of this element, which is included in amino acids, proteins and pigments. The nitrogen cycle is carried out through two mutually balanced processes: nitrification (sequential oxidation of free nitrogen to nitrates absorbed by plant roots) and denitrification (reduction of nitrogen-containing compounds to the free form). Both processes are carried out by bacteria. Biological nitrogen fixation is approximately 126 million tons per year. Due to abiogenic fixation (for example, during lightning discharges or volcanic eruptions), the biosphere receives additional 26 million tons of nitrogen in the nitrate form.

Biogeochemical phosphorus cycle (Fig. 2.6). This important and necessary element for living organisms circulates gradually transitioning from organic compounds to phosphates, which can be used by plants again. In contrast with nitrogen, the phosphorus reservoir is not the atmosphere, but rocks and other sediments formed in past geological times. These rocks are gradually eroded, releasing phosphates into ecosystems. Large amounts of phosphates get into the sea, where they are partly deposited in shallow sediments and partly lost in deep waters. Mechanisms for phosphorus returning to the cycle are probably suboptimal and do not make up for losses. Human activity leads to increased loss of phosphorus due to soil erosion. Moreover, the active use of phosphorus in fertilizers leads to eutrophication ("excessive fertilization") of water, followed by rapid reproduction of algae ("water bloom"), which absorb dissolved oxygen and emit toxic metabolic products. This leads to the destruction of the formed natural ecosystems.

Biogeochemical sulphur cycle (Fig. 2.7). This cycle covers air, water and soils, where oxidation and reduction processes take place, due to which sulphur is exchanged between the sulfate available to plants (SO_4)

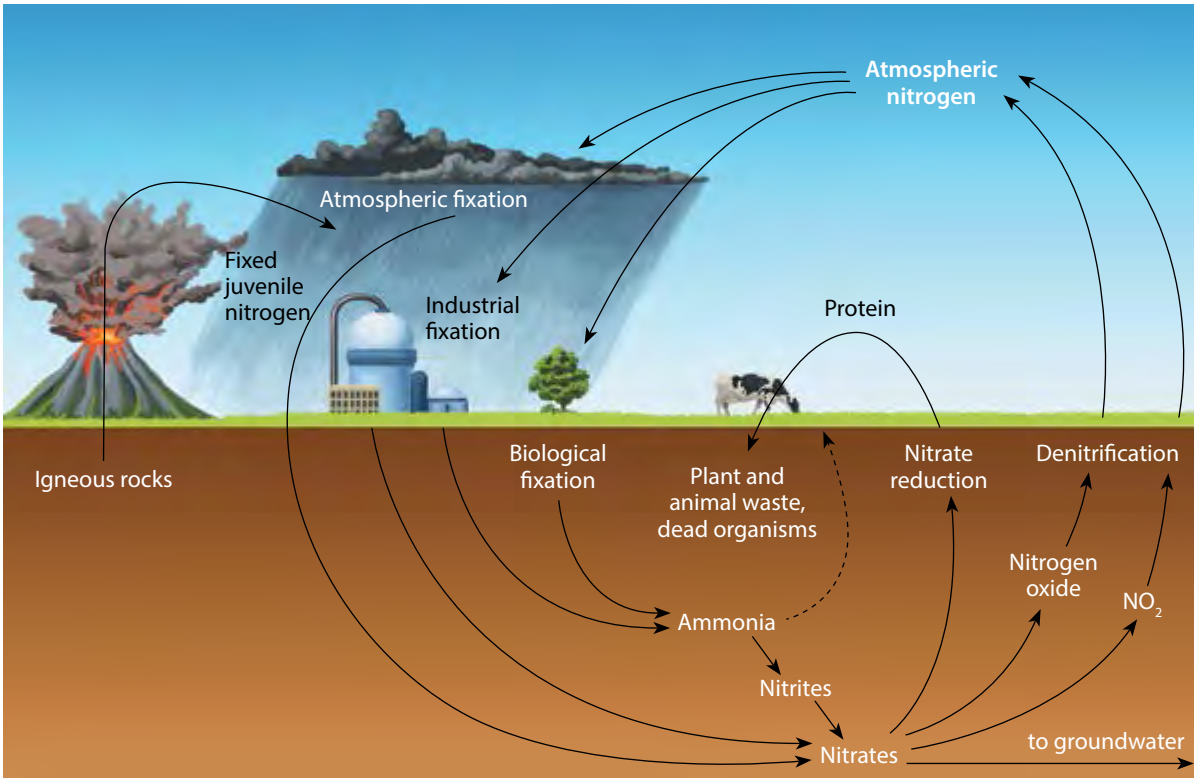


Fig. 2.5. Biogeochemical nitrogen cycle

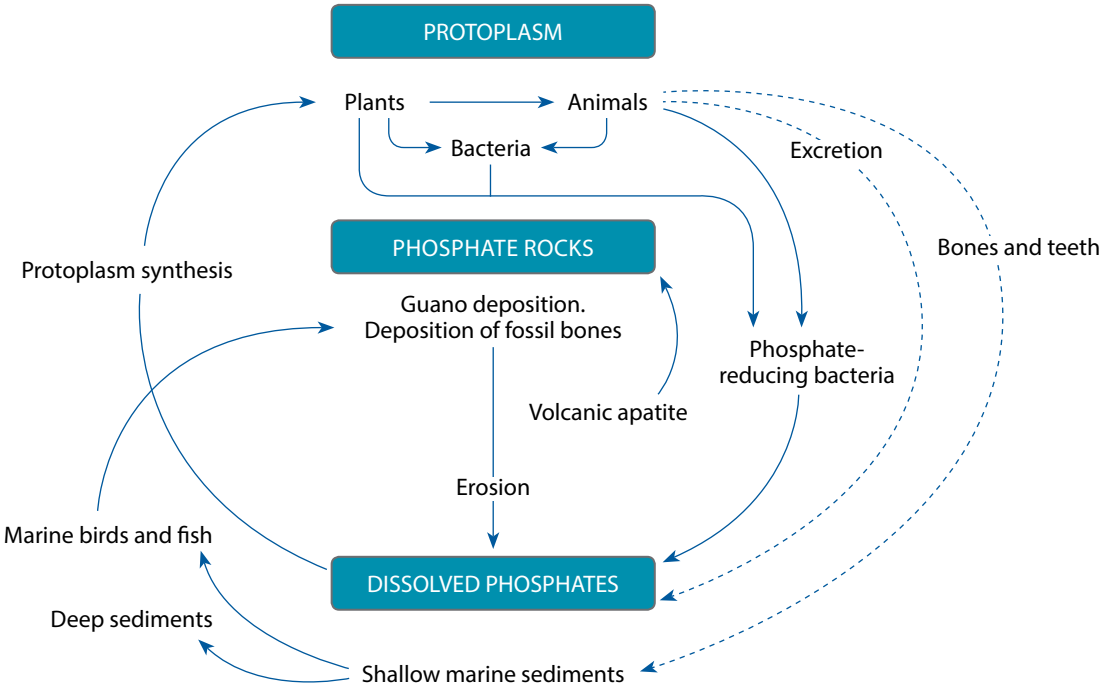


Fig. 2.6. Biogeochemical phosphorus cycle

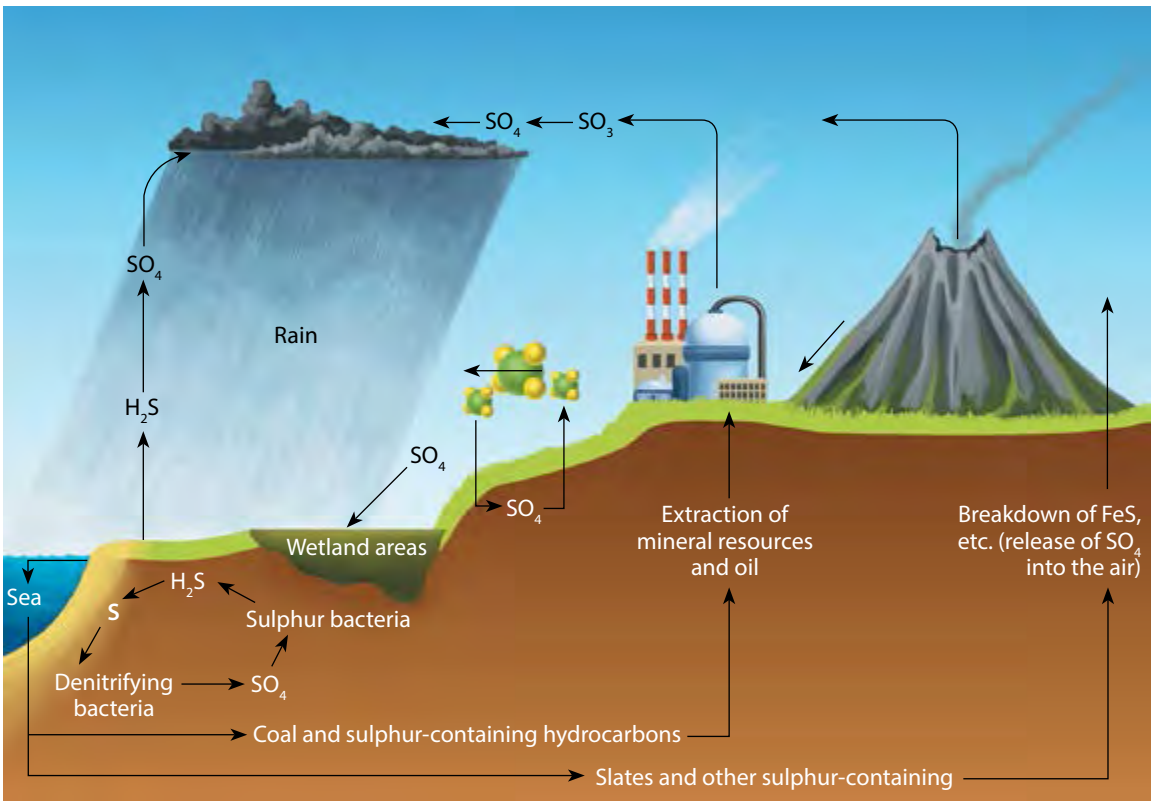


Fig. 2.7. Biogeochemical sulphur cycle

and the iron sulfides storage, which are deep in the soil and sediments. These chemical reactions are performed by specialized microorganisms — sulphur bacteria.

The nitrogen and sulphur cycles are increasingly affected by industrial air pollution. Nitrogen oxides (N_2O and NO_2) and sulphur oxides (SO_2), in contrast to nitrates and sulfates, are toxic. The main source of SO_2 is coal combustion, and of NO_2 — exhaust gases and other industrial emissions. Sulphur dioxide reacts with water vapor. This process forms drops of sulphuric acid, which fall to the ground with acid rain. Acid rain has become a serious problem, causing drying of trees and acidification of lakes over vast areas of Europe and North America.

Industrial emissions of carbon dioxide and a concurrent expansion of oxygen consumption, which is also accompanied by deforestation, threatens to destroy the balance of O_2–CO_2 in the atmosphere, which can cause global climate cataclysms.

Careless human intervention in the natural course of biogeochemical cycles which have formed over tens and hundreds of millions of years of biosphere evolution can cause catastrophic consequences.

Biogeochemical chains for the chemical elements (Fig. 2.8). Microelements are a group of chemical elements contained in the human and animal body in the range of 10^{-3}–10^{-12} of their total body weight. Microelements are very unevenly propagated in the biosphere, and they are all included in the cycle of biogeocenoses, affect the growth, development, reproduction, morphological and physiological variability of living organisms.

The accumulation of chemical elements by living organisms is determined by the biological nature, geochemical properties of the environment, food chains.

The soil composition is heterogeneous in the content of chemical elements. There are regions (areas) with increased or decreased concentration of microelements, and this affects the local flora and fauna in different ways. Such areas are called "biogeochemical provinces".

Heavy metals cycle. Heavy metals are chemical elements with a high relative atomic mass and density (from 5.36 g/cm^3 for germanium to 22.48 g/cm^3 for osmium). In terms of ecology, heavy metals that are most widely used in human production and are toxic and dangerous to living organisms in the context of biological activity deserve to be highlighted. Such elements include lead, mercury, cadmium, zinc, bismuth, cobalt, nickel, copper, tin, antimony, vanadium, manganese, chromium, molybdenum and arsenic.

Heavy metals create "metal pressure" on the biosphere. The cycle of heavy metals occurs according to the following scheme: natural deposits or source of pollution (emissions, discharges, solid waste, pesticides, mineral fertilizers, etc.) environment of deposition (air, soil, water, food) living organisms, including humans.

Cadmium cycle. World's output of cadmium reaches 14.000 tons per year. The average concentration in the environment is 1.6×10^{-5}. About 9.000 tons of cadmium enter the atmosphere annually. Cadmium does not decompose in the environment, it accumulates in the upper soil layers. About 70 % of the cadmium entering the soil binds with group chemical compounds and is absorbed by plants. Cadmium is biologically available; therefore, it is accumulated by bacteria, mollusks, aquatic organisms. Zinc prevents the entry of cadmium into plants. Roots of plants have more cadmium than leaves. It negatively affects the physiological processes in plants, in particular inhibits the processes of photosynthesis. Cadmium accumulates in high concentrations in horse mushrooms, tobacco leaves. Cadmium is soluble in organic acids, so it is easily converted into food.

Mercury cycle. The world stock of mercury is approximately 590.000 tons, and world production is 8.400 tons per year. The average concentration of mercury in

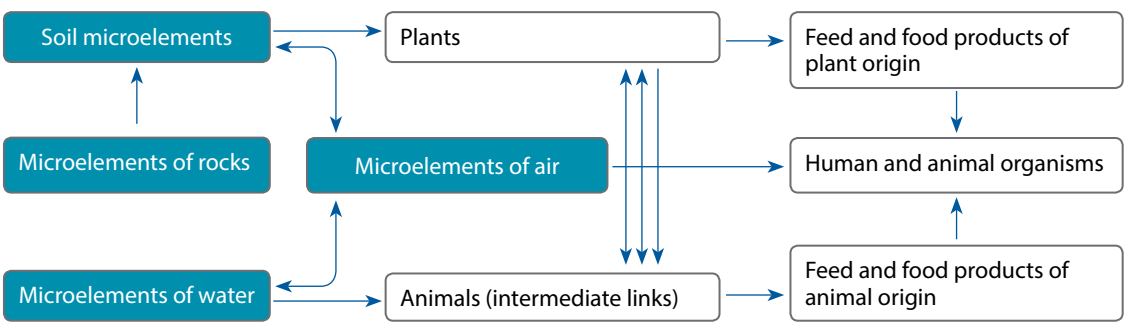


Fig. 2.8. Biogeochemical chains for the chemical elements

the biosphere is 2×10^{-5}%. The mercury cycle is intensive due to its high volatility, atmospheric sediments solubility, ability to exist in different phase states, high absorption in soil, green plantings. Mercury enters plants from soil and air. Atmospheric emissions are more dangerous for plants because leaves absorb mercury and accumulate it. Mercury in different parts of plants is uneven, for example, the concentration of mercury in cereal grain is less than in straw.

Alimentary products may contain atomic mercury, oxygenized mercury (Hg_2^{2+}), and alkylmercury, which is the most dangerous. This compound enters the body of fish (pike, tuna, and swordfish) with plankton or even through the gills. It enters the human body by animal origin products in the form of methylmercury. It goes out of the body by the urinary and biliary excretion. Methylmercury resulting from biliary secretion is again absorbed by the intestinal tract. Methylmercury accumulates in erythrocytes, in the brain in an organic form. In other tissues, its organic compounds are demethylated and converted into inorganic mercury.

Lead cycle. The world's supplies of lead are 85×10^6 tons, and global production reaches 4.1×10^6 tons per year. The average lead content in the biosphere is 8×10^{-6}%. The highest lead level is in the soil: 3–189 mg/kg. Lead migrates from the soil to plants and combines with organic compounds. It accumulates in higher concentrations in plant roots. Lead from the atmosphere accumulates in leaves. It reduces photosynthesis and water absorption in plants. When entering the water reservoir the metal accumulates in fish, crustaceans and other aquatic organisms. While in water, lead slowly combines with complex compounds, organic and inorganic ligands. Lead enters human body by food, water and air.

Thus, the biosphere performs a number of functions:

1. Energy function. Absorption of solar energy (photosynthesis), biomass production and its conversion. A part of the energy is dissipated in the form of heat, and another part forms fossil fuel reserves (oil, peat, coal, gas, etc.).
2. Concentration function. This is a selective accumulation of substances needed to build biomass.
3. Destructive function. Organic matter destruction into simple inorganic matter is performed by microconsumers-saprophages (from sapros — rotten). The biosphere carries out a cycle of substances involving biotic and abiotic components.
4. Transport function. It consists in various transfers of matter against gravity force, movement of the Earth, precipitation, etc.
5. Environment-forming function. Atmospheric air, soil, water composition, and climate are the result of the biosphere: it provides the essential content of biogenous elements. V. I. Vernadsky considers that life itself creates conditions conducive to its existence.

2.5. Structure, composition and properties, hygienic significance of the atmosphere

The **atmosphere** (from Greek *atmos* — vapor, steam, *sphaira* — ball, sphere) is a gaseous envelope surrounding our planet. The mixture of gases that form the atmosphere is called air. Moreover, the atmospheric air is considered the air of open spaces (outdoor spaces), not the air of residential, public and industrial premises.

All vital processes take place in the atmosphere. It resembles an ocean, where there are different types of currents: extremely slow, rapid, and similar to a whirlwind. Without atmosphere, the Earth would turn into a lifeless planet. The sun's rays and cold of outer space would kill all living things. In addition to changing the appearance of the Earth's surface, all processes and phenomena related to the atmosphere would disappear: there would be no winds, clouds, precipitation, aurora borealis, and the sky would change from blue to red forever.

The composition of the atmosphere and its physical properties are different and depend on the distance to the Earth's surface. With distance from the Earth, the force of gravity weakens and the atmosphere density decreases.

Depending on the composition and properties, the Earth's atmosphere is divided into 5 layers:

1. Troposphere.
2. Stratosphere.
3. Mesosphere.
4. Thermosphere.
5. Exosphere (see Fig. 2.9).

The **troposphere** is the lowest layer of the atmosphere. Its height reaches 8–10 km in the polar latitudes and 16–18 km in the equatorial zone. Almost 80% of the total mass of the atmosphere is concentrated in the troposphere. The boundary between the upper layer of the troposphere and the lower layer of the stratosphere is called the tropopause. It lies above the equator at an altitude of 17–18 km, in middle latitudes — at an altitude of 10–12 km, and in polar latitudes — at an altitude of 8–9 km.



Fig. 2.9. The Earth's atmospheric structure

The troposphere air is characterized by intensive horizontal and vertical movements. Due to the active displacement of air and its movement in this part of the atmosphere the following processes are most active: thermal, hydrodynamic and chemical with the formation of zones with high or low pressure, heating and cooling of large air masses. Almost all water vapor is concentrated here; the phenomena of water evaporation and condensation of water vapor occur with the formation of clouds and precipitation. This is a consequence of intense heating of the Earth's surface because of solar radiation.

The air temperature in the troposphere depends on the altitude, and the highest temperature can be near the Earth's surface, and at a distance from the surface, it gradually reduces to –60...–70 °C. It is associated with a decrease in air density in relation to the altitude and heat transfer drop. The air has no time to warm up. The temperature reduction per each kilometer of altitude averages 6 °C.

The **stratosphere** is located above the troposphere and extends to a height of 60 km, and along with this its mass is only 5–15 % of the atmosphere's mass. This is explained by the high rarefaction of air in the stratosphere. There is almost no water vapor. In the lower part of the stratosphere, the temperature reduction depending on altitude stops, and at an altitude of about 25 km, the temperature remains constant. In relation to the density of the troposphere layer, the temperature reaches the following values: above the equator –70…–80 °C, in the polar latitudes –45…–50 °C. At an altitude of more than 30 km the air temperature rises by an average of 1–2 °C per kilometer, at an altitude of 40 km it reaches –30 °C.

The presence of ozone makes conditions for optical phenomena (mirages), causes the acoustic reflection and affects electromagnetic radiation. There is an air movement, and the wind speed can exceed 100 km/h.

The **mesosphere** is at an altitude of 60–80 km and contains 0.3–5 % of the mass of the entire atmosphere, therefore, it is characterized by a high rarefaction of the gaseous medium. The temperature drops to –80 °C. The movement of air masses remains the same reaching 100 km/h.

The **thermosphere** extends at an altitude of 80 to 1000 km. It is similarly characterized by an extreme rarefaction of the gaseous medium. It contains less than 0.05 % of the atmosphere. About the temperature, one can say only in view of energy and molecular velocity. This gas envelope is electrically conductive.

The **exosphere** is located at an altitude of over 1000 km. Low air density and high molecular velocity cause their transition after overcoming gravity into interplanetary space. Atmospheric gases are dispersed from here to outer space due to dissipation; therefore, the exosphere is also called the scattering sphere.

Thus, the atmosphere has no distinct boundary. It becomes rarefied gradually. Then the atmosphere smoothly passes into outer space. However, some authors consider the Karman line, which runs at an altitude of 100 km, to be a conditional boundary between the atmosphere and outer space (for example, the Fédération Aéronautique Internationale (FAI) considers it such a boundary).

Not only the composition and properties of the lower layers of the atmosphere are important for life on the Earth, but also the processes that take place in its upper layers. The upper layers of the atmosphere, which are under the constant exposure to solar radiation, present a large place of chemical, photochemical and ionization transformations. Under the Sun's radiation, gas molecules in the upper layers of the atmosphere are dissociated into individual atoms and ionized. In addition to the effects of electromagnetic radiation from the Sun, there is also the effect of corpuscular radiation ("solar wind"), which consists of electrons, protons, alpha particles, neutrons and other elementary particles of matter emitted by the Sun.

Atmospheric air is a physical mixture of gases, which due to changes in the density of the atmosphere at different altitudes change only its partial pressure (Table 2.1). Practically, the ratio of different atmospheric gases is the same up to an altitude of 80–100 km. Besides the components of the atmosphere, it can contain a variety of accompanying elements of natural origin and pollution caused by anthropogenic impact. The constant gas composition of the atmosphere is maintained in consequence of the biological cycle of substances of the biosphere ecological systems, an integral part of which is the atmosphere, as well as in consequence of the continuous movement of air masses in the horizontal and vertical directions.

The main components of this complex mixture of gases, which are not a chemical compound, should be considered nitrogen and oxygen.

Nitrogen is a colorless, odorless, tasteless, inactive gas which does not support respiration and combustion. Thus, it is called "lifeless". However, it has been found that nitrogen is an important component of amino acids that form proteins. Nitrogen also is an essential element in the natural cycle of substances. Leguminous plants with the help of specific microorganisms, nodules and other bacteria absorb nitrogen directly from the air and fix it in the soil in the form of nitric acid and ammonium salts. After that, nitrogen in a bound form enters the body of herbivorous animals and, thus, enters into the composition of animal proteins, and later — human protein. Nitrogen enters the atmosphere mainly during plant decomposition and volcanic emissions. It belongs to inert gases. Under a high pressure, nitrogen is a drug.

Its physiological role is determined by creating the level of atmospheric pressure required for vital processes. An increase of nitrogen level in the air can lead to hypoxia and asphyxia due to a decrease in the oxygen partial pressure.

When pressure increases, the nitrogen solubility in the blood and tissues increases too. This causes a grave condition of people, because due to the rapid transition to the normal pressure nitrogen forms small bubbles in the blood that leads to a blood-vessel occlusion and provokes caisson disease.

Oxygen is the main component of air and a prerequisite for existence of life. It is a colorless gas with high

Table 2.1. Content and concentration of gases (%) in dry air at a temperature of 0 ºC and atmospheric pressure of 760 Mm Hg

Gas	Content, %		Concentration, mg/m³
	by volume	*by weight*	
Nitrogen	78.09	75.51	976 300
Oxygen	20.95	23.15	299 300
Argon	0.93	1.28	16 550
Carbon dioxide	0.03	0.046	591
Neon	0.001 8	0.001 25	16.2
Helium	0.000 52	0.000 072	0.9
Methane	0.000 22	0.000 12	3.7
Krypton	0.0001	0.000 29	—
Nitrogen oxide	0.000 05	0.000 09	0.98
Hydrogen	0.000 05	0.000 003 5	0.045
Xenon	0.000 008	0.000 036	0.45
Ozone	0.000 001	0.000 001 7	0.21
Radon	0.10–18	—	—

water solubility. Oxygen played an important role in the advent of all life on the Earth. This gas is included in almost all organic substances. Its presence in the air is required for respiration, combustion and putrefaction. The source of oxygen in nature is photosynthesis.

A man at rest breathes 25 liters of oxygen per hour and exhales 22.6 liters of carbon dioxide. All tissues and cells of the body continuously absorb oxygen, which leads to a significant change in air composition (Table. 2.2).

Carbon dioxide (CO_2) is a colorless water-soluble gas with a sour taste and a peculiar odor. Main sources of carbon dioxide are as follows: the respiration of humans, animals, plant particles, the decomposition of organic matter and the release of gas from the soil.

Increasing the carbon dioxide content in the inhaled air has a negative effect on the body. When the content of CO_2 in the air reaches 1 %, human respiration becomes rapid and deep. Its gradual increase causes a feeling of pressure in the head and cephalgia, tinnitus, hyperphrenia. The presence of 20 % carbon dioxide in the air after a few seconds causes paralysis of the cerebral cores.

Ozone (O_3) is contained in the atmosphere in small quantities. It is formed during a thunderstorm due to electric discharges, as well as due to the photochemical effect on oxygen by UV radiation. This simple substance is a transformation of oxygen. Ozone has a strong oxidizing action. Due to the interaction with organic substances, ozone decomposes very easily with the release of an oxygen atom. Therefore, ozone actively oxidizes all air pollutants; consequently, it serves as an indicator of air purity. It has a disinfecting effect, so it is used for air and water purification.

Table 2.2. Composition of atmospheric and exhaled air (percentage by volume)

Air	Nitrogen	Oxygen	Carbon dioxide	Water vapor
Atmospheric	78.09	20.7–20.9	0.03–0.04	Different amount
Exhaled	78.26	15.4–16.0	3.4–4.7	Saturated

Ozone, which is formed due to the interaction of high-energy quanta of gamma rays, X-rays and short (region C) ultraviolet rays of solar radiation with atmospheric oxygen, causes the formation of the ozone layer (ozonosphere) at an altitude of 18–30 km above the Earth's surface. Within the ozonosphere, the concentration of ozone molecules is 10 times higher than near the Earth's surface.

Inert gases (helium, neon, krypton, xenon) are present in the atmosphere in small quantities and associated with continuous processes of natural radioactive decay.

The Earth's atmosphere performs a number of functions that determine its great hygienic value:

1. Meteorite avoidance.
2. Heat protection.
3. Bioprotective.
4. Climate forming.
5. Weather forming.
6. Industrial.
7. Productive.
8. Thermotechnical.
9. Toxicological.
10. Epidemiological.
11. Sanitary and cleaning.
12. Biogenic.
13. Physiological.
14. Heat-exchange.

Meteorite avoidance role. The atmosphere protects the Earth's surface from meteorites, 99% of which burn mainly in the mesosphere at an altitude of 80–400 km. (A meteorite is a solid body of space origin that fell to the Earth's surface from space). It is considered that 5–6 tons of meteorites fall per day, i. e. 2.000 tons — per year. Moreover, meteoritic dust falls on the Earth's surface in the quantity of 300 to 20.000 tons per day (meteoritic dust is solid particles formed during the fragmentation of meteorites in the atmosphere).

Heat protection role. The atmosphere regulates seasonal and daily temperature fluctuations (if the Earth's atmosphere did not exist, daily temperature fluctuations on the Earth's surface would reach 2000 °C).

Bioprotective role. The atmosphere protects living organisms from the harmful effects of γ-rays of the Sun with a wavelength λ less than 0.1 nm, X-rays with λ = 10–0.1 nm and short ultraviolet rays of region C with λ = 280–10 nm.

Climate forming role. The angle of incidence of sun and infrared rays determines the thickness of the atmosphere, i.e. the path of these rays to the Earth's surface. The sharper the angle of incidence, the longer the path of heat rays in the atmosphere, the less they reach the Earth's surface, and the less this surface is heated. Additionally, the intensity of heating of the geological substrate is an important climatic factor.

Weather forming role. In the consequence of the uneven heating of the atmosphere by sun rays and the Earth's rotation (Coriolis forces), the so-called atmospheric circulation is formed as the main weather-forming factor with the subsequent formation of cyclones, atmospheric fronts and other weather phenomena on the Earth.

Industrial role. The Earth's atmosphere is a source of oxygen, nitrogen and other gases for industrial use.

Productive role. The atmospheric air under the high pressure is used during the operation of pneumatic hammers (or moulding hammers) and other devices in production, for driving piles during the construction (in mines, during road construction, etc.).

Thermotechnical role. Heated air is used to heat the subway, shopping malls, public and residential premises.

Toxicological role. By means of air currents there is a wilful (attack by the poisonous substance — mustard gas — near the Ypres city in the First World War, the use of carbon monoxide, poisonous substances "Zyklon B" in the gas chambers of Auschwitz concentration camp, CO in gas vans or gas wagons during World War II, anesthetic gases in the concert hall "Nord Ost" in Moscow, etc.) or unintentional poisoning (household carbon oxide) of people, animals, etc.

Epidemiological role. Causative agents of a number of infectious diseases (influenza virus infection, acute respiratory diseases, diphtheria, pertussis, scarlet fever, meningitis, varicella, tuberculosis (white plague), legionellosis, parotitis) are characterized by airborne transmission, i.e. through inhalation of pathogens from the air.

Sanitary and cleaning role. Emissions of pollutants (soot, smoke, etc.) from the high pipes of industrial enterprises are mixed with air, dissolved in the atmosphere, reducing the concentration. Thus, the air cleans these emissions.

Biogenic role. The emergence of life on Earth, the formation of organic matter, proteins, fats, carbohydrates, and vitamins as signs of life, photosynthesis and respiration are possible in the presence of atmospheric oxygen.

Physiological role. A human is able to survive without food for 5 weeks, without water — 5 days, but without air — up to 5 minutes. Atmospheric oxygen is necessary for respiration of all living organisms and is spent on oxidative processes. A person makes 18 breathing movements per minute, inhaling 0.5 liters of air per breath; a

person absorbs 16 g of oxygen per hour from the atmosphere.

Heat-exchange role. Thermoregulation of the human body is carried out partly owing to the mechanism of convection, i.e. by heating the air.

2.6. Structure, composition and properties, hygienic significance of the lithosphere

Soil is a complex multicomponent low-dynamic dispersed system in which the dispersed medium is represented by minerals (crystalline quartz, aluminosilicates, argillaceous minerals, natural macro- and microelements), and the dispersed phases are organic substances, all types of soil moisture (hygroscopic, pellicular, capillary, gravitational or free), air, micro- and macroorganisms. This system, according to V. V. Dokuchaev, was formed of parent rock under the influence of local climate, microorganisms, plants and animals, terrain relief and time.

In addition to the term "soil", the term "land" is used in the scientific legal literature. In business, administrative and legal activities, the term "land" refers to the surface layer of terrestrial area occupied by any type of land use for settlements, agriculture or forest lands, roads, railways and more.

The main properties of the soil. Soils are extremely diverse depending on the conditions of their formation, especially climatic conditions and vegetation.

On the territory of Ukraine, there are more than 90 types of soils, among which the following 3 types are dominant: sod-podzolic, gray forest, chernozem (black humus soil). Hygienists conditionally divide soils according to their purpose into three types:

1. Natural — outside settlements that can be used for new construction or cultivation of crops.
2. Artificially created soils of settlements, which were formed from natural ones, are a result of their mixing with wastes of anthropogenic origin (domestic, industrial). This species also includes shifted soils formed as a consequence of vertical planning. Both types of artificial soils are united by the term "vegetable soil layer of settlements".
3. Artificial soil coverings (asphalt, gravel, concrete, etc.).

Soil consists of mineral, organic compounds and organo-mineral complexes, as well as soil solutions, air and soil microorganisms (abiotic and biotic component). For hygienic assessment of the extent of soil pollution, it is important to know its natural composition, because any statistically significant deviation from the natural composition of the soil type or the appearance of foreign substances should be considered as pollution of some degree.

Soil is a huge natural "laboratory" in which various complex processes constantly take place: destruction and synthesis of organic substances, formation of new inorganic compounds, extinction of pathogenic bacteria, viruses, protozoa, and helminth eggs. The soil is used for remediation and disposal of domestic wastewater from households, liquid and solid waste generated by human activities in settlements. Soil has a significant impact on the local climate, vegetation development, planning and development of settlements and individual buildings, their improvement and operation.

In the context of agricultural production, a large amount of various mineral fertilizers, soil binders, pesticides, plant growth stimulators is purposefully applied to the soil. Surfactants (SF), polycyclic aromatic hydrocarbons (PAH), a large amount of heavy metals, and petroleum products enter the soil through liquid or solid domestic and industrial waste, wastewater, emissions from industrial enterprises and vehicles. These pollutants migrate from the soil to other environments — enter underground and surface watercourses — sources of water supply, and from there into drinking water; accumulate in agricultural plants and, consequently, in food of plant origin, fodder for cattle and food of animal origin; evaporate into the atmosphere. Soil can be a factor of the spread and transmission of infectious and invasive diseases. In view of this, it has a great impact on the health of the population.

Hygienic role of the lithosphere (soil):

1. Geological.
2. Industrial.
3. Agricultural (nutrition).
4. Climate forming.
5. Weather forming.
6. Endemic.
7. Toxicological.
8. Epidemiological.
9. Sanitary and cleaning.
10. Nutrition.

Geological role. There are mineral deposits in the lithosphere: metalliferous, non-metalliferous, fossil fuels (oil, gas, coal).

Industrial role. Metals (iron, gold, silver, lead, tin, etc.) are extracted from the soil.

Agricultural (nutrition) role. Wheat, rice, corn, and other food crops are grown in the soil.

Climate forming role. The geological substrate (black humus soil, sand, snow) has a different heat reflection factor (albedo), resulting in the formation of different climates (polar, desert, forest, semisavanna, etc.).

Weather forming role. The interaction of the geological substrate, the uneven distribution of solar radiation and the peculiarities of atmospheric circulation form the weather conditions in a particular area.

Endemic role. Abnormal natural content of certain chemicals in the soil leads to the development of certain diseases in humans or animals that consumed the phytomass grown on the land of these endemic regions (selenium excess in the soil — selenium toxicosis or alkaline disease in humans or livestock; selenium hypomineralization — Keshan disease, molybdenum excess in the soil — molybdenum arthragra (molybdenum hypermineralization), iodine hypomineralization — endemic goitre, fluorine hypermineralization — fluorosis, fluorine hypomineralization — dental caries (saprodontia), etc.).

Toxicological role. In the consequence of the soil contamination by industrial emissions, the incidence of the following diseases is increasing: arsenic — foul-in-the-foot, nickel — schizophrenia, lung and stomach cancer, mercury — diseases of the nervous and endocrine systems, boron — boric enteritis, lead — malignant neoplasms, polychlorinated biphenyl — Yu-Cheng or oil disease, etc.

Epidemiological role. Causative agents of infectious diseases can maintain viability, virulence and pathogenicity in the soil for a long time. During this time, they can contaminate undergroundwater sources and infect humans by fecal-oral route. Contaminated soil can act as a factor of the transmission of infectious diseases and human invasions: intestinal infections of bacterial (typhoid fever, paratyphoid fever A and B, bacillary dysentery, cholera, colibacillosis), viral (hepatitis A, enterovirus infections: infantile paralysis, Coxsackie, ECHO) protozoal (amebiasis, giardiasis) etiology; zooanthroponosis (canicola fever: infectious jaundice or Weil's disease, bovine leptospirosis, brucellosis, tularemia, anthrax); mycobacterium tuberculosis; spore-forming clostridia — causative agents of tetanus (lockjaw), gas gangrene, botulism; geohelminthiasis — ascariasis, trichuriasis, hookworm (ancylostomiasis).

Sanitary and cleaning role — soil is a natural environment for the neutralization and disposal of liquid or solid household and industrial waste.

2.7. Structure, composition and properties, hygienic significance of the hydrosphere

Water, along with air, is an integral part of the existence of all animals and plants. It is present in all cells, tissues and fluids of animals and plants. It is worth pointing out that the waters of the primordial ocean became the origin of life. Water has always been a symbol of immortality and fertility; without it, humanity and everything human-created would cease to exist.

The problem of clean water is one of the problems that cannot be solved without ecological and hygienic knowledge. The gigantic paces of development of industry and agriculture require more and more water every year; along with the development of cities and population growth the need for clean water for public utilities and sanitary and hygienic services is increasing. While water consumption by humans, industry and agriculture increases, so does its pollution, which is already a threat to human health. The presence of pathogenic microorganisms and toxic chemical impurities in the water causes many diseases. This creates a very urgent problem of sanitary protection of water sources.

The Earth's water envelope — the hydrosphere — unites all the waters of the planet: oceans and seas, rivers and lakes. It is bound to polar water, groundwater and atmospheric vapor. It is tied together by a water cycle of the Earth in a closed system "ocean — atmosphere — continent — ocean".

The essence of the physiological significance of water comes down to the fact that for the human and any other living organism, water is an extremely necessary substance. It is part of all tissues and organs, is the basis of all liquid media. The body of an adult contains about 65 % of water. Water in the body is distributed as follows: in the blood — about 81 %, in tissues with a high density — 75 %, in bones — almost 20 %. There is a complex mechanism in the human body that ensures a normal water balance, i.e. the amount of water consumed should be equal to the required water. Water and salt balance of a human is calculated by the daily intake of water and salts and its excretion from the body.

A person consumes an average of 2.5 liters of water per day by drinking fluids, 1 liter — with food and 0.3 liters is formed in the body during metabolism; it is endogenous (metabolic) water. The body must excrete the same amount of fluid in 24 hours.

Water of the Earth (the hydrosphere) is of a great hygienic importance (role):

1. Sun-protective.
2. Heat-protective.
3. Climate forming.
4. Weather forming.
5. Soil forming.
6. Factor of geological movement of the biosphere.
7. Industrial.
8. Agricultural.
9. Transport.
10. Sanitary and cleaning.
11. Sanitary and household.
12. Endemic.
13. Toxicological.
14. Epidemiological.
15. Biogenic.
16. Physiological.
17. Biochemical.
18. Nutrition.
19. Therapeutic.
20. Balneological.
21. Conditioning (enhancement) of the organism.

Sun-protective role. Clouds, which consist of water vapor, reflect into space 26 % of solar radiation entering the Earth.

Heat-protective role from the solar wavelength range of 100.000–760 nm, only short thermal infrared rays with a wavelength of 4.000–760 nm reach the Earth's surface. Atmospheric water vapor absorbs 16 % of solar radiation, which determines the heat supply of the atmosphere.

Climate forming role. Uneven heating of the seas and oceans by solar radiation, the formation of warm (the Gulf Stream) and cold (the Labrador) sea currents are an important basis for the formation of climates. Sea currents affect the temperature conditions, the circulation of the atmosphere and thus form the climate.

Weather forming role. Heat supply of atmospheric water vapor is one of the driving factors of atmospheric circulation, which forms the weather on the Earth.

Soil forming role. Large (or global) nature water cycle is accompanied by erosion of mountains (rock decay) and the formation of bottomlands from soils.

Factor of geological movement of the biosphere. The global water circulation (precipitation — surface run-off and underflow — infiltration — evaporation — condensation — precipitation) is an essential prerequisite for the chemical substances movement in the biosphere and the exchange of chemicals between organic and inorganic nature.

Industrial role. Water is used for production needs in any and every types of industrial enterprises. The production of 1 ton of cast iron requires 200 m^3 of water, 1 ton of copper — 500 m^3 of water, 1 ton of nickel — 4000 m^3 of water.

Agricultural role. The large quantity of water is used in crop growing and horticulture, in greenhouses (growing houses), and animal husbandry. The production of 1 ton of wheat requires 1.500 tons of water, 1 ton of cotton — 10.000 tons of water.

Transport role. Marine and river transport operations account for 40–60 % of all types of transportation in much of the world (and in the island states — Great Britain, Japan — up to 90–95 % of transportation).

Sanitary and cleaning role. Water is utilized for cleaning (washing) of premises, houses, adjacent territories, city streets in general, livestock breeding complexes, poultry farms, etc.

Sanitary and household role. Water is used to maintain the cleanliness of the human body, housing (cooking, washing dishes, laundry, indoor cleaning, maintaining the cleanliness of household and care articles). Household water needs are 200–500 liters per day for one person.

Endemic role. Endemic fluorosis (fluorine content in water over 1.5 mg/l), endemic caries or saprodontia (fluorine less than 0.5 mg/l), water-nitrate methemoglobinemia (nitrates over 45 mg/l), molybdenum arthragra (molybdenum over 0.25 mg/l), endemic goiter (iodine deficiency <0.1–0.5 mg), Kashin — Bek disease (Sr, Fe, Zn, Pb, F polyhypermineralization affected by the low Ca content), selenium Keshan disease (Se hypomineralization), selenosis (Se hypermineralization), boric enteritis (excess of boron), endemic nephropathy (excess of silicon).

Toxicological role. Intoxication due to the chemical contamination of water with an excess of the MAC: oil disease (Yu-Cheng disease) — polychlorinated biphenyls (PCB) is over 0.5 mg/l in water, saturnism or plumbism (lead is over 0.03 mg/l), Itai-Itai disease (cadmium is over 0.001 mg/l), foul-in-the-foot disease (arsenic is over 0.05 mg/l), chromium dermatitis and ulceration (over 0.5 mg/l), Minamata disease (mercury compounds over 0.0005 mg/l), liver and kidney carcinogenesis by trihalomethanes (chloroform is over 0.06 mg/l), polytropic action of dioxins (over 20 mg/l) or polycyclic aromatic hydrocarbons (MAC of 3.4-benzpyrene — 0.01 mg/l).

Epidemiological role. It plays an important role in the mechanism of the transmission of intestinal pathogens, the emergence of epidemics and pandemics.

The most widespread water epidemics with the most severe consequences of public health disorders are related with the possibility of spreading intestinal pathogens with water, which are characterized by fecal-oral route. The possibility of spreading cholera, typhoid fever, paratyphoid fever A and B, salmonellosis, shigellosis, colibacillosis, leptospirosis, tularemia (Francis disease), and brucellosis through water has been proved. Epidemic hepatitis viruses (Botkin's disease), rotavirus gastroenteritis, adenoviruses, and enteroviruses (poliomyelitis, Coxsackie, and ECHO) are often found in water sources.

Main principles of the classification of infectious diseases (with water participation in the mechanism of transmission) proposed by WHO experts:

I. Diseases caused by the use of contaminated water for drinking purposes:

1. Intestinal infections (the leading mechanism of transmission — fecal-oral route).
2. Respiratory tract infections, the causative agents of which can sometimes be spread by fecal-oral route.
3. Skin and mucous membranes infections, which may have a fecal-oral transmission mechanism (anthrax or splenic fever).
4. Blood infections that may have a fecal-oral transmission mechanism (Coxiella burnetii infection).
5. Zooanthroponoses that may have fecal-oral transmission mechanism (tularemia, leptospirosis and brucellosis).
6. Helminthiasis.

II. Skin and mucous membranes diseases that occur due to the contact with contaminated water: trachoma, Hansen disease, anthrax, contagious epithelial, fungous diseases (epidermatomycosis, mycosis, etc.).

III. Diseases caused by helminthes living in water (schistosomiasis, dracunculiasis or Dracunculus medinensis).

IV. Transmissible (arthropod-borne) infections spread by transmitting insects breeding in the water (malaria, yellow fever).

Biogenic role. According to the academician Oparin's theory, life on Earth originated in the aquatic environment — the "primordial soup" — the interaction of solar radiation and chemical complexes of nutrients — "coacervates".

Physiological role. About 65 % of the human body consists of water. All vital biochemical, physiological and physicochemical processes of metabolism and energy take place in the human aquatic environment: digestion, respiration, anabolism (assimilation) and catabolism (dissimilation), synthesis of proteins, fats, carbohydrates, etc. Water in the human body is involved in all vital processes: absorption, transport, decomposition, oxidation, hydrolysis, synthesis, osmosis, diffusion, resorption, filtration, excretion, etc. The body's need for water is 1.5–3 liters per day.

Biochemical role. All biochemical processes in the body take place in the aquatic environment.

Nutrition role. Water is one of the six essential nutrients in a healthy diet, along with carbohydrates, proteins, fats, vitamins and minerals.

Therapeutic role. Depending on the mineral composition of water (more than 1000 mg/l), internal water consumption is used to treat the gastrointestinal tract, urology, and musculoskeletal system diseases, etc.

Balneological role. External use of water with a certain mineral composition (baths, thermal waters) promotes recovery from neurological, oncological, occupational diseases, and musculoskeletal system diseases.

Conditioning (enhancement) of the organism. Water hydrotherapeutic procedures (contrast showers, washing, bathing, ice swimming, snow (ice) baths, steam baths, and sauna) are used to increase the overall non-specific resistance of the human body.

3 CHAPTER ADVANCES IN SCIENCE AND TECHNOLOGY AND THEIR IMPACT ON THE EARTH'S BIOSPHERE

V. G. Bardov, S. T. Omelchuk, N. V. Merezhkina

3.1. Concept of advances in science and technology

The organism of a living being is in continuous interrelation with the environment. On the one hand, the environment affects the organism. On the other hand, living beings, primarily human and society, exert an influence on the environment.

At different historical stages, the human and nature relationship and human influence on the environment have depended on the level of acquiring and use of possibilities, the level of development of scientific knowledge.

Over the course of millennia, these forms of relationships have undergone only slight changes and have been characterized by the direct appropriation and use of available products of nature by human with the help of rudimentary tools and expenditure of high efforts.

Since the middle of the 20th century, mankind has begun a new stage of industrial relations, which was called advances in science and technology. What is it?

Advances in science and technology is a stage of social development, which is characterized by a complex mechanization of production processes, the use of new types of energy (nuclear), the development of electronics and cybernetics, chemicalization of industry, agriculture and households, urbanization (i.e. a sharp increase in the number of cities and urban population), a snowballing of new scientific information.

Advances in science and technology (AST) is a progress of science and technology, the evolutionary development of all elements of the productive forces of public production on the basis of extensive knowledge and development of nature's external forces; this is an objective, permanent pattern of material production development, the result of which is the continual improvement of equipment, technology and organization of production, increasing its efficiency.

3.2. Evolutionary and revolutionary forms of advances in science and technology

Advances in science and technology take two forms: evolutionary and revolutionary.

The **AST evolutionary form** is characterized by the improvement of the equipment and technology used in production on the basis of already available scientific knowledge. An example of this form of AST is the development and improvement of steam power, electricity or nuclear energy, etc.

The **AST revolutionary form** is the transition to technics and technology, built upon breakthrough scientific ideas. For example, the transition from hand tools to machines, the replacement of steam power by electrical or nuclear energy, the application of laser and other state-of-the-art technologies.

The scientific and technological revolution (STR) is a qualitative leap in the development of the productive forces of society on the basis of sweeping changes in scientific knowledge. For example, the last revolution in science has begun in the middle 90s: the creation of the first computer, the first adoption of the nuclear energy, the genetic engineering development, the usage of synthetic material (plastics, artificial diamonds), the implementation of nanotechnologies, etc.

3.3. Positive and negative effects of advances in science and technology

Advances in science and technology have many positive effects in society:

- in industry;

- in transport;
- in energy;
- in agriculture;
- in medicine.

The essence of advances in science and technology in these areas involves such innovations:

- electronization of the national economy: providing all spheres of production and social life with highly efficient means of computer technology which includes the use of the principles of artificial intelligence, new generation of satellite communication systems, etc.;
- overall automation of all branches of the national economy on the basis of electronization: introduction of flexible manufacturing facilities, industrial robots, multi-operational machines, computer-aided design systems, process automation systems;
- creation and use of materials with new properties: superconductivity, radiation resistance, wear resistance; ultra-pure materials with prescribed properties;
- development of fundamentally new technologies: membrane, laser, plasma, vacuum, detonation, etc.;
- accelerated development of biotechnology contributing to the creation of waste-free technological processes, raw materials production and food resources ramp-up.

For example, if the speed of human transportation in 10.000 years to the middle of last century has doubled — from 10–15 km/h on foot to 25–30 km/h on horseback, then in 130 years after the AST, speed has increased by 500 times — up to 15–20 thousand km/h on a modern rocket.

However, two main aspects of the global problem of "human — biosphere" relations are already emerging, i.e. the negative effects of advances in science and technology:

1. Techno-economic aspect associated with the growing depletion of natural resources, which poses many new scientific and technical challenges for scientists and specialists.
2. Environmental aspect related to global pollution of the biosphere.

3.4. Positive impact of advances in science and technology on public health

Advances in science and technology have led to significant changes in the public health:

1. Decrease in mortality rates.
2. Increasing life expectancy.
3. Acceleration.
4. Changing the epidemic profile of the population to non-epidemic.

These changes in the health status of the population have become possible due to the advances of medical sciences: immunology, transplantology, surgery, internal medicine, genetic engineering, pharmacology, etc.

Achievements of AST in medicine are the results of revolutionary technologies: artificial blood-circulation apparatus (or heart-lung apparatus), hemodialysis apparatus, artificial kidney apparatus, insulin production for diabetic patients with the help of genetically modified bacteria, electronic and optical surgical equipment, computer technologies, technologies for hyperbaric oxygen therapy, humane methods of anesthesia, use of polymers, new antibiotics, hormones, enzymes, protein and gene synthesis, deciphering of genetic code, spatial organization of mitochondria and chromosomes, ultracentrifugation, electrophoresis, chromatography, photometry, television microscopy, telemedicine, microphotography.

3.5. Global pollution of the biosphere

As a result of advances in science and technology in various manufacture branches, there is an intense pollution of the biosphere.

Pollution of the biosphere is an entry into the biosphere or the emergence of new, usually abnormal, physical factors, chemical and biological substances that harm humans and natural ecosystems.

The main types of pollution of the biosphere:

1. Physical:
   - thermal;
   - noise;
   - electromagnetic;
   - light;
   - radioactive.
2. Chemical:
   - aerosol (particulate pollutants);
   - chemical substances;
   - heavy metals;
   - pesticides;
   - plastics;
   - S-SF (synthetic surfactants).
3. Biological:
   - biotic (biogenic);
   - microbiological;
   - genetic engineering.

The main sources of biosphere pollution:

1. Natural processes: volcanic eruptions, earthquakes, forest fires, dust storms.
2. Anthropogenic pollution:
   - industrial production (heavy, light, food, and primary industries, etc.);
   - fuel and energy complex (thermal power plants, hydroelectric power plants, nuclear power plants);
   - transport (motor-vehicle, maritime, river, railway, and air transport);
   - agricultural industry (chemicalization of agriculture, livestock breeding complexes, poultry farms);
   - pharmaceutical industry;
   - specific hospital waste;
   - man-made, chemical, and natural disasters;
   - technological and nanotechnological processes;
   - military activity;
   - space industry;
   - grassroots sports, amateur and professional hunting, etc.

Side by side with this, enormous amounts of pollution are released into the environment (Table 3.1)

Biological pollution of the biosphere. Biological pollution is considered as the interference of human activity in ecosystems. In addition, these interventions are abnormal for living organisms of ecosystems (plants, animals, viruses, bacteria, etc.) and worsen the living conditions of biocenoses or affect human health.

The main sources of biological pollution are wastewater from almost all types of industrial production, agriculture, public utilities of cities and towns, household and industrial landfills, cemeteries, etc. Various organic compounds of iron and pathogenic microorganisms from sources enter the soil and groundwater.

Table 3.1. Global volume of emissions released to the environment in 2015 (million tons)

Gaseous emissions into the atmosphere	50.8
Dust emissions into the atmosphere	0.7
Hydrocarbon emissions into the atmosphere	0.25
Chemical fertilizers into soil	0.6
Pesticides into soil	0.015
Liquid waste into water	5800
Excrements into water and soil	24.3
Organic waste into the atmosphere, soil and water	13

The biological contamination by causative agents of infectious and parasitic diseases (such as plague, smallpox (or variola), cholera, dysentery, tick-borne encephalitis, AIDS and so on) represents a particularly serious hazard, in view of the fact that its destruction is significantly difficult.

In recent years, a new environmental threat has arisen — the potential hazardous situation of microorganisms and biologically active substances ingress from laboratories or factories into the environment resulting in a negative impact on the living organism and its communities, health and gene-bank. It is associated with the rapid development of biotechnology and genetic engineering.

Water and especially dead soil, as distinct from air, are able to accumulate and store pollution, including biological. Soil and water are the habitats of lower animals and microorganisms, such as bacteria, fungi, viruses, etc. Some of them are pathogenic: Bacillus anthracis, Clostridium tetani, Clostridium botulinum, gas bacillus, causative agents of dysentery, cholera, typhoid fever, plague, foot-and-mouth disease, brucellosis, etc.

Disease-causing pollution comes from insufficiently neutralized solid and liquid household waste (especially health-care activities waste), also waste from animal burial sites, from livestock breeding complexes and slaughtering plants, biological-manufacturing plants, etc.

Other type of biological contamination involves insects and other disease-carrying organisms, such as mosquitoes (malaria), ticks (encephalitis), lice (typhoid fever), mice and rats (plague), and so on.

Heavy damage is caused by animals and plants that have come from one ecosystem to another ecosystem, where they have no natural enemies (ecophages). Examples: the population boom and expansion of rodents in Australia, where there are no wolves and foxes; the rapid spread of the Colorado potato beetle from America to Europe and Asia; excessive expansion of eucalyptus in the Colchian forests (Georgia); it was imported from Australia and planted to drain the swamps.

General patterns of biosphere pollution:

- global scope;
- continuous accumulation;
- circulation between objects;
- transition through food chains;
- combined, complex and connecting action;
- intermittent nature;
- long-term effects (mutagenic, embryotoxic, carcinogenic).

3.6. The scale of the environmental problem on planet Earth

1. About 20 billion hectares of soil are depleted annually.
2. 6 million hectares of lands of agricultural use become deserts.
3. The desert zones are expanding (the Sahara "captures" 50 sq. km of land per year).
4. Over the last 60 years, the forest area has decreased from 15 % to 7 % of the land area.
5. Annually deforestation destroys its 11 million hectares.
6. The area of burned tropical forests is over 300 thousand square kilometer per year (which is approximately equal to ½ the territory of France).
7. 20 billion tons of CO_2 enter the atmosphere annually. Its quantity has increased by 10 % since the beginning of the century. It is the basis of the greenhouse effect.
8. The World ocean is polluted by 30 billion tons of petroleum refinery products, 50.000 tons of pesticides and 5.000 tons of mercury per year.
9. Motor vehicle exhaust gas is up to 30–60 % of the total amount of air pollution in different countries.

For this reason, humanity is faced with a vital necessity to protect the biosphere from pollution.

3.7. Scientific bases and ways of the biosphere protection from pollution

The impact of environmental pollution on the public health was summarized by WHO in the form of the Table 3.2.

This negative impact was also registered on the health of the population of Ukraine.

Adverse changes in the health of the population of Ukraine in 10-year period (2005–2015):

1. Population growth is 3 times lower than in the CIS countries as a whole.
2. Overall disease incidence increased by 35 %
3. Increase in disablement in 2 times.
4. Continuing growth of the incidence of:
   - malignant neoplasms;
   - diseases of the circulatory system;
   - bronchial asthma;
   - diabetes mellitus;
   - allergic diseases;
   - gastrointestinal tract diseases.

Table 3.2. Environmental factors affecting public health

	Air pollution	Unsatisfactory level of sanitation and waste management	Water pollution or water resources mismanagement	Food contamination	Poor living conditions	Global changes in the environment
Acute respiratory infections	*				*	
Gastrointestinal diseases		*	*	*		*
Other infections		*	*	*	*	
Malaria and other transmission diseases		*	*		*	*
Injuries and intoxication (or poisoning)	*		*	*		*
Mental disorders					*	
Cardiovascular diseases	*					*
Oncological diseases	*			*		*
Chronic respiratory diseases	*					

A similar effect is registered through the analysis of the causes of death in Ukraine (Table 3.3).

This situation is not accidental!

According to the Pollution Index 2018 Mid-year, Kyiv ranks 10th, Lviv — 30th and Kharkiv — 31st in the ranking of the most polluted cities in Europe by air and drinking water quality, total level of water pollution, waste management, subjective perception of the environmental situation in the city by the population, noise pollution level, availability of parks and green areas.

There is a growing global movement to protect the environment and reduce the impact of its pollution on public health. For this purpose, the United Nations General Assembly had created a special Economic and Social Council, which developed the United Nations Environment Programme (UNEP). A number of international health organizations operate within UNEP (Fig. 3.1).

These organizations develop and control the protection of the biosphere from pollution by atmosphere, lithosphere and hydrosphere protection systems.

Table 3.3. The mortality from respiratory diseases in Ukraine (per 100.000 population)

Cause of death	Cities with a population of			Countryside
	100.000 and more	*50.000 –100.000*	*less than 50.000*	
Pneumonia	47.9	39.22	35.75	31.55
Bronchitis	61.56	53.82	48.77	36.94
Other respiratory diseases (except influenza virus infection)	11.19	9.71	10.6	9.66
In total:	120.65	102.75	95.12	78.15

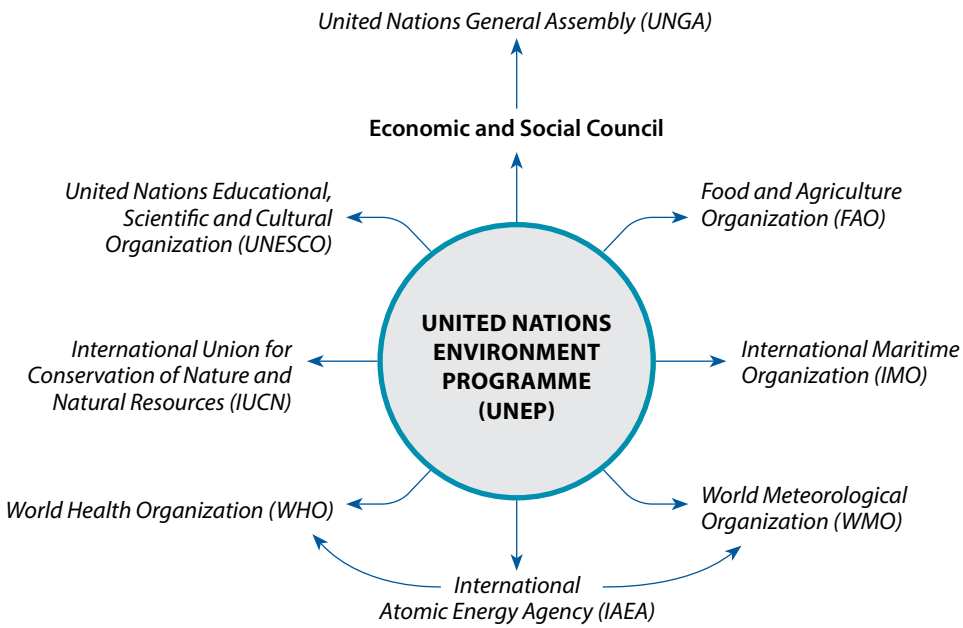


Fig. 3.1. Structured scheme of world biosphere protection organizations

4 CHAPTER AIR POLLUTION AND ITS HEALTH EFFECT. PROTECTION AGAINST POLLUTION

V. G. Bardov, S. T. Omelchuk, N. V. Merezhkina

4.1. Air pollution and its impact on public health

The following data indicates the nature and the degree of influence of human domestic activity on the state of the atmosphere.

Currently, the planet's atmosphere is polluted by more than 700 million tons of harmful substances per year.

Air pollutants are divided into the following types (Table 4.1):

1. Natural: mineral, organic and space dust.
2. Artificial (anthropogenic):
   - mechanical: cement dust, smoke or fume, soot;
   - chemical: dust, gas.

Every 10 years, the atmospheric emission doubles (Table 4.2). In the hygienic context, this pollution is very

Table 4.2. Annual atmospheric emission (according to data for 2015)

Contaminants	Atmospheric emissions, million tons	
	natural	*anthropogenic*
Solid particles (ash, dust, etc.)	3700	1000
SO_2	650	100
NOx	770	53
CO	5000	304
CnHm	2600	8
CO_2	485 000	18 300

Table 4.1. Sources of atmospheric emissions

Contaminants	Main sources	
	natural	*anthropogenic*
Solid particles (ash, dust, etc.)	Volcanic eruptions, dust storms, forest fires, etc.	Fuel combustion in industrial and domestic facilities
SO_2	Volcanic eruptions, oxidation of sulphur, sulfates that are dissipated in the sea	Similar source
NOX	Forest fires	Industry, motor-vehicle transport, heat and power stations
CO	Forest fires, oceans emissions, oxidation of terpenes	Motor-vehicle transport, industrial power plants, ferrous metallurgy
Volatile hydrocarbons	Forest fires, natural methane, natural terpenes	Motor-vehicle transport, waste afterburning, evaporations of petroleum products
Polycyclic aromatic hydrocarbons	—	Motor-vehicle transport, chemical and oil refinery plants
Plant-protecting agents (pesticides, agrochemicals)	—	Agriculture, field cultivation

dangerous, because it is concentrated mainly in the lower atmosphere, especially over big cities, industrial centers and its surrounding areas.

Intense emission sources are heat and power stations, metallurgy, petrochemical, cement and other industries (Fig. 4.1, Fig. 4.2, Fig. 4.3, Fig. 4.4). If we take into account only heat and power stations, they emit 100–120 million tons of ash and about 60 million tons of sulphur dioxide annually. Taking into consideration that heat and power stations capacity is expected to increase 10 times by 2020, it is estimated that emissions of ash will increase to 1 billion tons and sulphur dioxide — up to 450 million



Fig. 4.1. Air pollution by industry and heat and power stations. Source: *Wikimedia Commons*



Fig. 4.2. Air pollution during oil and gas production. Source: *REUTERS*



Fig. 4.3. Air pollution by industrial and domestic facilities. Source: *Dirk Meister Getty Images*



Fig. 4.4. Air pollution by oil refinery plants. Source: *sibpress.ru*

tons. Air pollution in many cities is 10–60 times higher than the maximum allowable concentration.

Different sources of air pollution in different countries have their own proportions (Table 4.3).

The Ministry of Ecology and Natural Resources of Ukraine has made a ranked list of enterprises that cause the most environmental damage. The main contaminators of air in Ukraine are: ArcelorMittal, Kryvyi Rih; Ilyich

Table 4.3. Proportions of pollutant emissions from various sources into the atmosphere

Source	USA	England	France	Ukraine
Motor-vehicle transport	60.6	33.5	32	35
Industry, electric power and heating systems	39.4	66.5	78	65

Iron and Steel Works, Mariupol; Burshtyn CP, Burshtyn; Kurakhiv CP, Kurakhiv; DTEK Pavlohradvuhillia, Pavlohrad; Zaporizhia CP, Energodar; Vuglegirska CP, Svitlodarsk; Ladyzhyn CP, Ladyzhyn; Azovstal, Mariupol; Zaporizhstal, Zaporizhia.

Motor vehicle is a main source of air pollution

About 300 million vehicles emit 400 million tons of carbon monoxide (CO and CO_2), more than 190 million tons of hydrocarbons, hundreds of thousands of tons of lead annually. In big cities, about 60 percent of emissions are vehicle exhaust gas (Fig. 4.5, Fig. 4.6, Fig. 4.7, Fig. 4.8, Fig. 4.9). Urban air pollution with carbon monoxide exceeds the maximum allowable concentration by 3–40 times. Sulphur dioxide pollution increases in a similar way.

The majority of modern vehicles are equipped with internal combustion engines. During their running, hydrocarbon fuel is burned, and large amounts of various chemical compounds are released into the atmosphere. Since the mid-1960s, exhaust emissions have become a concern for many people.

Global climate change is one of the key features of the 21st century. These changes are largely due to human activities. In particular, greenhouse gas emissions have increased significantly in recent decades. The main source of emissions is the vehicle exhaust gases (30 % of which are greenhouse gases).

Greenhouse gases exist naturally and perform the function of regulating the temperature of our blue planet, but even a small increase in their amount in the atmosphere can lead to serious global consequences. The most dangerous greenhouse gas is CO_2, or carbon dioxide. It accounts for about 80 % of all emissions, most of which are related to the combustion of fuel in the vehicle engines. Carbon dioxide remains in the atmosphere for a long time in an active state, which increases its danger.



Fig. 4.5. Transport-related air pollution. Source: *beatify.org*



Fig. 4.6. Air pollution from vehicles. Source: *recambioscolon.com*



Fig. 4.7. Air pollution from vehicles. Source: *actualidadmotor.com*

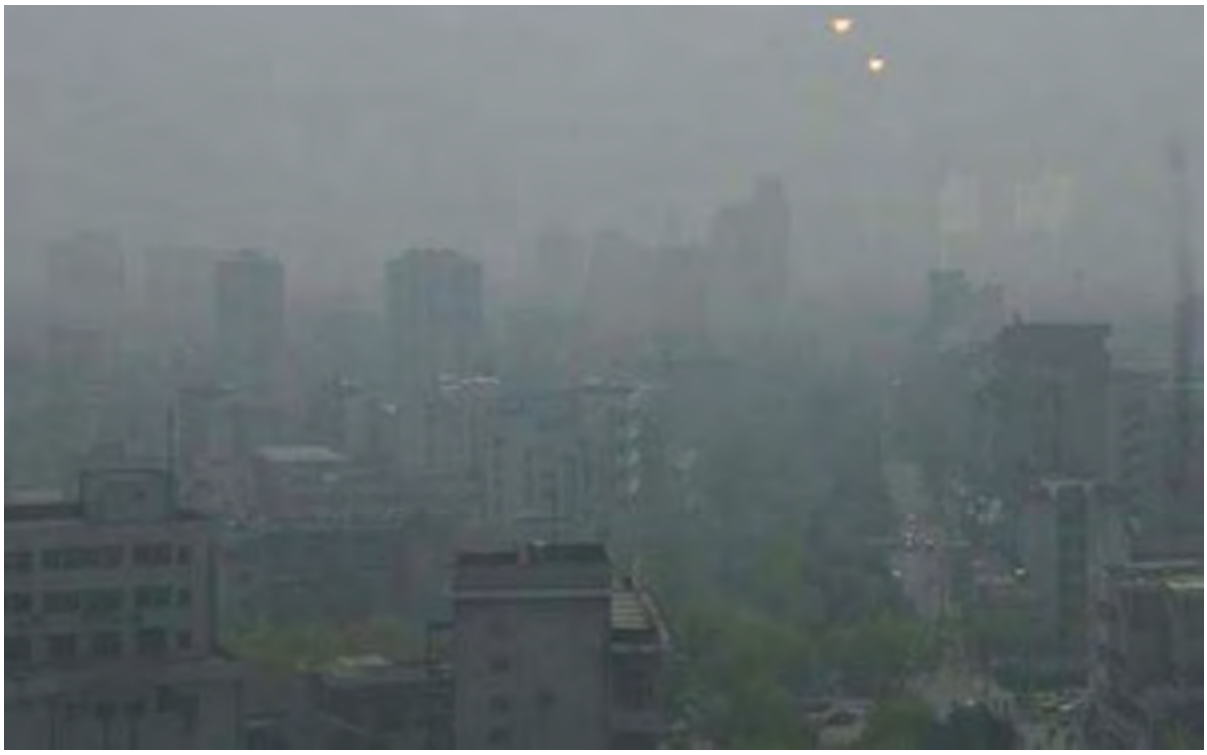


Fig. 4.8. Urban air pollution from vehicles (Los Angeles (photochemical) smog). Source: *carmenvidal.wordpress.com*



Fig. 4.9. Chemical agricultural smog. Source: *actualidadmotor.com*

In addition to CO_2, engines emit carbon monoxide (CO), hydrocarbon residuals, nitrogen oxides, sulphur and lead compounds, and particulate pollutants. All these compounds in large amounts get into the air leading to a global increase in temperature and the emergence of serious diseases in people living in big cities. Moreover, exhaust gases of various vehicles differ in composition: it entirely depends on the type of fuel used — gasoline or diesel fuel. Thus, the gasoline combustion produces a multitude of chemical compounds, which consist mainly of carbon monoxide, nitrogen oxides, hydrocarbons and lead compounds. Exhausts from diesel engines contain soot (which leads to the formation of smog), unburned hydrocarbons, nitrogen oxides, and sulphur dioxide.

Permanent and long-term influence of exhaust gases on the human body leads to a weakening of immune system, bronchitis. Damage is caused to blood vessels and the nervous system.

At present, all vehicles pass the mandatory smog test for compliance with the established ecological standards. The following exhaust gases cause maximum damage to the environment:

- carbon monoxide and carbon dioxide;
- various hydrocarbon residues.

However, up-to-date standards in the developed countries also set requirements for the level of nitrogen oxide emissions into the atmosphere and for the control system of the process of fuel evaporation from the fuel tank.

Carbon dioxide (CO_2). Of all the pollutants, carbon dioxide is the most dangerous because it has no color or odor. Vehicle exhaust gas damage to the health is significant, because the concentration in the air of only 0.5 % can cause loss of consciousness and death within 10–15 minutes; such a concentration as 0.04 %, leads to cephalalgia. This product of the internal combustion engine running is formed in large amounts when the gasoline mixture contains a lot of hydrocarbons and small amount of oxygen. In this case, the fuel is incompletely burned and CO_2 is formed. The problem can be solved by properly adjusting the carburetor, replacing or cleaning the dirty air filter, setting the valves that inject the fuel mixture, and some other measures.

A large amount of CO_2 is emitted in the exhaust gases during the engine warming-up, because it is cold and combust the gasoline mixture partially. Therefore, the vehicle should be warmed-up in a well-ventilated room or outdoors.

Hydrocarbons and organic oils. Hydrocarbons and organic oils, which do not burn out in the engine, but evaporate, are substances that determine the main harm of vehicle exhaust to the environment. Independently, these chemical compounds do not pose a danger; however, when released into the atmosphere, they react with other substances under the action of sunlight. The resulting compounds cause eye irritation and labored respiration. In addition, hydrocarbons are the major cause of smog in big cities.

Nitrogen oxides. About 78 % of atmospheric air consists of nitrogen. It is a quite inert gas, but at fuel combustion temperatures above 1300 °C nitrogen is split into individual atoms and reacts with oxygen forming various types of oxides.

Exhaust gas damage to human health is also related to these oxides. In particular, the respiratory system is most affected. At high concentrations and long-term exposure, nitrogen oxides can cause cephalgia and acute bronchitis. Oxides are also harmful to the environment. When released into the atmosphere, they form smog and deplete ozone. To reduce emissions of nitrogen oxides, a special exhaust gas recirculation system is used in vehicle. The principle of this system is to maintain the engine temperature below the threshold of formation of these oxides.

Thus, the harm of exhaust gases to the environment is unquestionable. At present, the reduction of emissions from each vehicle and replacement of gasoline with alternative and more environmentally friendly energy sources (such as solar or wind energy) are important tasks that are constantly being worked on. Great attention is paid to hydrogen fuel, because the result of its combustion is water vapor.

Effects of exhaust emissions on human health. The exhaust gases damage to human health can be very serious. Carbon monoxide is especially dangerous. It causes loss of consciousness and even death (if its concentration in the atmosphere is high). Additionally, sulphur oxides and lead compounds, which are released in large amounts from the vehicle exhaust pipe, are harmful. Sulphur and lead are known for their strong poisonous effects and can remain in the body for a long time.

Hydrocarbons and soot particles, which also enter the atmosphere due to a partial combustion of fuel in the engine, can cause severe diseases of the respiratory system, including malignant tumors.

Air pollution has a significant effect on public health.

This effect can be acute or chronic.

Effects of air pollution on public health:

1. *Acute effect (smog).*
2. *Chronic effect:*

- respiratory system diseases (bronchitis, bronchial asthma);
- allergic diseases;
- oncological diseases;
- occupational dust disease (pneumoconiosis), etc.

According to the World Health Organization 2012, air pollution was the cause of every eighth death on the planet. The rate of deaths caused by polluted air (WHO): in the world — Table 4.4, in Ukraine — Table 4.5.

The World Health Organization has made a list of the 10 major threats to humanity in 2019:

1. Air pollution and climate change.
2. Non-communicable diseases.
3. Global influenza pandemic.
4. Vulnerability of the population in an economic slump.
5. Resistance of bacteria to antibiotics.
6. Dengue Hemorrhagic Fever.
7. Ebola fever.
8. Primary health care.
9. Refusal to vaccinate.
10. HIV.

Air pollution and climate change are the most harmful among the main threats to human health. Nine out of ten people in the world breathe polluted air every day. In 2019, air pollution has been considered by WHO as the most serious ecological risk to human health. According to WHO, air pollution kills 7 million people each year because of diseases such as cancer, stroke, heart and lung disease.

Table 4.4. The rate of deaths caused by polluted air (%)

Cause of death	% of the total number of deaths
Coronary heart disease	40
Apoplectic attack	40
Chronic obstructive pulmonary disease	11
Lung cancer	6
Acute respiratory tract infection in children	3

4.2. Main chemical pollutants of the atmosphere

Scientists have developed a system for assessing harm to human health through the use of the maximum allowable concentration (MAC) for comparative evaluation of the chemical pollutants content in the atmosphere.

MAC is the maximum allowable concentration of chemical elements and their compounds in the air, which does not cause adverse effects in living organisms. The norms of maximum allowable concentrations of harmful substances are approved legislatively, controlled by sanitary and epidemiological services (in Ukraine — State Service of Ukraine on Food Safety and Consumer Protection), and are based on of toxicity studies. The MAC of each hazardous substance is included in the regulatory documents, compliance with which is mandatory. In case of violation of the MAC by any enterprise, it will face with the imposition of fine or even closure. The MAC is set for people who are most exposed to chemicals (children, senior citizens, people with respiratory diseases, etc.). The MAC value for air is measured in mg/m^3 (Table 4.6). There is also a MAC for water, soil and food.

Table 4.5. The mortality in Ukraine from respiratory diseases (per 100.000 population)

Cause of death	Cities with a population of			Countryside
	100.000 and more	*50.000 – 100.000*	*less than 50.000*	
Pneumonia	47.9	39.22	35.75	31.55
Bronchitis	61.56	53.82	48.77	36.94
Other respiratory diseases (except influenza virus infection)	11.19	9.71	10.6	9.66
Total:	120.65	102.75	95.12	78.15

Table 4.6. MAC of some harmful substances in the air

Substance	Substance hazard category	mg/m³	MAC_{DA}, mg/m³
Carbon monoxide (CO)	4	5	3
Ammonia (NH_3)	4	0.2	0.04
Xylene (C_8H_{10})	3	0.2	—
Nitrogen oxide (NO)	3	0.4	0.06
Sulphur dioxide (SO_2)	3	0.5	0.05
Toluene (C_7H_8)	3	0.6	—
Hydrogen sulfide (H_2S)	2	0.008	—
Chlorine (Cl_2)	2	0.1	0.03
Formaldehyde (HCOH)	2	0.035	0.003
Nitrogen dioxide (NO_2)	2	0.085	0.04
Phenol (C_6H_6O)	2	0.01	0.003
Benzene (C_6H_6)	2	0.3	0.1
Ozone (O_3)	1	0.16	0.03

The MAC of harmful substances in the air is different:

1. MAC_{MS} is the maximum single concentration of a substance. It should not affect living organisms for 20–30 minutes.
2. MAC_{DA} is a daily average concentration. This MAC should not adversely affect living organisms indefinitely.

Classification of dangerous substances. Based on the degree of effect on the human organism, dangerous substances are divided into four hazard categories. Each category has its own MAC. There are the following hazard categories of substances of the air:

- extremely hazardous substances (MAC less than 0.1 mg/m³);
- highly hazardous substances (MAC 0.1–1 mg/m³);
- moderately hazardous substances (MAC 1.1–10 mg/m³);
- marginally hazardous substances (MAC more than 10 mg/m³).

There is also a classification of harmful substances by the effect on the living organism. In this case, some substances belong to several classes:

1. General toxic substances. These substances cause general poisoning of the body: convulsion, nervous system disorders, paralysis.
2. Irritating agents. Substances that affect the skin, mucous membranes of the respiratory tract, lungs, eyes, epipharynx. Prolonged exposure leads to respiratory disorders, intoxication and death.
3. Sensitizers. Chemicals that cause an allergic reaction.
4. Carcinogens. One of the most dangerous groups of substances that provokes cancer.
5. Mutagens. Substances that alter the human genotype. They reduce the body resistance to diseases and cause premature aging; also can affect the offspring health.
6. Reproductive toxicity substances. They cause abnormalities in the development of offspring (not necessarily in the first generation).

Carbon monoxide (CO). It is common to find in everyday life, for example, CO is released due to malfunctions of gas-fired water heaters and kitchen stoves. Poisoning with this gas requires a very small concentration. Carbon monoxide has no color or odor, which makes it even more dangerous. Poisoning occurs rapidly, a person may lose consciousness in a matter of seconds. Despite the fact that carbon monoxide has the hazard category 4, its impact leads to death in just a few minutes. In case of such symptoms as labored respiration, cephalgia, impaired concentration, diminished hearing and vision, it is necessary to open all windows and doors and leave the room as soon as possible.

Ammonia (NH_3). Ammonia is a colorless gas with an aggressive, pungent odor. Ammonia water (or spirit of

ammonia) is a ten percent aqueous solution of ammonia. Inhalation of ammonia vapors has a stimulating effect and helps with fainting fits. However, ammonia irritates the mucous membrane of the eye, causes asphyxia; at high concentrations, it leads to corneal burns and blindness, affects the nervous system inducing permanent changes, reduces cognitive function of the brain, provokes hallucinations.

Xylene (C_8H_{10}). Xylene belongs to the hazard category 3. It can cause acute and chronic hematopoietic organ lesions. Xylene is a colorless liquid with a distinctive odor. This substance is used as an organic solvent for the manufacture of plastics, varnishes, paints, construction adhesives. At low concentrations, xylene is not harmful to humans, but prolonged inhalation of xylene vapors causes drug dependence. Xylene also affects the nervous system, irritates the skin and mucous membranes of the eyes.

Nitrogen oxide (NO). Nitrogen oxide is a poisonous colorless gas. It does not irritate the respiratory tract, thus it is difficult for human to feel it. NO interacts with hemoglobin to form methaemoglobin, which blocks the respiratory tract and causes hypoxia. Interacting with oxygen, NO is converted into nitrogen dioxide (NO_2).

Sulphur dioxide (SO_2). Sulphur dioxide has a distinctive odor similar to that of a burning match. Inhalation of SO_2, even in small concentrations, can cause respiratory tract inflammation, cough, runny nose and hoarseness. Long-term exposure provokes speech defects, sense of not getting enough air, pulmonary edema. Lung tissue lesion is also possible, but its manifestation appears only a few days after exposure. People with respiratory diseases, such as asthma, are most vulnerable to the effects of SO_2 exposure.

Toluene (C_7H_8). Toluene enters the human body not only through the respiratory system but also through the skin. Symptoms of toluene poisoning: irritation of the ocular mucous membrane, lethargy, disturbances of the vestibular apparatus, hallucinations. Additionally, toluene is extremely inflammable and has a narcotic effect. Toluene was a part of the composition of "Moment" glue (superglue) and is still found in some solvents for varnishes and paints.

Hydrogen sulfide (H_2S). Hydrogen sulfide is a colorless gas with an odor reminiscent of rotten eggs. H_2S is highly poisonous. It primarily affects the nervous system, causes severe cephalgia, convulsions and can lead to coma. The lethal concentration of hydrogen sulfide is approximately 1000 mg/m^3. The concentration of 6 mg/m^3 leads to headaches, dizziness and vomiting sickness.

Chlorine (Cl_2). Chlorine in the form of gas has a yellow-green color and a pungent, acrid odor. Main first symptoms of chlorine poisoning: eye redness, coughing fits, chest pain, temperature rise. The development of bronchopneumonia, bronchitis is possible. Chlorine is a potent carcinogen. It provokes cancer and tuberculosis. At high concentrations, death can occur after several breaths.

Formaldehyde (HCOH). The formaldehyde content in the air is especially high in big cities, because it is a product of combustion of motor fuel. Formaldehyde emissions also occur at chemical, leather processing and woodworking enterprises. It adversely affects the genetic material, reproductive, renal and respiratory systems, liver. Poisoning begins with growing nervous system damage — dizziness, apprehension (feeling of fear), shivering, unsteady gait, etc. Formaldehyde is officially recognized as a carcinogen, but also has allergenic, mutagenic and sensitizing effects.

Nitrogen dioxide (NO_2). Nitrogen dioxide is a reddish-brown poisonous gas with a distinctive pungent odor. NO_2 is a result of combustion of automotive fuel, activities of cogeneration plants (CP) and industrial enterprises. At the initial stage of exposure, nitrogen dioxide disrupts the upper respiratory tract, and subsequently can cause bronchitis, inflammation or pulmonary edema. This gas is most dangerous for people suffering from bronchial asthma and other lung diseases. Due to the color of nitrogen dioxide, its emissions are called "foxtail". This gas is associated with the fox not only in color, but also in "cunning": to "hide" from people, it impairs sense of smell and vision, so it is not so easy to detect.

Phenol (C_6H_5OH). Phenol is one of the industrial pollutants that is harmful to animals and humans. Inhalation of phenol vapors causes depression of strength, vomiting sickness, dizziness. Phenol has a negative effect on the nervous and respiratory systems, as well as the renal system, liver, etc. The use of phenol often leads to unfortunate results. In the 70s in the USSR, it was used in the construction of residential buildings. People, who lived in "phenolic houses", complained of low well-being, allergies, cancer and other health problems. Although phenol-formaldehyde resins are used in the production of furniture, construction materials, etc., unscrupulous manufacturers may exceed the permissible limit or use poor quality chemicals.

Benzene (C_6H_6). Benzene is a dangerous carcinogen. Benzene vapor poisoning cause headache, vomiting sickness, mood swings, heart rhythm disorders, and fainting fits (occasionally). The permanent effect of benzene on the body is manifested by fatigue, sleep disorders, bone marrow dysfunction, leukemia, anemia. The first evi-

dence of benzene poisoning is predominantly euphoria, because inhalation of its vapors has a narcotic effect. This chemical compound is a part of gasoline and used for the production of plastics, dyes, synthetic rubber.

Ozone (O_3). Ozone is a gas with a distinctive odor; at high concentrations, it has a blue color. Ozone is a natural antiseptic that disinfects water and air. Unfortunately, ozone has extremely negative consequences. It aggravates allergies, exacerbates cardiac diseases, and causes decrease in immunity and respiratory disorders. Over the longer term, ozone has a slow but extremely harmful impact. This gas is especially dangerous for children, senior citizens and asthma patients.

Lead (Pb). Lead pollution occurs as a result of industrial activities: non-ferrous metal industry, battery production, canned-foods industry. Lead belongs to the first hazard category; it means that it is extremely dangerous for the human body. Lead poisoning does not appear immediately and has an insidious form: the substance remains in the body for a long time accumulating in bones and tissues. Lead causes the dysfunction of the cardiovascular, circulatory and auditory systems; the substance also leads to a decrease in intellectual abilities. The first symptoms are similar to the signs of strong overfatigue — apathy, dizziness, bad mood, etc. These symptoms are the reason for physician visit; otherwise, the prolonged exposure causes convulsions, muscle pain, speech abnormality. Severe poisoning can lead to paralysis, coma and death.

4.3. Physical pollution of the atmosphere

Besides the chemical pollution, of special interest is the physical environment change, for example, pollution of the atmosphere by noise and radio frequency electromagnetic fields. At present, thousands of radio broadcasting, TV and radio detecting and ranging stations operate everywhere in the world. The Earth's planetary emission in the VHF band has become hundreds of times greater than similar radiation from the Sun.

4.4. Atmospheric effects of air pollution

Atmospheric effects due to air pollution:

- "greenhouse" effect (CO_2, methane, nitrogen oxides, chlorofluorocarbons, trifluorocarbons, water vapor);
- "nuclear winter" effect (aerosol — dust, soot);
- "ozone hole" effect (freons, chlorofluorocarbons);
- acid rain (dissolution of oxides SO_2, CO, NO_2 in water vapor clouds);
- smog:
  - London-type sulfurous smog;
  - Los Angeles-type photochemical smog;
  - volcanic smog *(vog)*;
  - Alaskan-type ice smog;
  - forest fires smog;
  - chemical agricultural smog.

4.4.1. Greenhouse effect

The greenhouse effect leads to the accumulation of Earth's radiant heat flux and, as a consequence, to the climate warming and global warming (Fig. 4.10).

Natural causes (sources) of the greenhouse effect (global warming):

1. Forest fires: the release of large amounts of CO_2. Deforestation (trees are responsible for CO_2 absorption and O_2 release).
2. Eternal congelation: frozen soil contains a lot of methane, which pollutes the atmosphere.
3. The oceans emit a lot of water vapor.
4. Volcanic eruptions emit a lot of CO_2, soot, cinder.
5. Living organisms exhale CO_2.
6. Animals emit methane.

Anthropogenic causes — the main causes of global warming:

1. Oil fields and industry. Combustion of gas and oil leads to the release of large amounts of CO_2, soot and the like into the atmosphere.
2. Mineral and organic fertilizers promote the release of greenhouse gas — nitrogen dioxide NO_2.
3. Deforestation leads to an increase in the amount of CO_2 (greenhouse gas) and a decrease in the amount of O_2.
4. Overpopulation of the planet Earth.
5. Creation of a large number of waste deposits.

British and Swedish scientists have found that global warming began on Earth due to an extremely strong volcanic eruption on the Scottish island of Skye (56 million years ago). Then the air temperature on the planet rose by 5–8 °C. Scientists have called this stage of Earth's history the Paleocene Eocene Thermal Maximum (Scientific Reports Journal).

Global warming will result in many negative effects, which are already experiencing in many regions.

1. With rising average temperature by 2 °C, due to the melting of glaciers in the Arctic and Antarctica, the

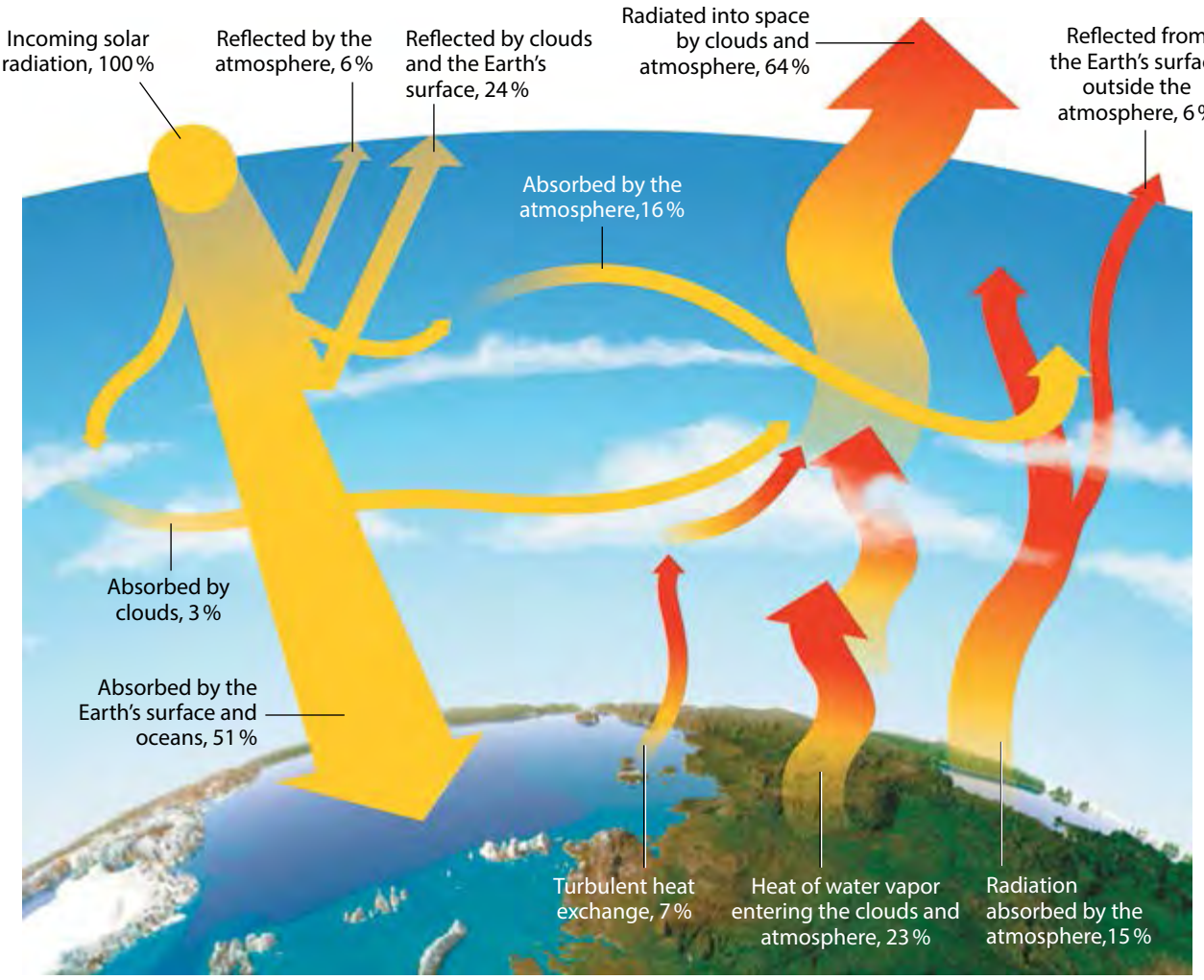


Fig. 4.10. Heat transfer phenomenon in the Earth's atmosphere

water level of the oceans will rise by 50–60 cm, and then there will be a world-wide flood (Fig. 4.11). The Netherlands (Fig. 4.12), London (Fig. 4.13), New York, Miami, Mumbai will be flooded.

The south of Ukraine will be under water, the Crimean Peninsula will become an island, Odesa, Kherson, Berdiansk, Mariupol, Feodosia and other cities of Ukraine can be under water (Fig. 4.14).

In Ukraine, the Black and Azov Seas could flood 34 cities, 62 villages, 660 hazardous facilities, 200.000 hectares of agricultural lands and 98 objects of nature reserve fund by 2100. 75.000 Ukrainians risk becoming ecological migrants.

The salinity of the World Ocean will also decrease.

1. Increasing the number of dead zones on the planet (Fig. 4.15). Some deserts will become larger and snow will fall in the Sahara.
2. Reduction in harvest from the fields; some agricultural crops will disappear completely.
3. Global warming may soon even leave humanity without a range of foods. In the future, the Earth will heat up to such a degree that some plants simply will not survive. As a consequence, chocolate (cocoa trees will disappear), wine (grapes will disappear) and beer (barley will disappear) will become inaccessible to humanity.
4. Winter will be much colder, and summer will be either abnormally hot or quite cold.
5. Global reduction in drinking water.
6. Global climate disasters, tornadoes and whirlwinds, heavy rainfalls, cyclones, winds will become a constant phenomenon in places where they did not exist before.

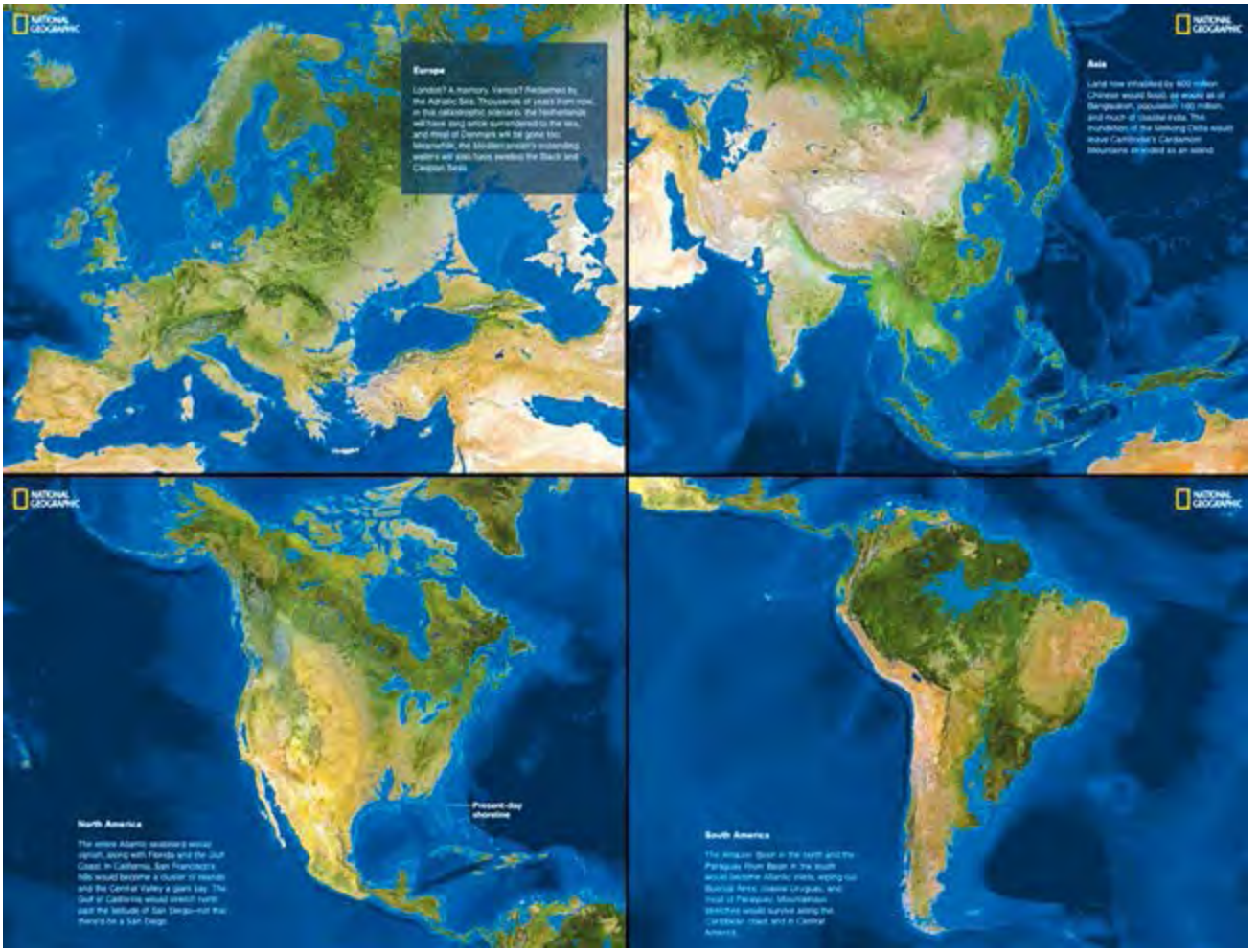


Fig. 4.11. World-wide flood (blue colour shows the land areas that will be flooded) when the temperature rises by 2 °C. Source: *National Geographic*



Fig. 4.12. Forecast of the Netherlands flooding during the world-wide flood (+2 °C). Source: *air-worldwide.com*



Fig. 4.13. Forecast of the London flooding during the world-wide flood (+2 °C). A still from the disaster movie *Flood, 2007*

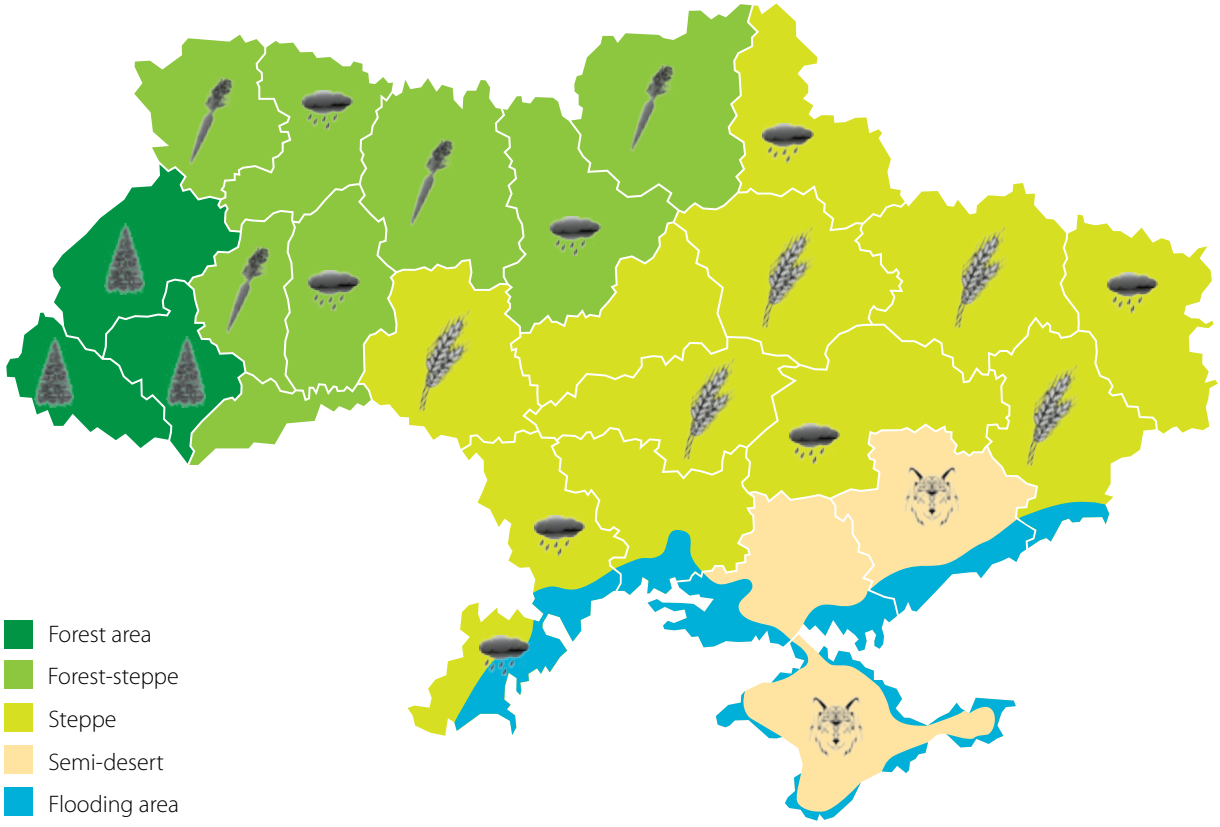


Fig. 4.14. Forecast of the Ukrainian regions flooding as a result of climate change (flooded areas are indicated in blue colour). Source*: newsplot.org*



Fig. 4.15. Dead zone instead of fertile land due to climate change. Source: *osservatorioagr.eu*

7. Rapid climate change will lead to the extinction of many species of animals and plants.

Scientists report that 2019 was the hottest year in human history. The El Niño phase has begun (El Niño is the warming of the surface waters of the Eastern Pacific) triggering extreme weather conditions that have already worsened due to climate change. The effects of El Niño have been more significant in recent years due to global warming, and these effects will be even worse as temperatures continue to rise.

Global warming means more and more manifestations of devastating fury of nature and dangerous conditions, such as heat wave, forest fires, floods and severe storms.

In 2018, there were 79 tropical (or revolving) storms in the Northern hemisphere; this is higher than the average for the last 53 periods. Powerful and often the most severe storms caused devastation, enormous economic damage and resulted in the losses of human life. The heat waves led to a high loss of productivity, because it was stiflingly for work or to go outside.

Climate change in the form of warming and droughts is causing conflicts, wars and population migration, for example, the recent migration waves from the Middle Eastern countries.

The halt of greenhouse effect is very challenging, but it's pretty possible. Appropriate measures:

- replacement of fuel exhaust gases with hydro-, helio- or aqua-energy;
- application of waste-free technology;
- minimization of methane emissions;
- development of CO_2 absorption technology;
- halt of mass deforestation;
- increase of green areas.

Since December 2018, it has been reported that the World Bank will allocate $200 billion to combat climate change. This information was announced prior to the 24th UN Climate Change Conference in Katowice, Poland.

Previously, the Climate Transparency consortium of G20 countries published a report on monitoring the observance of the Paris Agreement on climate.

According to the report, most countries, with the exception of India, use fossil fuel. This situation does not comply with the terms of the Paris Agreement on climate. Under current conditions, by the end of the 21st century, global temperature could rise by 3.2 °C. In order for the warming not to exceed 1.5 °C, as provided for by the Paris Agreement, the G20 countries must reduce their emissions in half by 2030.

Scientists call upon the leading world politicians and all of mankind to keep global warming within 1.5 °C by 2030, otherwise the alteration of course of man-made climate change will be very costly or even impossible. Humanity needs to spend $2.4 trillion to hold the temperature rise within 1.5 °C.

4.4.2. Nuclear winter effect

"Nuclear winter" is a hypothetical global state of the Earth's climate as a result of major nuclear war (Fig. 4.16, Fig. 4.17, Fig. 4.18).

The release of large amounts (millions of tons) of smoke, soot, large-scale fires in consequence of the explosion of 30–40 % of the world's inventory of nuclear bombs, will lead to a drop of the planet's temperature to the Arctic temperature (–30 °C) due to a significant increase in reflection of solar radiation into space (Fig. 4.19, Fig. 4.20).

Clouds of smoke and ash will remain in the atmosphere for several years ("nuclear night"). During such a human-induced ice age, the most of life on Earth will disappear. When dust and soot settle to the ground, a "nuclear winter" is followed by a "nuclear summer" caused by carbon dioxide emissions and the greenhouse effect. A nuclear summer will be accompanied by a rapid climate warming and desertification. The Earth's surface must turn into a harsh desert.

It is asserted on the YouTube channel Kurzgesagt that 15.000 nuclear bombs have been created in the world, and 14.000 of them are in Russia and the United States.

If all the world's nuclear weapons are detonated, 4.500 large cities could be destroyed and about 3 billion people killed.

If all the stockpiles of nuclear weapons exploded in one place, a fireball with a diameter of 50 kilometers would be formed. The shock wave will destroy three thousand square kilometers and round the Earth dozens of times in a matter of weeks. In addition, within a radius of 250 kilometers from the center of atomic explosion, every living thing will burn.



Fig. 4.16. The nuclear bomb explosion over the city. Source: *picserio.com*



Fig. 4.17. The nuclear bomb explosion beyond the Arctic Circle. Source: *U.S. Air Force via Reuters*



Fig. 4.18. The nuclear bomb explosion in a tropical climate. Source: *wikimedia.org*

4.4.3. "Ozone hole" effect

Passing through the Earth's atmosphere, high-energy quanta of γ-rays, X-rays and short ultraviolet rays of the Sun at different altitudes (from 80 km above the Earth's surface) interact with oxygen molecules (O_2), lose their energy and form ozone (O_3). At the same time, radiation less than 34 km with a wavelength shorter than 280 nm was not registered. Then positive (biogeneous) ultraviolet rays with a wavelength of 281–400 nm follow to the Earth.

Thus, at an altitude of 34–100 km atmospheric oxygen protects all life on the Earth from hard γ-rays, X-rays and Sun ultraviolet radiation with a wavelength shorter than 280 nm. Ozone is a by-product of this process.

Due to the fact that ozone is 1.62 times heavier than air, it is concentrated at an altitude of 18–30 km (maxi-



Fig. 4.19. "Nuclear night" as a result of a nuclear war (hypothesis). Source: *artofgregmartin.com*



Fig. 4.20. "Nuclear winter" as a result of a nuclear war (hypothesis). Source: *retroreport.org*

mum 20–25 km), where the density of the atmosphere is in equilibrium with ozone.

This zone of the atmosphere at an altitude of 18–30 km with high ozone concentration is called the "ozone layer". In the ozone layer, the concentration of ozone molecules is 10 times higher than in the atmosphere near the Earth's surface. It does not participate in the absorption of biologically dangerous (abiogenic) solar radiation with a wavelength shorter than 280 nm.

"Ozone holes" is a decrease in the amount of ozone in the atmosphere ozone layer by more than 30 %.

"Ozone holes" were recorded in the ozone layer over the Antarctic in September — October, and over the Arctic in January — March. The cause of these "ozone holes" is the absence of solar radiation when these parts of the atmosphere are in the shadow of the Earth during the polar night.

Other "ozone holes" were recorded over the industrial regions of highly-developed countries (industrial region in Ruhr area, Germany; Silicon Valley, USA; Donetsk-Prydniprovskyi economic region before the war, Ukraine).

These "holes" resulted from the ozone depletion by volatile chemically active air pollutants (chlorofluoromethanes, trifluoromethanes, freons, etc. One molecule of chlorine destroys 100.000 molecules of ozone). "Ozone holes" occur when rockets are launched from space-vehicle launching sites due to the air pollution by chemically active combustion products of rocket fuel and oxidants.

Thus, "ozone holes" are only an indicator of intense air pollution in the troposphere above the particular Earth area.

4.4.4. Acid rains

Acid rains include all types of meteorological precipitation (snow, rain, hail, fog, rain and snow mixed), when the pH falls below 5.5 due to their combination with oxides [sulphur oxide CO_2, nitrogen oxides NO_x (N_2O, NO_2)], carbon dioxide and chlorine, acids are formed (H_2SO_4, HNO_3, $HClO_4$, H_2CO_3).

In the late 20th and early 21st centuries, acid precipitation has become an essential component of the atmosphere. Acid rains occur in Europe, North America, as well as in areas of the largest agglomerations of Asia and Latin America.

The problem of acid rain differs from area to area; it depends on the concentration of gases in the atmosphere. Acid rain is particularly harmful in some countries: Germany, USA, the Czech Republic, the Netherlands, Slovakia, Australia, Switzerland, etc.

True acid rain, which causes negative effects, is formed as a result of a chemical reaction between various oxides of nitrogen, sulphur oxide and water.

The main sources of acid-forming emissions:

1. Natural sources of gas emissions:
   - volcanic eruptions;
   - forest fires.
2. Anthropogenic sources:
   - traffic emissions;
   - emissions of thermal electric power plants, iron and steel enterprises;
   - coal and ore extraction;
   - emissions from waste recycling plants and from the unauthorized disposal fields burning.

In addition, one of the sources of acid rain is also livestock business. The issue is about a large amount of animal by-products and waste. The manure contains ammonia, which is converted into acid by bacteria. The acid evaporates to combine with nitric oxide present in the fertilizer. This contributes to the fall of acid rain.

Harmful effects of acid rain on ecosystems, monuments of architecture and people

Negative effects of acid rain on the environment:

- death of forests, vegetation; harvest failure;
- decay of buildings and cultural monuments;
- negative impact on pipelines;
- corrosion increase of vehicle bodies;
- soil pH increases, therefore, reduction in yields;
- rise of possibility of toxic metals percolation into the soil layers with underground water sources;
- acidification of water bodies (ponds, lakes, rivers, gulfs), which leads to the death of all living things (flora and fauna).

Acid precipitation negatively affects aquatic ecosystems causing the death of fish and other aquatic life. Acidification of rivers and lakes water has a major influence on terrestrial animals, because many animals and birds are part of the food chain that begins in aquatic ecosystems. Along with the loss of lakes, forest degradation also becomes apparent. Acids damage the protective wax coating of leaves, making plants more vulnerable to insects, fungi and other pathogens. During drought, damaged leaves lose more moisture due to evaporation. Leaching of nutrients from the soil and the release of toxic elements are the factors of stunting and dieback of trees. When forests dieback, wild animals migrate or die. De-

stroyed forest ecosystem results in disastrous effects: soil erosion, water reservoirs contamination, floods, degraded water resources. Acidification of the soil with nitric-acid rains stimulates the development of forest pests. In consequence of soil acidification, there is a dissolution of the nutrients vital to plants; these substances are carried by rains into groundwater. Concurrently, heavy metals are leached from the soil and absorbed by plants, causing serious damage. By using such plants in food, human also receives an increased dose of heavy metals. Degradation of edaphon causes yield decrease, agricultural products quality deterioration, whereby a deterioration in the health of the population takes place. Under the action of acids, rocks and minerals release aluminum, mercury and lead, which then enter surface and groundwater.

Aluminum is liable to cause Alzheimer's disease (a type of premature aging). Heavy metals that get into natural waters have a negative effect on the renal system, liver, central nervous system, causing various oncology diseases. The genetic effects of heavy metal poisoning can occur in 20 years or more, not only in those people who drink contaminated water, but also in their offspring.

Air pollution by acid-forming emissions has a variety of harmful effects on the human body. Inhalation of moist air containing sulfur dioxide is especially dangerous for the senior citizens suffering from cardiovascular and pulmonary diseases. In severe cases, pulmonary edema may occur. It is also harmful for healthy people, because SO_2 and sulfate particles have a carcinogenic effect. It is found that there is a strong correlation between increased mortality from bronchitis and increased concentrations of sulfur dioxide in the air. During the dangerous London fog of 1952, more than 4.000 deaths were attributed to high levels of sulfur dioxide and sulfate particles in the moist air. Numerous studies have shown an increase in the number of respiratory diseases in areas where the air is polluted with nitrogen dioxide (NO_2). When entering the respiratory tract, it interacts with hemoglobin in the blood, hampering the oxygen transfer to organs and tissues, causing respiratory, asthmatic and cardiac diseases. In February 1972, more than 70.000 people in Japan fell ill for that cause; for many of them the disease was fatal.

Damage of monuments and forests. Acid rains corrode metals, paints, synthetic compounds, destroy architectural monuments. Many sculptures and houses in Rome, Venice and other cities, architectural monuments such as the Parthenon in Athens, Cologne Cathedral, etc., have received much more damage in the last few decades than in all previous times. More than 50.000 statues of the Yungang Grottoes in China, created 15 centuries ago, are in danger of complete destruction due to acid rain. Acid rains are the most typical phenomenon for industrialized countries with highly developed electric power industry. Harmful precipitation caused the greatest loss to the forests of Central Europe; in particular 35 % of the Germany forests (over 2.5 million hectares) were damaged (Fig. 4.21). The damage caused by acid rains to European forests is estimated at 118 million m^3 of wood per year (of which about 35 million m^3 — in the European territory of Russia). Agricultural plants suffer from acid rains in a smaller degree (Fig. 4.22), considering that soil acidification can be controlled by agrochemicals.

The fight against acid precipitations. There are several ways to solve the problem of acid rains:

- reduction of motor vehicle emissions; transition to the use of quality fuel with a minimum of additives;
- need to introduce environmental policy to large industrial enterprises. Installation of effective pollution control facilities with several stages of air purification (emissions);
- use of low-sulfur coal as fuel;
- use of alternative energy sources (solar, wind, etc.).

4.4.5. Smog. Types of smog

One of the most common types of air pollution in large cities is smog (the term "smog" is a contraction of the words "smoke" and "fog" to refer to smoky fog). This is an aerosol consisting of smoke, fog, dust, sulfur oxides, carbon, nitrogen and other emissions (Fig. 4.23, Fig. 4.24).

Smog is divided into the following types:

1. London-type moist (sulfurous) smog.
2. Los Angeles-type photochemical (dry) smog.
3. Alaskan-type ice smog.
4. Volcanic smog.
5. Forest fires smog.

1. London-type moist (sulfurous, fumy) smog (Fig. 4.25) is a thick fog with foreign matters of soot and SO_2.

The Great Smog was first recorded in 1952 in London. It is formed at 100 % humidity, calm weather, high concentration of combustion products of sulfur-containing fuels, such as coal or fuel oil. During the "Great Smog" in London, about 4.000 people died of pulmonary or cardiovascular diseases, and about 100.000 became ill with respiratory diseases.

2. Los Angeles-type photochemical (dry, white) smog (Fig. 4.26, Fig. 4.27, Fig. 4.28) was first registered in 1944 in Los Angeles during a heavy traffic.



Fig. 4.21. The forest is damaged by acid rains



Fig. 4.22. Corn crop damage due to acid rain



Fig. 4.23. London-type moist smog. Source: *pinterest.com*



Fig. 4.24. London-type smog in the city. Source: *@Tatiana Yanushkova flickr.com*



Fig. 4.25. London-type moist smog. Source: WordPress.com

Smog is formed under the conditions of high air pollution (especially vehicle emissions), cloudless sunny weather, low humidity, zero wind condition. Under the action of long-wavelength (over 290 nm) ultraviolet radiation of the Sun, reactions of decomposition of components of motor emissions occur: photolysis (light decomposition), oxidation (oxygen degradation), pyrolysis (decomposition by heating), hydrolysis (decomposition by water vapor), ozonolysis (ozone degradation).

As a result, substances more toxic than the initial ones are often formed: nitrogen oxides (nitrogen dioxide), tropospheric (ground-level) ozone, evaporation of volatile organic compounds (vapors of gasoline, paints, solvents, pesticides, etc.), nitrate peroxide. A light brown or yellow-blue mist is formed, which leads to adverse effects: severe irritation of mucous membranes, mass poisoning of people, death of plants and animals. Smog increases the corrosion of metals, the destruction of buildings, monuments, rubber and other materials.

3. Volcanic smog *(vog)* is formed as a result of a volcanic eruption (Fig. 4.29, Fig. 4.30, Fig. 4.31, Fig. 4.32, Fig. 4.33), in which toxic emissions react with solar radiation and atmospheric oxygen. The toxic substances formed provoke an exacerbation of pulmonary diseases and other diseases. This type of smog is of frequent occurrence on the islands of Indonesia, Iceland, Hawaii, etc.

The eruption of the Yellowstone supervolcano will also lead to a "volcanic winter". It means a sharp cooling of the lower Earth's atmosphere due to the release of huge amounts of cinder and gases (cinder will cover the Sun for



Fig. 4.26. Los Angeles-type smog in the modern city. Source: *shutterstock.com*



Fig. 4.27. City at the time of photochemical smog and without it. Source: *dailymail.co.uk*



Fig. 4.28. Los Angeles-type smog. Source: *capal.org*

a long time). As a result, humanity will no longer be able to provide itself with the necessary food supply: according to WHO, the available foodstuff will be enough for 74 days, after which famine will begin around the world.

4. Alaskan-type ice smog (Fig. 4.34) is formed when there are intense sources of air pollution, very low air temperatures, zero wind, high humidity. Dust and aerosol particles are adsorbed on the ice crystals formed.



Fig. 4.29. Fuego volcano eruption in Guatemala on November 18, 2018. Fuego volcano is located about 40 kilometers from the capital of Guatemala and near the popular tourist city of Antigua



Fig. 4.30. On October 13, near Bellasta (northern Sumatra, Indonesia), Sinapeng volcano erupted volcanic debris and volcanic cinder. The volcano slept for 400 years and erupted on September 15, 2013. It caused dozens of deaths and thousands of people were forced from their homes



Fig. 4.31. The eruption of Kilauea volcano on the island of Hawaii has created new volcanic holes in the ground, slowly releasing lava and toxic gas



Fig. 4.32. The eruption of Kilauea volcano on the island of Hawaii

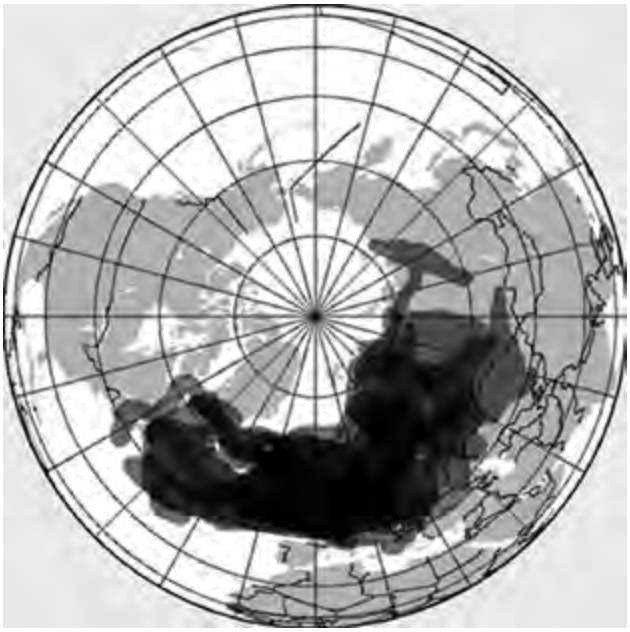


Fig. 4.33. The composite map of a volcanic ash (cinder) cloud from the Eyjafjallajokull volcano in Iceland, April 14–25, 2010

A fog is formed, which adversely affects people with pulmonary and cardiovascular diseases.

Burning forests in Indonesia are the cause of haze fog similar to smog. It extends to Malaysia, the Philippines, Singapore and Thailand (Fig. 4.35).

As a result of peat fires, Kyiv, St. Petersburg, and Moscow are often covered with haze fog similar to smog for several weeks (Fig. 4.36).

4.5. Protection of the atmosphere from pollution

Scientists believe that the Earth's atmosphere can be protected from environmental crisis in the following ways:

1. Limit the population.
2. Reduce energy consumption and utilization.
3. Reduce atmospheric emissions.
4. Use natural energy sources.
5. Use pollution control facilities (filters) in heavily contaminated areas.

Different groups of measures are used to protect the atmosphere:

1. Legislative measures.
2. Technological measures.
3. Improvement of fuel.
4. Pollution control facilities.
5. Planning.
6. Green planting.
7. Hygienic control.
8. International co-operation.



Fig. 4.34. Ice smog (Siberia)



Fig. 4.35. Forest fires in Sumatra and Kalimantan



Fig. 4.36. Heavy smog caused by peat fires near Moscow

1. Legislative measures:
   - Constitution of Ukraine of June 28, 1996.
   - Law of Ukraine "On Environmental Protection", 1991.
   - "Fundamentals of the legislation of Ukraine on Healthcare", November 19, 1992.
   - Law of Ukraine "On Atmospheric Air Protection", October 16, 1992.
   - Law of Ukraine "On Ensuring Sanitary and Epidemic Welfare of the Population", February 24, 1994.
   - "State sanitary rules for the protection of ambient air of the settlements (from the contamination with chemical and biological substances)", DSP-201–97.
2. Technological measures aimed at ensuring of environmentally-clean manufacturing:
   - use of environmentally-clean energy sources: tidal energy, solar power generators, turbine towers (wind), etc.;
   - waste-free production technologies: waste from one link in the ecosystem is used by other links.
3. Improvement of fuel and protection from vehicle exhaust gases: substitution of internal combustion engines by electric ones (Fig. 4.37); compressed gas vehicles; substitution of diesel fuel or gasoline by a mixture of alcohols, hydrogen, etc.
4. Pollution control facilities — development and implementation of cleaning filters (mechanical, electrical, magnetic, sound and others) to capture dust, vapors and gases. For example, the "sponge mountain" made of cement in Turin (Italy) (Fig. 4.38), the facades of buildings-filters covered with titanium dioxide (Mexico City, London), towers for air purifying ("Smog Free Tower", Beijing).
5. Planning: factories and plants, highways should be separated from residential areas by a buffer system of green planting (water reservoirs); they should be located on the leeward side (taking into account the wind rose) on elevated areas, and so on.
6. Green planting for cities and industrial centers: greenery through photosynthesis frees the air from carbon monoxide and enriches it with oxygen (Fig. 4.39).
7. Hygienic control is the state sanitary supervision in the field of air protection. It is carried out in the form of precautionary state supervision in the selection and allocation of land for construction of industrial enterprises, expertise of their construction and reconstruction projects, commissioning, and current state sanitary supervision of settlements of currently operating facilities, and compliance of sanitary norms and rules, MAC or TS(E)L.
8. International cooperation on atmospheric protection. The most important activities in the framework of UNEP, UNESCO, WHO, etc.:
   - Kyoto Protocol (United Nations Framework Convention on Climate Change, Kyoto, Japan, 1997).
   - Framework Convention on Climate Change, Rio de Janeiro, 1992.



Fig. 4.37. Electric motor car



Fig. 4.38. "Sponge mountain" made of cement in Turin (Italy). Source: *archdaily.com*



Fig. 4.39. Futuristic eco-village in the industrial area of Brussels (Belgium). Source: *vincent.callebaut.org*

- Paris Agreement within the United Nations Framework Convention on Climate Change (2016) (the following measures):
  - to keep the global temperature rising within 1.5 °C (much lower than + 2 °C);
  - to increase the capacity to adapt to the effects of climate change, to support the combating climate change;
  - to harmonize financial flows aimed at combating climate change and achieving low emissions of industrial gases;
- The 24th Katowice Conference (2018) of the Parties to the United Nations Framework Convention on Climate Change under the Kyoto Protocol.

Addressing emissions in large cities

Evaporation of fuel. Simple evaporation of fuel from a tank can be one of the intense sources of environmental pollution. As a result, special tanks have been manufactured for the past few decades, the design of which is aimed to solve this problem. The fuel tank must "breathe". In this regard, a special system was invented: the cavity of the tank is connected by tubes to the reservoir, which is filled with activated carbon. This activated carbon is able to absorb the resulting fuel vapor when the vehicle's engine is not running. As soon as the engine is started, the corresponding port opens and the vapors absorbed by activated carbon arrive in the engine for their burning. The correct operation of this whole system from the tank and tubes must be constantly monitored, because of the possible leak of fuel vapors that will pollute the environment.

Large modern cities combine dozens of thousands of factories, millions of people and hundreds of thousands of cars. All this greatly pollutes the atmosphere and causes the main problem of the 21st century. The city authorities are introducing a set of administrative measures to address it. Thus, in 2003, a protocol was adopted in London on addressing the environmental pollution by automobile transport. According to this protocol, drivers who drive through the central areas of the city are charged an extra fee of 10 pounds. In 2008, the London authorities approved a new law that began to effectively regulate the movement of trucks, buses and cars in the central part of the city, setting an upper speed limit for them. These measures have reduced the content of harmful gases in the atmosphere over London by 12 %. Since the 2000s, similar measures have been taken in many cities with a million-plus population: Tokyo, Berlin, Athens, Madrid, Paris, Stockholm, Brussels, etc.

The opposite effect of the anti-pollution law. Protection from motor vehicle exhaust gases is by no means simple. Dramatic examples are the two most polluted cities on the planet: Mexico City and Beijing. Since 1989, a law has been in force in Mexico's capital, prohibiting the use of a personal car on certain days of the week. At first, this law began to demonstrate positive trends and gas emissions were reduced, but after a while residents began to buy a second old car, so they began to drive daily on personal vehicles, replacing one car with another during the week. This situation has further aggravated the state of the Mexico's atmosphere. A similar situation is observed in the Chinese capital. According to data from 2015, about 80 % of Beijing residents own several cars, which allow them to drive a car every day. In addition, a huge number of violations of the anti-pollution law are recorded in this megacity.

Ten countries have announced a program to stop selling and registering cars with internal combustion engines (gasoline and diesel) by 2030–2040 in order to reduce transport emissions and increase efforts to achieve the goals of the Paris Climate Agreement. Among them: Norway, Denmark, the Netherlands, Great Britain, Ireland, France, Iceland, Sweden, Israel, Germany. India and China announce about the same time frames.

What measures can an individual use to be protect him/herself from air pollution?

1. More walking, cycling or use public transport.
2. Use a personal respiratory protection (Fig. 4.40, Fig. 4.41).
3. When outdoors, stay away from sources of air pollution (highways, thermal power plants and central heating stations, factories, etc.).
4. Use electric household appliances instead of gas household appliances.
5. Use air conditioners, filters, etc.
6. Avoid substances (paints, solvents) with a high content of volatile organic compounds.

If the apartment windows look onto the street with heavy traffic or an industrial enterprise, the air change should be done properly. Open windows, letting in dangerous gases, only worsen the atmosphere in the house. In this situation, the ventilator or "breather" will help: the filtration system of the device will clean the air from harmful substances coming from the street.

During the vacation or on weekends it is best to get out of the city and to choose places where there are mountains, forests and clean water. Clean, fresh air has a beneficial effect on immunity and health.



Fig. 4.40. Personal respiratory protection (safety mask). Source: *AFP/Getty Images*



Fig. 4.41. Personal respiratory protection (respirator). Source: *pinterest.com*

It is widely agreed that houseplants help to deal with harmful substances in the air. But that's not entirely true. Although they absorb carbon dioxide and some other substances, their cleaning abilities are greatly overestimated. Air purifiers will help better.

Before going outdoors in cities people use telegram-bots "Air Quality Index" according to Air Visual.

There are four levels of safety in Kyiv according to the air quality index:

- 0–50 — the air is clean; you can go for a walk and do sport;
- 51–100 — the risk is insignificant; you can go for a walk and ventilate the room;
- 101–150 — there is a risk to health; do not go outside with no need for;
- more than 151 — it is dangerous to go outside without a protective mask;
- the medical forecast of the air quality index in Kyiv is published daily on the Internet (Fig. 4.42).

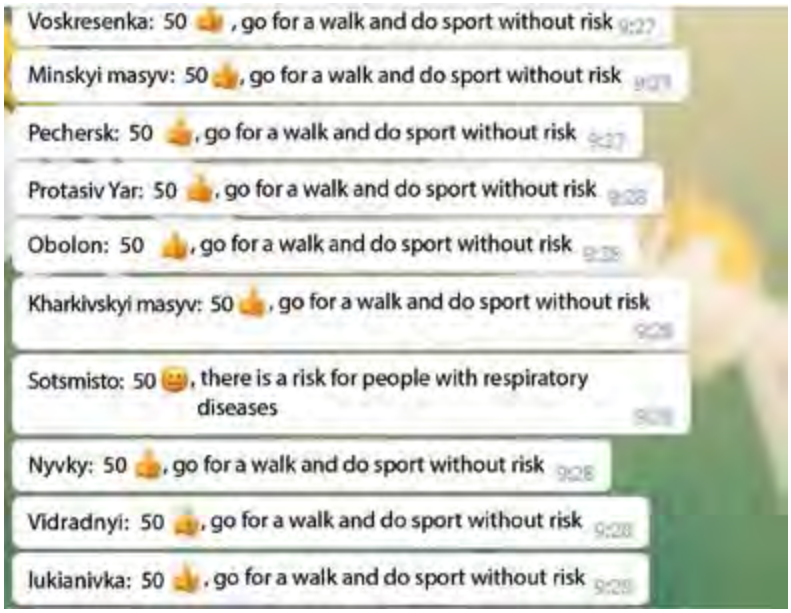


Fig. 4.42. The air quality index in Kyiv

5 CHAPTER WATER POLLUTION AND ITS HEALTH EFFECT. PROTECTION AGAINST POLLUTION

V. G. Bardov, S. T. Omelchuk, N. V. Merezhkina, S. I. Garkavyi, V. I. Fedorenko

5.1. Water quantity and quality problems in the hydrosphere

There are multitude problems that are directly related to the hydrosphere, but the most global are the following:

Rising sea level. This new problem can affect many people and ecosystems around the world. Inflow level measurements show a global increase in sea level of 15–20 cm, and the IPCC (Intergovernmental Panel on Climate Change) has suggested that the increase is caused by quantity water increase in ocean due to rising environmental temperatures, melting of mountain glaciers and ice caps. Most of the Earth's glaciers are melting due to global climate change, and the speed of this process is increasing. This situation significantly affects the global sea level.

Approximately 93 % of solar energy, which is captured by CO_2 and other greenhouse gases, is accumulated in the World Ocean. This indicator is only slightly dependent on annual variations such as El Niño or intense volcanic eruptions. If there are no measures to reduce greenhouse gas emissions, by the end of the century the temperature of seawater in the upper layer with a thickness of 2 thousand meters will increase by 0.78 °C. This will raise the sea level due to thermal expansion by additional 30 cm before the rise of the strandline due to melting glaciers.

Rising temperature of the World Ocean will trigger more severe storms, hurricanes and extreme precipitation.

Reducing the amount of Arctic sea ice. Over the past few decades, Arctic sea ice has significantly reduced in size. Recent NASA research shows that it is shrinking at a rate of 9.6 % over the decade. Such thinning and shrinking of ice affects the ocean salinity, the balance of heat and habitat of animals. For example, polar bear populations are declining due to an ice breach that separates them from land, and most animals drown in attempts to swim across (Fig. 5.1, Fig. 5.2). This loss of sea ice also affects the albedo, or reflectivity of the Earth's surface, causing dark oceans to absorb more heat.

When the temperature rises by 2 °C, the Arctic Ocean will be left without ice, the number of tropical insect-borne diseases in the northern countries will increase, and also 18 % of insect species, 16 % of plants and 8 % of vertebrates will be destroyed.

Change in precipitation. An increase in precipitation can provoke floods and landslides, and a decrease — can lead to droughts and fires. El Niño phenomenon, monsoons and hurricanes are also affecting short-term global climate change. For example, the change in ocean currents off the coast of Peru associated with the El Niño phenomenon could lead to changes in weather conditions throughout North America. Changes in the nature of monsoons due to rising temperature can cause drought in areas around the world that depend on seasonal winds. Hurricanes, which increase with increasing sea surface temperature, will become more harmful to people in the future.

Permafrost thaw. As the global temperature rises, the permafrost of the tundra melts. This has the significant impact on people living in this natural area, as the soil on which houses are located becomes unstable. Besides this immediate effect, scientists are worried that the permafrost thaw will release huge amounts of carbon dioxide (CO_2) and methane (CH_4) into the atmosphere, which will significantly affect the environment over the long term. The released greenhouse gases will trigger the further global warming due to the release of heat into the atmosphere.

5.2. Anthropogenic impact on the hydrosphere

Humans had a significant influence on the hydrosphere of our planet, and this influence will prolong as the Earth's population and human water demand increase.



Fig. 5.1. Global warming reduces the area of Arctic ice and causes the polar bear populations declining. Source: *pic2.me*



Fig. 5.2. The melting of Arctic ice leads to reducing populations and destroying rookeries of Arctic penguins. Source: *@Pauline Askin, Reuters*

Global climate change, pollution of water resources, rivers flooding, drainage of wetlands, reduction of flow and irrigation have put pressure on existing freshwater hydrosphere systems. The stable state is destructed by the release of toxic chemicals, radioactive substances and other industrial wastes, as well as the leakage of mineral fertilizers, herbicides and pesticides into the Earth's water sources.

Acid rain caused by the release of sulfur dioxide and nitrogen oxides from the combustion of fossil fuels has become a global problem. it is generally believed that the acidification of freshwater lakes and the increased concentration of aluminum in their waters are responsible for significant changes in lake ecosystems. In particular, in many lakes today, there are no significant populations of fish (Fig. 5.3).

Human-induced eutrophication is becoming a problem for freshwater ecosystems. As far as excess nutrients and organic matter from agriculture and industry sewage are released into water systems, they become artificially enriched. This affects seashore ecosystems, enter of organic matter into the oceans. This moreover has caused biotic changes in some areas, such as the North Sea, where cyanobacteria have better growth and diatomic algae — worth.



Fig. 5.3. Mass death of fish due to water pollution

The problem of the amount of water is becoming increasingly acute for humanity. What is not commonly known is that every person consumes on average 1 ton of water per year, besides that 600 tons are used for industrial production of all necessary foodstuff and cooking, 300 tons — for hygienic needs. A household need requires 200–500 liters per 1 person a day. The main consumers of water are industry and agriculture (Table 5.1).

It takes several liters of water to make one brick, 350 liters — to make 1 kg of steel, 4 tons — to cultivate 1 kg of wheat, and 20 tons — to get 1 kg of meat. At the same time, freshwater sources no longer meet all people's needs. Many countries around the world, including India, Israel, the UAE, Qatar, Turkmenistan, Botswana and others, are at risk of water deficiency.

Water storage of Ukraine stands at 50–70 billion m^3. On the territory of the country, there are more than 22 thousand of rivers. Groundwater reserves are about 16 billion m^3. However, in many places the reserves of underground fresh deep-well water are already depleted. Lack of water often limits the development of industry, negatively affects yields, pose a threat to human life. However, due to irresponsible economic activity, pollution of rivers and lakes continues, because billions of cubic meters of insufficiently purified industrial and commercial effluent are discharged into them.

5.3. Water pollution and its impact on human health

As a consequence of human activities, the hydrosphere undergoes quantitative (volume of safe and usable water) and qualitative changes (water pollution).

Table 5.1. Water consumption (m^3) for producing 1 ton of products

Product	Water volume
Agriculture	
Wheat	1500
Cotton	10 000
Industry	
Cast iron	200
Copper	500
Nickel	4000

Along with the development of industry, rivers and lakes were increasingly being polluted by emissions of insufficiently purified effluent, industrial waste and wastewater from hydroelectric power plants. Subsequently, pollution of rivers and lakes increased due to entering of fertilizers, pesticides and herbicides from agricultural lands, as well as acid rain. Pollution by industrial waste, agricultural fertilizers and pesticides has become a real threat to the entire hydrographic system of the Earth and human existence.

A certain type of water pollution is thermal pollution caused by the discharge of warm water from electric power facilities into water reservoirs. The immense amount of heat that comes with heated water to rivers and lakes significantly changes their thermal and biological conditions. Nuclear power plant is the heaviest pollutant among the thermal pollutants (Fig. 5.4).

According to observations, in the rivers located below the existing TPP and NPP, spawning conditions are misbalanced, zooplankton dies, fish are affected by diseases and parasites.

The main ways of water pollution (Fig. 5.5).

The main sources of pollution and clogging of water reservoirs are:

- effluent from industrial and public utility companies;
- wastes from ore and non-ore mining;
- air pollution;
- water from mines, collieries, oil fields;
- logging debris during harvesting, processing, floating of timber;
- emissions of water, railway and road transport;
- primary processing of flax, hemp and other industrial crops;
- radioactive waste pollution;
- washing down of mineral fertilizers and pesticides from agricultural lands, livestock waste.

The most intensive pollutants of surface waters are large pulp and paper mills, chemical, oil refining, food and textile enterprises, mining and metallurgical plants, as well as agricultural production (Fig. 5.6), oil leaks (Fig. 5.7).

Floating of wood is very dangerous due to the treatment with potent pesticides (wood preservatives). Wa-



Fig. 5.4. Thermal pollution of the water reservoir by a nuclear power plant. Source: *eurosense.com*

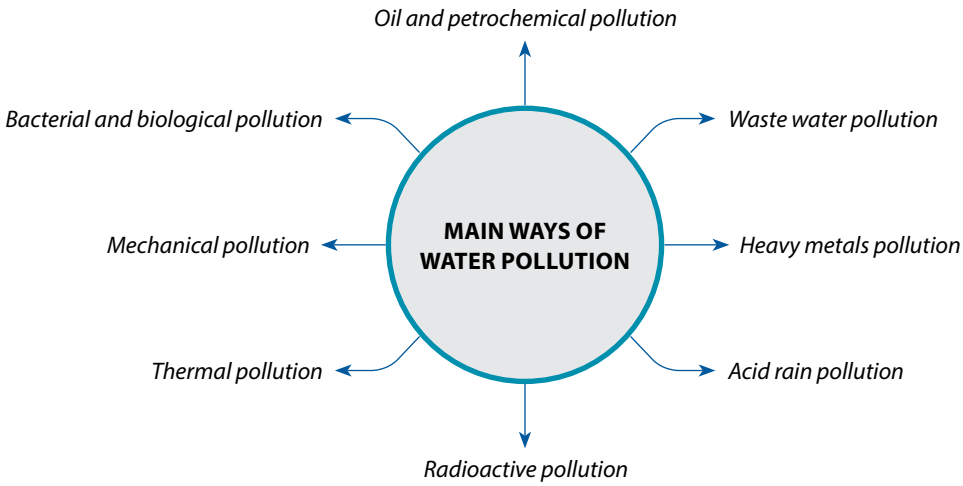


Fig. 5.5. Main ways of water pollution



Fig. 5.6. Marine pollution by industrial effluents. Source: *dailymotion.com*

ter becomes hazardous for consumption and for the life of aquatic organisms. During loose floating, a lot of wood sinks and rots at the bottom, which also leads to increased mortality of living organisms in the aquatic environment.

5.4. Drinking water problems in Ukraine

According to the UN, Ukraine is ranking 95th in drinking water quality.



Fig. 5.7. Oil pollution of the sea

Main water supply covers about 70 % of Ukrainians. The needs of 20 % of them are met by fresh groundwater, the other 80 % — from surface water such as the Dnipro and Desna rivers.

40 % of industrial and household waste, which enterprises discharge into rivers, are not purified or do not meet the established sanitary requirements (Fig. 5.8).

This problem has long been nationwide. Environmental experts considered that 60 % of water in Ukraine is importable. The worst situation is in Dnipro, Donetsk, Zaporizhzhia, Kyiv, Kherson, Odesa regions.

The Siverskyi Donets, Sula, Dnister, Kalmius and Western Bug rivers are the most polluted rivers of Ukraine. In the last mentioned river, the concentration of nitrogen is 15 times and heavy metals is 8 times higher than normal. In the tributaries of the Dnister, the level of manganese exceeds the permissible level by 29 times. The findings of studies of Kakhovka, Kyiv, Kremenchug and Dnipro water-storage basins indicate that they contain 80 times more copper and manganese than prescribed in the standards. Even bathing in such water can lead to skin diseases. It is dangerous to drink it without additional purification.

Ukraine is not included into the group of the countries with a high level of water supply. Furthermore, in terms of the use of renewable water resources, Ukraine is on the verge of crisis. The main method of purification was and remains coagulation, and the method of disinfection — chlorination, which leads to the formation of harmful organochlorine compounds.

Water pollution is divided into the following types: chemical, mechanical, radioactive, industrial, agricultural, biological, thermal, household.

Chemical pollution occurs when acids, alkalies, petroleum products, salts of heavy metals, pesticides and mineral fertilizers enter water reservoirs.

Water contaminated with salts of mercury, lead, copper, chromium, cadmium and other heavy metals is considered highly dangerous (Table 5.2). The main suppliers of these substances are the pulp and paper industry, oil refineries, metallurgical production, by-product coke plants, livestock breeding complexes.

Detergents are especially dangerous, because their presence in the water leads to the intensive growth of blue-green algae, water blooming, death of flora and fauna.

The amount of chemicals in the water is constantly growing; they have already been recorded about 1000 (959 species). The maximum allowable concentration of some chemicals in drinking water is given in the Table 5.3.

Mechanical pollution of water is associated with changes in its physical properties: transparency, the

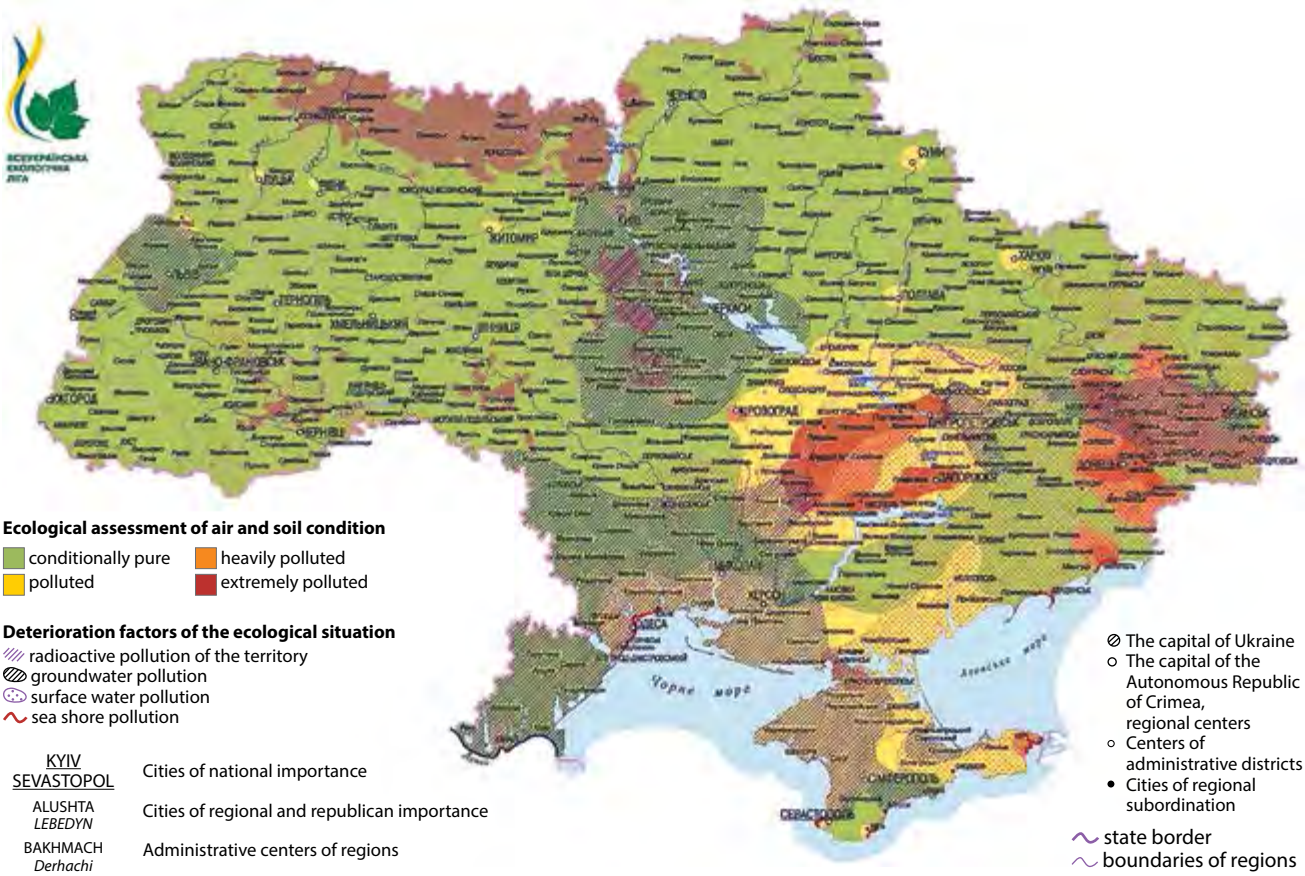


Fig. 5.8. Ecological situation and drinking waters state in Ukraine

presence of suspensions, temperature conditions. Suspensions (sand, clay particles, radioactive substances) inhibit the processes of photosynthesis of aquatic plants, contaminate the fish gills, effect the water taste.

Biological pollution of water occurs as a result of entering of different types of microorganisms (viruses, fungal diseases) to the water. The most of them are dangerous to humans, animals and plants (Table 5.4). Among the sources of biological pollution, the first place is occupied by energy and household effluents, as well as effluents from the microbiological, meat and dairy industries and sugar factories.

Thermal pollution of water reservoirs is associated with the discharge of thermal water from various power plants (TPP, NPP). Nuclear power plants are major polluters. Their emission temperature reaches 45 °C (Fig. 5.4). Thermal pollution leads to fish diseases and fish kill, decay of algae and microorganisms.

Household pollution of water reservoirs (Fig. 5.9). Water pollution is especially dangerous at places of mass recreation. Wastewater effluents entering water reservoirs in Ukraine does not meet current requirements. For example, the main causes of crisis situations in the Dnipro basins are: reservoir construction, large-scale land reclamation (or agricultural hydraulics), construction of large industrial complexes, considerable volumes of water withdrawal, discharges of nonpurified or insufficiently purified effluents.

According to the Ministry of Ecology of Ukraine, the most polluted wastewater are from the following enterprises: Kyivvodokanal, Kyiv; Azovstal Iron and Steel Works, Mariupol; Lvivvodokanal, Lviv; Dniprovskyi Iron and Steel Works, Kamianske; Dniprovodokanal, Dnipro; Zaporizhstal, Zaporizhzhia; Mykolaivvodokanal, Mykolaiv; Pavlohrad Regional Department on Water Supply and Refinement of Sewerage Systems, Pavlograd; Chernihivvodokanal, Chernihiv; Miskvodokanal, Sumy.

Wastewater discharge leads to the Dnipro and water-storage basin pollution by following substances (annual data): approximately 500.000 tons of nitrogen compounds,

Table 5.2. Effects of human consumption of chemically contaminated water

Type of water consumption	Pollutant	Diseases
Drinking and eating	Nitrates	Methemoglobinaemia
	Fluorine compounds	Endemic fluorosis
	Arsenic	Intoxication
	Selenium	Selenosis, intoxication
	Lead	Intoxication
	Polycyclic aromatic hydrocarbons	Cancer
	Low hardness water	Atherosclerosis, hypertension
	Chrome	Kashin – Bek disease
	Nickel	Skin allergies, destruction of the cornea
	Copper	Nervous system impairment
	Phenol	Poisoning

Table 5.3. Maximum allowable concentration of chemical substances in drinking water

Substance	MAC, mg/l
Nitrites	0
Nitrates	45
Sulfates	500
Phosphates	1
Chlorides	100
Fluorides	0.75
Cyanides	0
Iron	0.5
Copper	0.1
Chromium-4	0.01
Chrome (general)	0.5
Arsenic (general)	0.05
Organophosphorus toxic chemicals	0.03
Ether-soluble substances	0.1
Petroleum products	0.1–0.3
Acetates	45
Formiates	45
2.4-dichlorophenylacetic acid	1
Phenols	0.001

Table 5.4. Effects of human consumption of biologically contaminated water

Type of water consumption	Pollutant	Diseases
Drinking and eating	Pathogenic bacteria	Cholera, dysentery, enteric fever, gastroenteritis, leptospirosis, tularemia (or Francis disease)
	Virus	Infectious hepatitis
	Parasite	Amoebic dysentery, dracunculiasis, helminthiasis, echinococcosis
Washing-up, laundering (by using water)	Parasite	Schistosomiasis, dermatitis, strongyloidiasis
Living or being near water	Transmitting insects	Malaria, amarillic typhus amarillosis, Human African trypanosomiasis (or sleeping sickness), filariasis

40.000 tons of phosphorus compounds, 20.000 tons of potassium compounds, 1.000 tons of iron, 40 tons of nickel, 2 tons of zinc, 1 ton of copper, and 0.5 ton of chromium.

The state of the Dnipro water-storage basins is steadily deteriorating: radioactive contamination is constantly increasing; the concentration of iron, chromium, cobalt, mer-



Fig. 5.9. Water pollution by household waste. Source: *baomoi.com*

cury, lead, phenols and petroleum products is increasing. The Dnipro has consequently lost the self-purification capacity.

The state of other rivers is not much more favorable. For example, Desna is polluted by the Shostka Chemical Reagents Plant, enterprises of Chernihiv, Sumy, Smolensk and also by Kursk NPP, livestock farms and allotment gardens.

In Ukraine alone, the Desna is polluted by 10 million m^3 of contaminated and insufficiently purified wastewater per year. As a result, the Desna water increasingly resembles a "mixture" of amines, phenols, organic acids, aldehydes, organophosphorus compounds, and heavy metals. The quality of this water has long failed to meet regulatory requirements.

The Azov Sea is a zone of ecological catastrophe. In the recent past, this sea was unique. It was unequaled in the world in the number of species of fish stocks. Currently, the Azov Sea waters are contaminated with pesticides, heavy metals and toxic chemicals. The ecological situation of the Black Sea basin is not much better. Due to the contamination of inland water bodies, seas and oceans with toxic products, not only water but also fish and other seafood are dangerous.

Fish contaminated with salts of heavy metals may be found in the rivers of Ukraine, in the Black and Azov Seas. Fish of the Dnipro is moreover affected by radionuclides.

The drinking water quality depends not only on the degree of pollution of the rivers with industrial and agricultural toxic waste, but also on the condition of water supply stations and systems. Currently, it is necessary to improve and put in commission new pollution control facilities to avoid the penetration of harmful substances.

The water supply systems situation in Sumy, Luhansk, Kharkiv and Ternopil regions is especially threatening. Drinking water supplied to the population is characterized by a high content of microorganisms.

More than 240 settlements presently consume municipal water, the physical, chemical and bacteriological contamination of which exceeds all existing standards. With each passing day, the number of towns and village settlements that consume polluted water is increasing.

This process is primarily related to the deterioration of sewage-purification facilities. According to the State Housing and Municipal Services, 350.000 m^3 of nonpurified and 4.5 million m^3 of insufficiently purified domestic effluents are discharged into rivers and lakes per day. In Mykolaiv, outbreaks of cholera are observed more than for years, at the same time, 60 thousand m^3 of nonpurified effluents are discharged in the Bug estuary per day.

Kyiv uses 900.000 m^3 of water per day from the Desna, 400.000 m^3 — from the Dnipro and 320.000 m^3 — from underground sources for utility and drinking water supply.

The Dnipro and Desna water entering the water-intake facilities has an insufficient bacterial condition. It is also contaminated with various chemical compounds, radionuclides, synthetic detergents. Therefore, its complete treatment from harmful impurities is impossible. However, according to Vodokanal, the water coming to the Kyiv water supply system is suitable for consumption.

Liquefied chlorine, chlorination and rechlorination are used for biological treatment at the Dnipro and Desna water-intake facilities. This leads to an increase in the water chlorine content, as well as to the formation of chlorophos, which is very harmful to the human body. Drinking unboiled chlorinated tap water increases the risk of bladder cancer (21 %) and rectal cancer (38 %).

5.5. Protection of the hydrosphere

Different methods are used to protect the hydrosphere:

- legislative measures;
- non-refuse technology;
- recycling technology;
- disposal considerations;
- waste water purification;
- use of underground water.

Legislative measures are regulated by the water legislation of Ukraine, which addresses the issues of water use, property rights and protection of water from pollution:

1. The Constitution of Ukraine; Fundamentals of the Legislation of Ukraine on Health Protection, Laws of Ukraine On Ensuring Sanitary and Epidemic Safety of the Population, On Environmental Protection, On Drinking Water, Water Supply and Wastewater, the Water Code of Ukraine, National target program "Drinking Water of Ukraine" for 2011–2020, etc.
2. International regulations governing international water relations. For example: United Nations Convention on the Law of the Sea of December 29, 1982; The Convention on the Protection of the Black Sea against Pollution of April 21, 1992; Danube River Protection Convention of June 28.1994; The UNESCO Convention on the Protection of the Underwater Cultural Heritage of November 6, 2001, etc.
3. Resolutions of the Verkhovna Rada of Ukraine On the Concept of Water Management Development of Ukraine; National Program of the Dnipro Basin Environmental Recovery and Drinking Water Quality Improvement, etc.
4. Decrees of the President of Ukraine: On Regulations on the State Committee of Water Resources of Ukraine" of February 27, 2009; On the state of security of water resources and providing the population with quality drinking water in the settlements of Ukraine" of November 11, 2002, etc.
5. Normative acts of the Government of Ukraine, for example, the Regulation on Protection of Surface Waters from Pollution by Wastewater of March 25, 1999.
6. Departmental regulations of the Ministry of Ecology and Natural Resources, the Ministry of Health of Ukraine, for example, On approval of State Sanitary Code, "Drinking water. Hygienic requirements for water quality of centralized commercial and drinking water supply", the State Water Resources Agency of Ukraine, the State tax service of Ukraine, the State Agency of Land Resources of Ukraine, regulations of state power, local regulations.
7. Water legislation of the USSR in the absence of the current legal act of Ukraine, for example, SanPiN 4630–88: Sanitary rules and standards for preservation of surface waters against pollution, etc.

Waste-free technologies (or non-refuse technologies) allow to separate the polluted effluents into the purified water and the pollutant, from which we receive a pure product for the further use in technological processes.

Recycling water supply technologies involve waste water purification schemes and the use of a reversible cycle, which creates completely closed zero-discharge water systems. It is used in most integrated iron-and-steel works of Ukraine and other countries.

Closed recycling water supply technologies as the most effective method of protection of the hydrosphere.

Closed water cycles involve the use of natural water. It is pumped into the system once, and then the waste water is returned to the production cycle either after purification or without it. Used water can be supplemented with natural water due to losses in the production process. The advantage of such water consumption is almost complete cessation of wastewater formation and their entry into the hydrosphere. The use of recycling water supply reduces the consumption of natural water by 10–50 times. Circulating water can be as a heat transfer medium as well as a cooling agent (refrigerant), which increases production efficiency.

Disposal of pollutants is the processing of waste (or waste treatment) from water purification for efficient use. In this case, waste is a secondary raw material. For example, activated sludge is formed as a result of the use of biochemical methods of wastewater treatment. Sludge

is subjected to certain processing methods (dehydration, concentration, thermal treatment), after which it is used in agriculture or construction.

Waste water purification (or wastewater treatment). There are mechanical, chemical, physical and chemical, biochemical and biological purification.

Mechanical wastewater purification is a mandatory part of water treatment and is leading other treatment methods. Due to it, insoluble impurities are removed from the water, including those that are in a colloidal state. Before mechanical treatment, coagulants (substances that aggregate colloidal particles) and flocculants (substances that promote flotation processes, i.e. the separation of particles from the mixture due to repelling forces from the solvent, followed by aggregation) are added to wastewater. Polyethyleneamines and some other high-molecular substances are used as flocculants. Coagulants: aluminum, iron (III) sulfates, etc. When separating large particles of insoluble substances, the processes of filtration (on various filters and electrostatic precipitators), settling (clarification) (in settling tanks) and centrifugation (on hydrocyclones and centrifuges — the use of centrifugal effect) are used.

Chemical wastewater treatment (or purification) is based on the fact that soluble impurities react with precipitators or substances of other action (oxidants, reducing agents). This produces either insoluble substances, which are then removed mechanically, or non-toxic substances that do not harm nature. Limestone, lime milk (calcium hydroxide suspension) and other alkalis, oxidation by active chlorine, oxygen or ozone, etc. are widely used as precipitators and neutralizers. However, it should be noted that chlorine oxidation, although effective, is ecologically dangerous due to the occurrence of environmentally hazardous organochlorine compounds.

Physical and chemical methods of water purification are based on physicochemical processes, ion exchange, chemical processes from the influence of physical phenomena (electrolysis, electrocoagulation, etc.). The most environmentally efficient are the processes of complete removal of impurities from wastewater (for example, complete desalination using ion exchange resins containing hydrogen ions and hydroxide ions (OH^-). When using physicochemical methods, stable emulsified and suspended impurities, colloidal substances and solutes are removed. But these methods are very expensive and used only in particular cases.

Biochemical and biological methods of wastewater purification are based on the fact that some microorganisms are able to use contaminants as food, digesting which, they treat wastewater from such impurities. This is usually used to treat wastewater from organic and biological impurities. There are aerobic and anaerobic varieties of these methods. They are sold in aerotanks and biofilters or trickling filters (aerobic methods) or mainly in settling tanks. As a result of application of biochemical methods the activated sludge is formed for utilization.

Biochemical and physicochemical methods associated with the complete removal of impurities are the most promising, despite their high cost and difficulty of implementation.

The use of groundwater. There are waste waters that cannot be purified by the above methods (about 3 % of the rest of the waste water). Such waters are subjected to thermal neutralization or pumped into deep layers (the second is extremely dangerous from an environmental point of view and requires elimination). For a specific production, such methods are used that make it possible to obtain water that meets sanitary and hygienic requirements. Typically, these methods are used in an integrated manner to obtain the most positive results. These methods help to protect natural waters from pollution by industrial and domestic waste water. As mentioned above, the purification of gases helps to prevent pollution of the hydrosphere by pollutants from the atmosphere. However, there are other sources of pollution, in particular, agriculture (animal husbandry and farming), as well as water transport. Ship wrecks and accidents during transportation of various materials (oil, coal, food, and various raw materials) pose a great danger of pollution of the World Ocean. Environmental measures in these areas of human activity are strict adherence to the rules of transportation, the development of staff correct worldview from the standpoint of environmental consciousness, the participation of each person in activities that reduce pollution of environment, in particular, the hydrosphere (Fig. 5.10).



Fig. 5.10. Pure drinking water is used for baby food. Source: *ok.gov*

6 CHAPTER SOIL POLLUTION AND ITS HEALTH EFFECT. PROTECTION AGAINST POLLUTION

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6.1. Soil pollution and its impact on human health

According to the definition of WHO experts, soil pollutants are chemicals, biological organisms (bacteria, viruses, protozoan, and helminths) and products of their vital activities, which occur in the wrong place, at the wrong time and in the wrong amount. Soil pollution should be understood only as the content of chemical and biological pollutants that become dangerous to health in direct human contact with contaminated soil or through environments which in contact with the soil through ecological chains: soil — water — human; soil — atmospheric air — human; soil — plant — human; soil — plant — animal — human, etc. (Fig. 6.1).

6.2. Natural and anthropogenic soil pollution

Soil pollutants are divided into natural and anthropogenic.

- Natural pollutants include:
  - mineral resources — ore, non-metallic, fossil fuels (or caustobioliths);
  - chemical elements: ancient — 19 elements, 18th century — 29 elements, 19th century — 59 elements, and from the 20th century untill now — 80 elements (out of 107) and 200 minerals (out of 400);
  - oil and coal reserves. There are currently 10.000 oil platforms;
  - the World Ocean contains 6.5 billion tons of Na, 10 million tons of Au. Marine salt has thickness of 153 m across the planet Earth.

Anthropogenic pollutants include:

- industrial metallurgical complexes;
- thermal energy sector;
- chemical industry;
- public utility services;
- agriculture (livestock complexes, pesticides);
- radioactive substances (mines);
- irrigation of lands — (soil salination);
- land reclamation (or agricultural hydraulics);
- soil erosion.

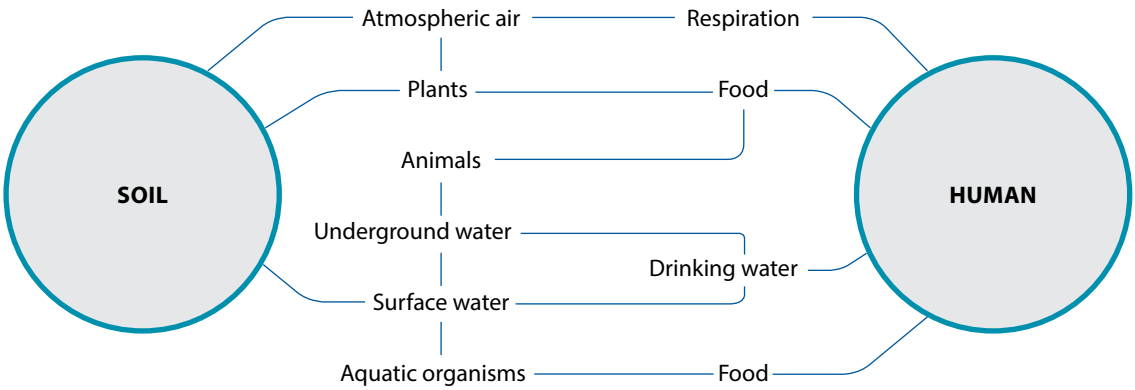


Fig. 6.1. The route of migration of chemicals from the soil into the human body

6.3. Soil pollution sources

There are various sources of soil contamination. The causes of soil contamination:

1. Use of pesticides in agriculture.
2. Extraction of mineral resources.
3. Mineral and organic soil fertilization, ingress of industrial and household wastes of various types, which are used as fertilizers for the moistening purpose, including soil fertilization with wastes of livestock complexes (farms) and individual households.
4. Ingress of chemicals into the soil with atmospheric emissions from industrial enterprises and motor-vehicles.
5. Release of radionuclides into the soil as a result of nuclear reactor accidents.

In consequence of human productive activity, in nature, there is an accumulation of waste, which becomes soil pollutants (Table 6.1).

6.4. Classification of soil pollutants

All soil pollutants can be classified into biological (viruses, bacteria, helminth eggs, protozoa) and chemical.

Chemical soil pollutants are divided into two major groups. The first group includes chemicals that are used for the soil application in a targeted manner, most commonly in agriculture and forestry: pesticides, fertilizers, soil improvers, plant growth stimulants, etc. This process is controllable. In case of inconsistency with agrochemical and hygienic regulations (excessive application into the soil), exogenous chemicals become soil contaminants and can pose a hazard to human health.

The second group of chemical pollutants includes chemicals that ingress into the soil by man-made (anthropogenic) accident involving liquid, solid and gaseous wastes. These are substances from domestic and industrial wastewater, solid waste, atmospheric emissions of industrial enterprises, vehicle exhaust gases, etc.

The danger of soil contamination with chemicals is associated, firstly, with their toxic properties (acute and chronic general toxicity, the presence of allergenic, mutagenic, carcinogenic, embryotoxic, teratogenic effects, reproductive toxicity, etc.), secondly, with substance's behavior in the environment (stability in soil and water reservoirs, migration ability).

All exogenous chemicals according to the degree of public health hazard are divided into three classes: 1st — highly hazardous chemicals; 2nd — moderately hazardous chemicals; 3rd — low-hazard chemicals.

Class 1 includes arsenic, cadmium, mercury, lead, benzo[a]pyrene, persistent organochlorine pesticides: dichlordiphenyltrichlormethylmethane (DDT), hexachlorocyclohexane (HCH), polychlorocamphene (PCC) and polychloroprene (PCP). *Class 2* includes boron, cobalt, nickel, molybdenum, chromium, group 2.4-D herbicides, etc. *Class 3:* barium, vanadium, tungsten (or wolfram), manganese, non-radioactive strontium, etc.

Most scientists agree that the public health deterioration over the past decades is due to the negative effects of chemical environmental factors. Cause-effect analysis indicates that chemical soil contamination is a main factor of the public health deterioration. The reason for this is that the soil occupies a central place in the cycle of substances of the biosphere. Additionally, soil is the main concentration point of persistent chemicals accumulation in the natural environment. It also acts as a starting point in migration of chemicals from the pollution source to the human body.

Table 6.1. Global industrial waste accumulation, 2000–2015 (billion tons)

Mineral deposit	Accumulation of extraction	Industrial waste	Waste/extraction ratio
Coal	74	518	7
Petroleum	60	60	1
Iron ore	18	108	6
Bauxites	1.6	11.2	7
Potassium salts	0.8	3.4	4
Phosphates	2.3	16.1	7

6.5. Exogenous chemicals for the soil application in a targeted manner

Due to the high economic effect associated with the use of products for pest control, plant disease control and yield enhancement, their use around the world in the 20th century has increased. Therefore, with each passing yearm, increasing amounts of pesticides, mineral matter, soil improvers, plant growth stimulants penetrate into the soil.

Pesticides (from Latin *pestis* — plague, *caedo* — kill) is a generally accepted in world practice collective term for chemical crop protection agents. Pesticides are used to destroy or stop the growth of living organisms (insects, mites, bacteria, viruses, fungal spores, harmful vegetation, etc.) that cause damage to crops and livestock. The terms "agricultural pesticides", "agrochemicals" and "chemical crop protection agents" are used as synonyms. The widespread use of pesticides come from the fact that the potential annual crop losses in the world can reach 13.8 % due to pests, 11.6 % due to diseases and 9.5 % due to weeds, i.e. more than a third (34.9 %) of world harvest (according to The Food and Agriculture Organization of the United Nations — FAO).

The use of chemical crop protection agents makes it possible to protect one-fifth of the world's wheat crop, one-sixth of the potato yield, and one-half of the apple yield. The use of pesticides allows to collect 2–3 quintals of grain, 5 quintals of rice, 15–20 quintals of potatoes from each hectare of agricultural land.

Currently, the world range of pesticides includes more than 1.000 names of active substances, of which almost 700 are most abundantly used.

Pollution of soil with pesticides is dangerous both in direct human contact with polluted soil and in the migration of pesticides from the soil to the environments that contact with human (water, air, plants). Apart from that, as affected by pesticides quantitative and qualitative changes in populations of soil microorganisms, changes in soil microbiocenosis, disrupting the processes of self-purification, can occur. Therefore, the uncontrolled use of chemical crop protection agents leads to irreversible changes in human habitat.

Expanding the assortment and application rates of chemical crop protection agents used in the second half of the 20th century led to an increase in cases of occupational pesticide poisoning. Thus, in the period 1945–1965, there were 40 thousand cases of pesticide poisoning in the world, but then in the next 20 years considering only developing countries — 500 thousand cases of acute poisoning by agrochemicals were recorded, including 5 thousand cases with a lethal outcome.

The migration of pesticides to plants, air, groundwater and surface water increases the pesticide exposure not only on professional contingents (agricultural workers), but also on the general population, which poses a real threat to their health. At the same time, the child population is most exposed to negative effects. A range of agrochemicals entering the human body from the soil through migration chains have a mutagenic effect, manifested by an increase in the frequency of point mutations and chromosome aberrations in somatic and germ cells, which lead to the development of neoplasms, miscarriages and perinatal fetal death, congenital malformations, infertility, etc.

Presently, considerable attention is paid to the safety improving of pesticide use. In view of this, the use of 1st hazard class pesticides and persistent organochlorine compounds (DDT, HCH) is strictly limited in all countries of the world; polychlorinated biphenyl production was discontinued and its use was prohibited. Safer ones are replacing toxic and persistent pesticide substances. Preparative forms of pesticides are improving in order to reduce the mobility and migration capacity of their active substances. Hygienic standards and regulations for the use of pesticides have scientific justification: acceptable daily intake; MAC in soil, water bodies of utility and drinking water supply, atmospheric air and workplace air; MAL in alimentary products; specified period of temporary access of agricultural workers to the chemically cultivated land; safety interval between pesticide application and harvesting, etc.

Mineral fertilizers. Mineral fertilizers include inorganic chemical compounds used in agriculture to increase soil fertility. There are macro- and micronutrient fertilizers. Mineral macronutrient fertilizers are substances containing the essential elements that increase fertility (nitrogen, phosphorus, potassium). Accordingly, macronutrient fertilizers are divided into nitrogenous, phosphated, potassic and complex.

In a relatively short period, the production and agricultural use of mineral macronutrient fertilizers has increased significantly. The range of mineral fertilizers has expanded. For example, the group of nitrogenous fertilizers includes ammonia (ammonia liquor), ammonium (ammonium sulfate), nitrate (potassium, sodium and calcium nitrate), ammonium and nitrate (ammonium nitrate), amide (carbamide, calurea) fertilizers. The group of phosphate fertilizers includes single and double (or con-

centrated) superphosphates, precipitated calcium phosphate, basic slags, etc. The group of potassium fertilizers includes potassium salt (potassium chloride), potassium magnesium fertilizer, potassium ammonium nitrate.

Modern technology of mineral fertilizer application prevents their maximum accumulation in agricultural plants phytomass.

Substantial proportion of the fertilizer is washed out from soil into groundwater, migrates with surface runoff, decomposes in the soil forming volatile products that enter the ground-level air atmosphere. To date, there is enough convincing evidence documented in the scientific literature stating that the irrational use of mineral fertilizers poses a real danger to human health and the environment.

Mineral micronutrient fertilizers are applied in relatively small quantities (10–100 times less than macronutrient fertilizers) to increase soil fertility. They contain a variety of microelements. The most common microadditives are: boron (0.5–1 kg/ha), molybdenum, copper (10–15 kg/ha), manganese (3–5 kg/ha), zinc (3–5 kg/ha), cobalt 0.1–0.2 kg/ha) and polymicrofertilizers (PMU-7, PMU-8, etc.). If the application rate of microfertilizers is exceeded, they can accumulate in the soil and plants in excessive amounts adversely affecting public health. Microfertilizers contain a lot of lead (0.3 to 1 %), sometimes cadmium and arsenic. Thus, the irrational microfertilizers application causes a hazard of soil contamination with heavy metals.

Soil improvers. Soil improvers are defined as chemicals that are applied into the soil of agricultural lands in order to improve its structure. These include surface-active compounds that are unstable and destructed relatively quickly under the action of soil microorganisms.

Plant growth regulators are natural and synthetic organic compounds that in small doses actively affect the plant metabolism. These include ethylene derivatives, nicotinic compounds, carbamates, phosphonium compounds, etc. The residual amount of these substances in the soil and plants depends on application rate. The retention period of chemicals in the soil, such as chlorocholine chloride, is increased when used in combination with nitrogen fertilizers. Synthetic growth regulators are stable in soil and toxic.

6.6. Soil pollutants with household and industrial waste

This group includes pollutants that ingress into the soil with household, industrial, drainage effluents, sewage from livestock complexes, solid household and industrial waste, atmospheric emissions from industrial enterprises, road and air transport. Chemicals that come with household waste, sewage from settlements and livestock complexes are mainly those organic compounds to the disposal and mineralization of which the soil has adapted over millions years of evolution. Aside from that, biological contaminants, such as pathogens and opportunistic pathogens, protozoa, viruses, geohelminth eggs, enter the soil from the above sources of pollution.

Household waste is the residuals of substances and objects that are formed as a result of household and economic human activities and which cannot be used at the place of origin, so their accumulation and storage interfere the environment sanitary condition. All household waste is grouped into liquid and solid. Liquid household waste includes sewage from cesspools of toilets (or latrines), pot-washings (from cooking, dishwashing, mopping, laundry, etc.) and sewage (household and storm sewage). Household solid waste includes: garbage (household waste), food waste (kitchen waste), waste from public food service establishments, trade establishments, health care facilities, educational (schools, children's preschool institutions, secondary and higher educational institutions) and other institutions, construction (or material) debris generated during the apartment remodeling (Fig. 6.2).

The solid waste consists of:

1. Secondary raw materials (paper, cardboard, fabric, metal, leather, etc.) — approximately 25 % by weight of waste.
2. The organic waste that can be neutralized is about 60–70 % by whole waste weight. The share of easily decaying, especially in the warm season, organic matter reaches 20–30 %.
3. Ballast (glass, stone, etc.) — 6–8 %.
4. Combustible materials that cannot be recycled (coal, wood, rubber, etc.) — 8–10 %.

From an epidemiological perspective, household waste is very dangerous. Household waste contains a huge amount of causative agents of infectious diseases, primarily gastrointestinal infections; 30–40 % of solid waste samples contain helminth eggs. Pathogenic microorganisms retain pathogenicity and virulence in the waste for a long time.

In settlements, solid waste is generated continuously and accumulates in large amounts (Fig. 6.3). Large cities have an average rate of solid waste accumulation — from 1 to 30 tons annually per citizen.



Fig. 6.2. Household waste of the modern city. Source: *gordon.ua*



Fig. 6.3. Garbage mountain in Ghazipur (New Delhi, India). Source: *theprint.in*

The problem of solid waste as a source of anthropogenic soil pollution has become extremely relevant today. A large amount of organic matter, microorganisms, and helminth eggs is released with household solid waste. The components of solid waste can be washed away from the soil by precipitation into surface water bodies and lead to pollution of water supply sources. Due to the decomposition of waste organic matter, especially easily decaying, gases with an objectionable odor are formed — ammonia, hydrogen sulfide, indole, skatole, mercaptans, which pollute air.

Industrial waste. A considerable proportion belonged to the waste of chemico-metallurgical raw material processing, as well as steelmaking, titanium-magnesium, ferromanganese ore, electrodeposition, and coke and by-product production, production of mineral fertilizers, bottom-ash from electric power industry and alumina sludge (Fig. 6.4).

In case of non-compliance with sanitary and hygienic norms and application rules, industrial waste accumulation become hazardous for the environment and human health. All solid industrial waste, depending on the toxicity due to physical, chemical and biological characteristics, is divided into four classes: I — extremely hazardous; II — highly hazardous; III — moderately hazardous; IV — marginally hazardous. The hazard class of industrial waste is grading by the value of the total hazard index, which is determined by the computational method according to special formulas that take into account: MAC of chemicals in the soil; their water solubility at a temperature of 25 °C; volatility of chemicals, i.e. saturated vapor pressure (in millimeters of mercury column) at a temperature of 25 °C; the amount of each substance in the total mass of waste.

Toxic industrial wastes, which contain harmful physiologically active substances and have a pronounced poisonous effect, pose a particular danger. The contact with such wastes can cause diseases or abnormalities in the health of living and future generations, as well as adverse changes in the environment (Fig. 6.5). Toxic wastes can contain beryllium, lead, mercury, arsenic, chromium, phosphorus, cobalt, cadmium, thallium, organometallic and cyanide compounds, carcinogenic substances of various chemical nature: benz[a]pyrene, nitrosamines, aflatoxins.

In places of their temporary storage, the violation of hygienic requirements for disposal, neutralization and landfill depositing (or final storage) of toxic industrial waste cause soil contamination, and then the migration



Fig. 6.4. Industrial and household waste. Source: *@M. R. Hassan*



Fig. 6.5. Impact of toxic industrial waste on the environment. Source: *hi-news.ru*

of toxic chemicals into the environment that is in contact with the soil, especially in groundwater and surface water.

In general, household and industrial waste occupies 4 % of the total surface area of the planet Earth.

6.7. Industrial atmospheric emissions

Emissions from industrial enterprises contaminate the atmosphere with various chemical substances, the qualitative and quantitative composition of which depends on the specific nature of the technological process. Thus, ash, soot, sulfur dioxide, nitrogen oxides, cyclic hydrocarbons, arsenic and fluorine compounds are released into the air with the emissions of thermal power plants; iron and steel works contaminate the air with mining dust, iron and manganese oxides; non-ferrous metallurgy sites — lead, zinc, cadmium, copper, arsenic and mercury oxides. Emissions from the chemical industry contaminate the atmosphere with aromatic and aliphatic hydrocarbons, sulfur compounds, acids, phenols, ethers, etc.

Due to the processes of natural self-purification of the atmosphere based on gravitational sedimentation (under the action of gravity) and precipitation scavenging, these chemicals from the air first fall on the soil surface and then begin to migrate. Through the surface runoff, they enter surface water bodies. Migration into the soil leads to contamination of the entire soil layer and entry into groundwater, especially subsoil circulating water. Chemicals migrate from the soil to the plants. Through soil dust and due to evaporation, volatile compounds enter the atmosphere. The soil annually receives 3 million tons of sulfur dioxide, 3.1 million tons of nitrogen oxides, 8.2 million tons of carbon monoxide, 1.75 million tons of organic compounds, 7 thousand tons of zinc, 6.5 thousand tons of lead, 80 tons of cadmium, about 600 other chemicals.

In recent decades, due to the ever-increasing pace of advances in science and technology, the lithosphere, especially its surface layer — the soil, is aggressively contaminated with heavy metals, such as vanadium, bismuth, iron, cadmium, cobalt, copper, molybdenum, nickel, tin, lead, selenium, antimony, tellurium, chromium, mercury and others, the atomic mass of which exceeds 50.

The distinctive feature of soil contamination by metals is a clearly defined localization of pollution zones (pollution "bubbles"). The largest amount of metals that contaminate the soil is detected near industrial enterpris-

es (within a radius of 1–2 km). At a distance of 3–5 km, the amount of metals in the soil begins to decrease, and this occurs up to a distance of 20–30 km. Outside these boundaries, in most cases it does not exceed the baseline value.

Accumulation of heavy metals in the soil in quantities exceeding the baseline value or even MAC, leads to changes in soil chemical composition, the appearance of toxic properties, upsetting of soil biocenoses, inhibition of soil self-purification, reducing its fertility. In the area affected by emissions of metallurgical productions, artificial technogenic biogeochemical provinces are formed. Their main features are: high heavy metal content in the soil in comparison with the regional baseline value; formation of stable technogenic cycles of heavy metal migration (atmosphere — soil, soil — plants, soil — water); ever-increasing pollution processes; the presence of a correlation between the concentrations of heavy metals in the environment and in the biological objects (plant and animal bioenvironment).

Heavy metals have pronounced cumulative properties, high biochemical activity toward sulfhydryl, thiol, carboxyl and other active groups of proteins. "Metal-protein" complexes can induce an allergic reaction. Some heavy metals have mutagenic and carcinogenic (cadmium, arsenic, nickel, chromium), gonadotoxic, embryotoxic and teratogenic (mercury, cadmium) effects. Therefore, an increase in disease incidence and mortality of population is observed in artificial biogeochemical provinces. Apart from that, heavy metals (mercury, arsenic, chromium, etc.) have the ability to penetrate the placenta, which increases the risk of pre-pathological and pathological conditions in newborns and infants.

6.8. Exhaust gases of motor-vehicles

Exhaust gases of motor vehicles contain carbon dioxide, hydrocarbons, benzo[a]pyrene, compounds of lead, cadmium, copper, manganese, and zinc. It has been established that the level of soil pollution along motorways depends on the vehicle density, duration of road usage, distance from the roadway platform. The surface (0–5 cm) soil layer at a distance of 10–15 m from the motorways with a vehicle density of up to 10 thousand road vehicle units per day contains 600–1000 mg/kg of iron, 20 mg/kg of zinc, 10 mg/kg of lead, 0.2 mg/kg of cadmium.

When there is a high traffic density of gasoline vehicles, the concentration of lead in the soil along roads can reach 300–500 mg/kg, the concentration of benzo[a]-pyrene — 50 mg/kg. Furthermore, it was found that benzo[a]pyrene is contained not only in the surface soil layer, but also extends depthward (up to 2 m), which makes it possible to enter groundwater. Naturally, the cultivation of any agricultural plants near motorways is hazardous to public health due to their contamination with heavy metals and benzo[a]pyrene.

6.9. Radioactive soil pollution

Radioactive soil pollution is the result of nuclear weapons testing and nuclear reactor accidents. The Chornobyl NPP accident led to radionuclide contamination of the soil of a significant part of the territory: more than 4.6 million hectares were contaminated, including 3.1 million hectares of agricultural lands.

Areas affected by radioactive contamination include areas of persistent soil contamination with radioactive substances that excess of the pre-accident level. According to the levels of soil contamination density with cesium, strontium and plutonium nuclides, four zones of radioactive contamination have been identified: exclusion zone, unconditional (mandatory) resettlement zone, guaranteed voluntary resettlement zone, and enhanced radioecological control zone. Radionuclide contamination lead to withdrawal from use of 119 thousand hectares of agricultural land, including 65 thousand hectares of plough lands.

Currently, almost 1.8 million people live in radioactively contaminated areas. More than 150 thousand people (including 60 thousand of children) were exposed to radiation doses higher than allowable. Almost 8 % of the population of Ukraine suffered from the ChNPP accident: 3.2 million people live in the contaminated area, 130 thousand were evacuated and settled out from the contaminated area, 350 thousand participated in the accident management. For the period from 1986 to 1997, 953 cases of thyroid cancer were reported in children and adolescents, and more than 1.000 children were declared disabled due to ChNPP accident-related diseases. There is a general tendency for an annual increase in the incidence rate among adults and children afflicted by ChNPP accident, both in overall incidence and in all categories of diseases. During the period 1987–1995, the disease incidence among affected adults increased 3.8 times, and the incidence of malignant neoplasms doubled.

In some categories of diseases, the population disease incidence in radioactively contaminated areas is much higher than in the entire population of Ukraine:

diseases of the hemic system and haematopoietic organs — 2.4 times, endocrine system — 1.7 times, digestive system — by 39.8 %, blood circulatory system — by 36.4 %. The post-accident dynamics of disease incidence and mortality rates of children and adolescents (aged 0 to 14 years) reflects a clear trend towards a outrunning health deterioration in the affected child population. If the overall and primary incidence among all children in Ukraine decreased (by 15.0 and 20.8 %, respectively) for the period 1987–1995, then among the afflicted people it increased: overall — 2.4 times, primary — 2.5 times.

Thus, soil contamination with exogenous chemical substances leads to the formation of artificial technogenic biogeochemical provinces, in which indirectly, through the soil-related environments (drinking water, food, air), an increased dangerous chemical exposure on the human body is formed. In order to have chemically safe food, drinking water, atmospheric air and not to disturb the process of soil self-purification, it is necessary to limit (regulate) the chemical burden on the soil according to specified concentrations. Currently, such criteria for the entry of exogenous chemicals into the soil are their MACs that are instrumental to all measures for sanitary soil protection.

6.10. Protection from soil pollution

Protection from soil pollution is a set of measures (organizational, legislative, hygienic or scientific, sanitary, sanitary-engineering, planning, land management, agrotechnical) aimed at limiting the entry of mechanical, chemical and biological pollutants into the soil to values that do not disrupt the processes of soil self-purification, do not lead to the accumulation of harmful substances in plants in amounts dangerous to human and animal health, do not cause air, surface and groundwater pollution, as well as do not limit the use of soil in agriculture.

Measures for sanitary soil protection:

1. Legislative, organizational and administrative measures.
2. Technological measures aimed at creating waste-free and low-waste technological schemes of production.
3. Sanitary-engineering measures that provide for the collection, removal, decontamination and management of waste contaminating the soil (sanitation of settlements).
4. Planning measures related to the selection of land plots for the construction of pollution control facilities, scientific substantiation and compliance with the size of sanitary protection zones between pollution control facilities and residential buildings and water withdrawal points, the selection of traffic patterns for special purpose vehicles.
5. Scientific measures to develop hygienic standards for assessing the sanitary condition of the soil in case of ingress of organic, biological (pathogenic and opportunistic viruses, bacteria, protozoa, helminth eggs) and chemical (pesticides, heavy metals, benzo[a]pyrene, etc.) pollutants.
6. Personal, social and health education.

There are different ways of protection from household waste in different countries. For example, if a person collected specified amount of plastic waste and put it into special automatic containers, he can receive an incentive bonus:

- free travel on public transport in Italy (Rome), Turkey (Istanbul), China (Beijing), Indonesia (Surabaya);
- free dinner at a restaurant in the UK (London) and India (Ambicapur);
- buy products at a discount in Denmark and the UK (Padsy);
- get money in Norway, Germany, Finland, Russia (Moscow, Krasnodar, Krasnogorsk);
- dinner with use of substandard products in Denmark (Copenhagen), Finland (Helsinki);
- discount on new items due to hand over of old items (H&M store in different countries), etc.

7 CHAPTER SOLAR RADIATION. INTERACTION WITH THE MAGNETOSPHERE AND ATMOSPHERE OF THE EARTH

V. G. Bardov, S. T. Omelchuk, N. V. Merezhkina, G. P. Bardov

7.1. Solar radiation, its spectral composition and properties

Solar radiation is the Sun's plasma radiation of corpuscular nature ("solar wind") and electromagnetic wave (photon) nature.

The "solar wind" spreads the solar plasma, consisting of helium nuclei, electrons, protons, neutrons, neutrinos, etc., in all directions of outer space at a speed of 300 km/sec at "quiet Sun" and at a speed of 1000–2000 km/sec at solar activity (solar chromospheric or proton flares, sunspots).

Photons of the Sun's electromagnetic waves (radio waves, infrared, visible, ultraviolet, X-rays and gamma rays) propagate in space at a speed of 300.000 km/sec.

The source of solar radiation is the Sun. Intranuclear processes in the Sun's interior are a cause of the formation of solar radiation, which spreads to space. Every second the Sun's loses about 4 million tons of its mass in the form of solar radiation. The Earth, located at a distance of 149 million km from the Sun, receives about 2×10^7 watts of solar radiative energy — this is 1/2000.000.000 of entire solar radiation. However, this amount of solar energy is enough for all the processes taking place on the Earth.

The amount of solar energy that reaches the Earth's surface is measured using special devices called actinometers. Measurement of direct solar radiation (or normal beam solar radiation) is called actinometry. Heliometers are used to automatically record the sunshine duration during the day. Pyranometers and pyrheliometers are used to measure the intensity of solar radiation. The intensity of solar radiation is expressed in cal/cm^2/min.

Through the special measurements it has been determined that if the Sun's rays fell directly perpendicular and there was no atmosphere around the Earth, every square centimeter of the Earth's surface would receive 1.95 small calories per minute. This value is called the solar constant.

When passing through the atmosphere, the amount of solar radiative energy decreases due to the scattering by air molecules, absorption by water vapor, dust particles and reflection from clouds. The degree of scattering depends on the season, solar elevation, and so on. The total solar flux from 1.7 cal/cm^2/min, when it is the high sun, decreases to 1.27 cal/cm^2/min when the height of the Sun is above the horizon of 10 degrees.

From 20 to 40 percent of solar radiation is lost as consequence of constant air pollution. The substantial proportion is lost in cities due to improper planning and construction. Window glass traps the most valuable part of solar radiation, namely ultraviolet.

7.2. Fundamentals of heliophysics

According to a contemporary view, the Sun is a slightly changing cool yellow star consisting of a core, intermediate and convective zones, photosphere, chromosphere and corona. The Sun's diameter is 1391 thousand km, which is 10^9 times exceeds the diameter of the Earth. It is a rotating ball of incandescent gas with a core temperature of 15.000.000–25.000.000 °K, pressure of up to 266.000.000 kPa (200.000.000 atm) and mass of 1.99×10^{30} kg, which is equivalent of 333.343 Earth masses. Most part (60 %) of the Sun's mass consists of hydrogen nuclei, protons reacting with each other (proton-proton reaction) with the formation of larger helium nuclei and the release of significant amounts of energy.

Thus, the Sun is an extremely powerful nuclear reactor located at a relatively safe distance (149.6 million km, or 10^7 diameters of the Sun) from the Earth.

The visible Sun's atmosphere is divided into several layers that flow into each other: the photosphere, chromosphere, corona. The photosphere is the most observable outer part of the Sun's atmosphere. Its thickness is

100–300 km, temperature — 6000 °K. The *photosphere* is the brightest Sun's layer, which is observed as a solar disk. It releases the major portion of the solar radiation. In the extreme and less bright photosphere parts, faculae are often observed, i.e. areas with higher brightness compared to the surrounding photosphere. The temperature of these areas exceeds the temperature of the atmosphere by several hundred degrees. The photosphere is the upper layer of the seething convective zone. Large elements of convection rise up in the form of granulation and supergranulation (Fig. 7.1).

Above the photosphere is the chromosphere, which can be observed during solar eclipses in the form of a narrow pink ring that envelopes the disk. It reaches about 14 thousand km above the visible edge of the solar disk, its density is low, and the temperature of the lower layers is 5000 °K. This is the source of bright, glowing gas streams up to 10.000 km high. These are the so-called spicules (Fig. 7.2).

The *solar corona* is the most rarefied layer of the Sun's atmosphere. It has a radial structure and extending in outer space for tens of solar radii.

The key feature of the Sun's atmosphere structure: the high temperature and strong rarefaction of matter create such conditions under which the gas has the form of a mixture of positively and negatively charged particles (ions, electrons, etc.), i.e. it has the appearance of plasma. The thermal energy of the corona particles is 106 °K. The rarefied outer layers of the Sun's atmosphere extend hundreds of millions of kilometers in outer space. The Sun is a source of various plasma radiation of corpuscular nature (electrons, protons, helium nuclei, etc.), the solar wind, and electromagnetic waves (infrared, visible, ultraviolet, X-ray, γ-radiation).

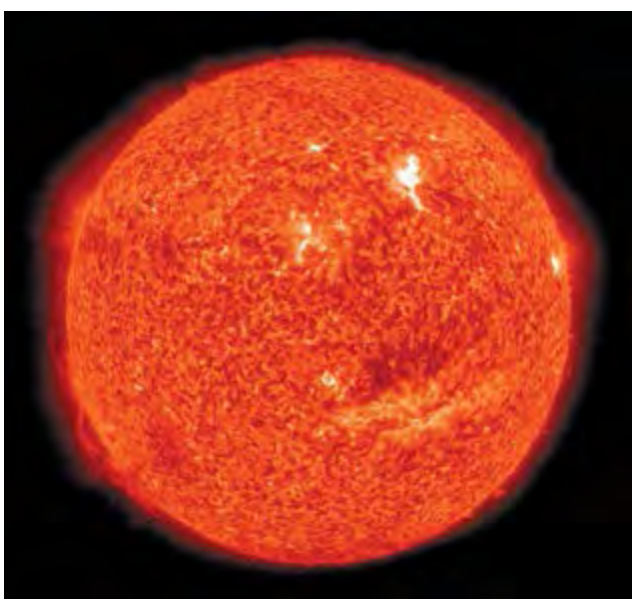


Fig. 7.1. "Quiet" Sun. Source: *Nasa.gov*

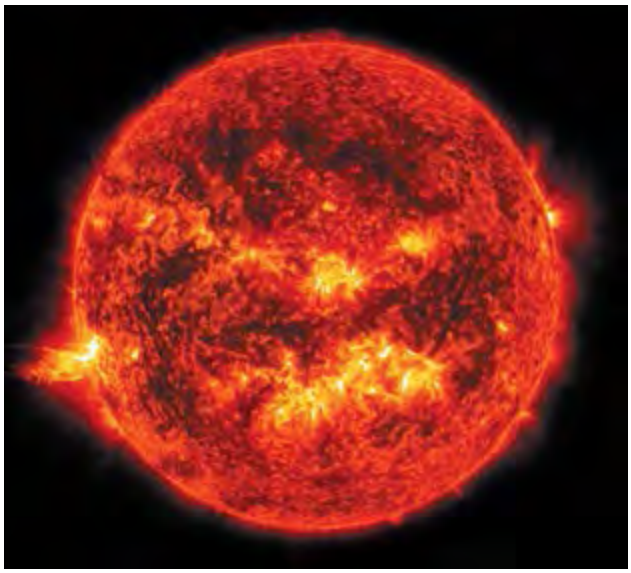


Fig. 7.2. Sun's spicules. Source: *Nasa.gov*

The *solar wind* is the propagation of the solar corona. It propagates the magnetic field of the Sun into space. The solar wind is directed almost radially from the Sun. By virtue of the Earth's orbital speed of 30 km/s, there is an aberration of about 5°.

An interplanetary magnetic field, formed by the Sun, is "frozen" in the solar wind plasma and almost entirely driven by current flow in the solar wind. The average magnetic field has several interplanetary magnetic sectors. This interplanetary structure rotates along with the Sun.

In contrast to the usual phenomena of the "quiet" Sun (Fig. 7.1), sometimes there are phenomena generally characterized by solar activity manifestations (Fig. 7.2, Fig. 7.3, Fig. 7.4). Solar activity is commonly determined as a totality of different phenomena in the Sun's atmosphere covering large areas with a width of at least several thousand kilometers. They are characterized by significant changes in the physical parameters of the atmosphere's corresponding layers.

Phenomena of solar activity are sunspots and solar flares.

Sunspots are huge electromagnets with a diameter of several thousand kilometers and a field strength of about 397.900 A/m (5.000 oersteds), i.e. thousands of times greater than the strength of the Earth's magnetic field.

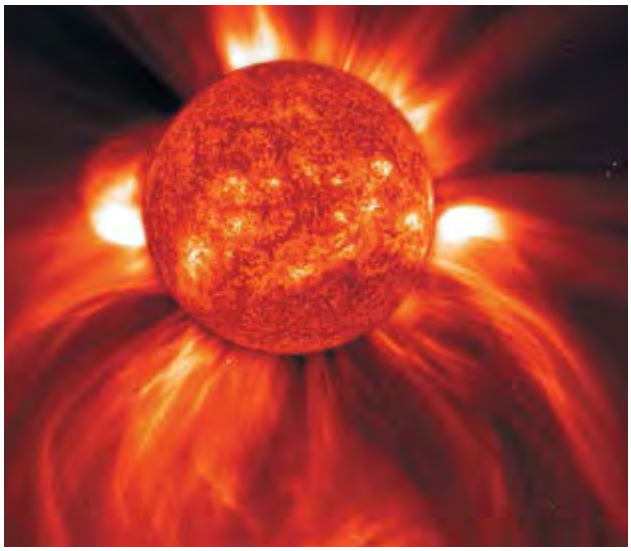


Fig. 7.3. Granulation and supergranulation of the Sun. Source: *Nasa.gov*



Fig. 7.4. Solar chromospheric flares. Source: *udf.by*

The temperature of the sunspot substance is 1500 °K lower than the ambient temperature, which makes them appear darker. Groups of spots are the coldest areas of the Sun's photosphere.

Solar flares are bursts on the Sun and more specifically short-term (slightly more than 1 min) powerful enhancements in brightness accompanied by the emission of solar particles, appearance of ionizing radiation bursts, intensification of X-rays. The power of the flare can be compared to the power of the explosion of thousands of thermonuclear bombs. Flares more often occur in several locations simultaneously. Because most of them occur in the chromosphere, they are also called *chromospheric* flares. Some of the most energetic flares can produce cosmic solar radiation, the protons of which have the most hazardous energy. Such flashes are specified as *proton*.

Solar activity significantly changes the spectrum of solar radiation by increasing emissions of high-energy particles and short-wave radiation. It is not constant, but cyclical. The cycle lasts 27 days (27.2 days), and it is equal to the synodic period of the Sun's rotation around its own axis, as well as 11-year (consists of epochs of maximum and minimum, i.e. extremums), 22-year, 80-year and 90-year cycles (Fig. 7.5).

There are two main views on the nature of solar activity cyclicity: the first associates cyclicity with the internal causes of the Sun, and the second accepts influence of the planets on the Sun.

Solar electromagnetic radiation propagates in space at a speed of 300.000 km/s and reaches the Earth's surface in just over 8 minutes; solar wind particles move at a speed of 300 km/s or 1000–2000 km/s (after powerful chromospheric flares) and reach the Earth in 2–3 days.

7.3. Interaction of solar radiation with the Earth's magnetosphere

On the path to the Earth, solar radiation faces obstacles in the form of various manifestations of the geomagnetic field and the Earth's atmosphere. At the geocentric distance, the plasma of the solar wind interacts with the geomagnetic field (Fig. 7.6, Fig. 7.7). The main current of the solar wind surrounds the Earth and carries the geomagnetic field into a long magnetic tail. Thus, the Earth is enveloped by a magnetic cavity — the *magnetosphere*, which transmits from the interplanetary environment to the Earth's atmosphere a part of the energy of the kinetic momentum and mass, which is transferred from the Sun by solar wind and solar energy particles.

Solar energy particles change the ionization conditions and the chemical composition of the Earth's mesosphere and stratosphere at high geomagnetic latitudes, resulting in changing of the absorption capacity of the Earth's atmosphere in the ultraviolet band. Such changes are dangerous for living organisms. Aside from that, ionization of the ionosphere leads to an increase in conductivity, the emergence of an electrical connection between the ionosphere and the lower atmosphere.

Particles, that enter the Earth's atmosphere mainly during substorms change ionization, chemical composition, heat the thermosphere, and transmit mechanical momentum to the neutral atmosphere. Consequently, magnetic substorms cause Aurora Borealis (or polar

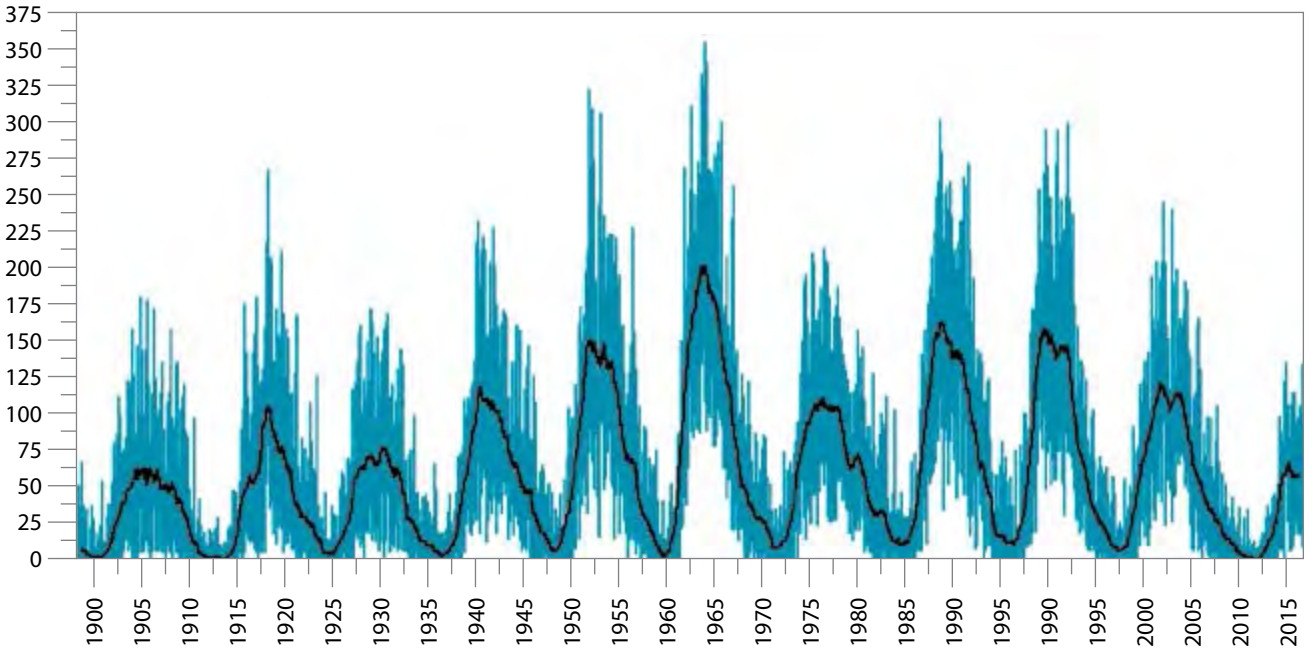


Fig. 7.5. Solar 11-year cycles

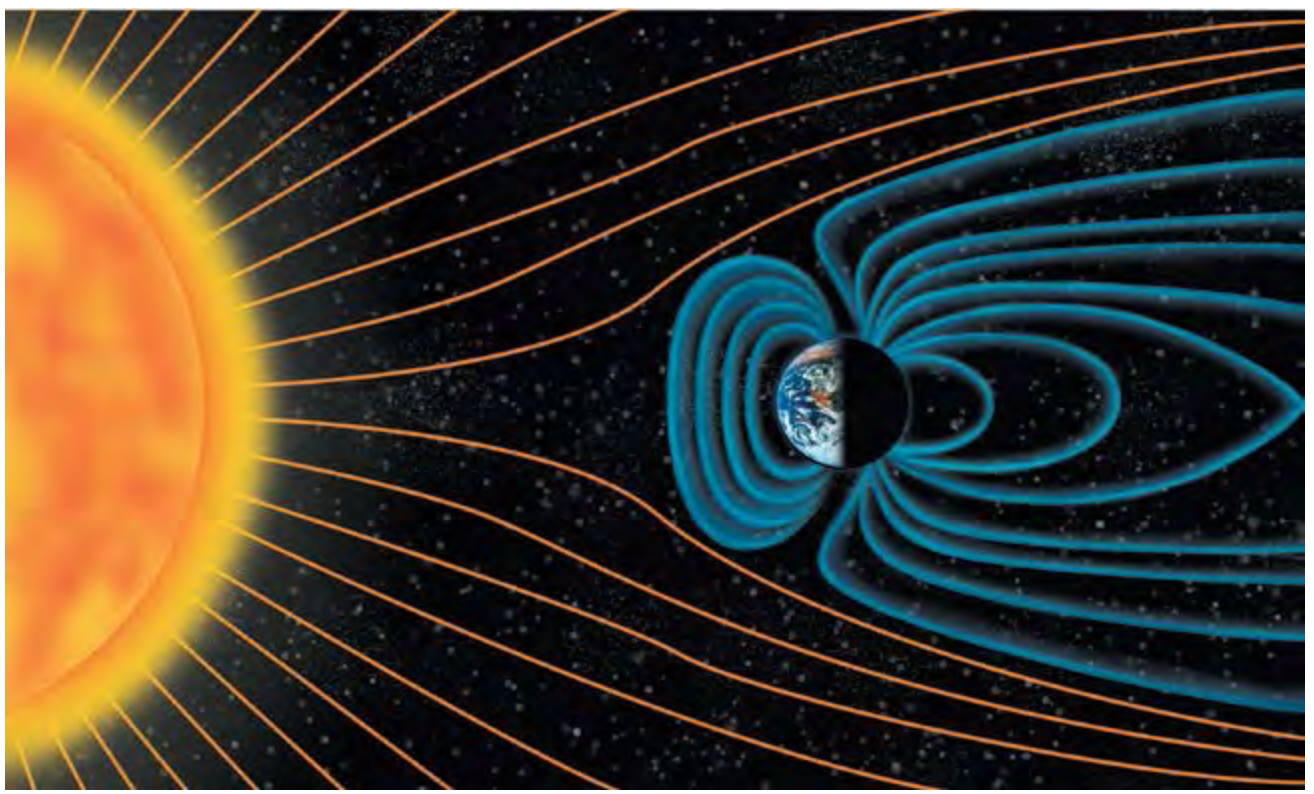


Fig. 7.6. The structure of the Earth's magnetosphere. Source: *pinterest.com*

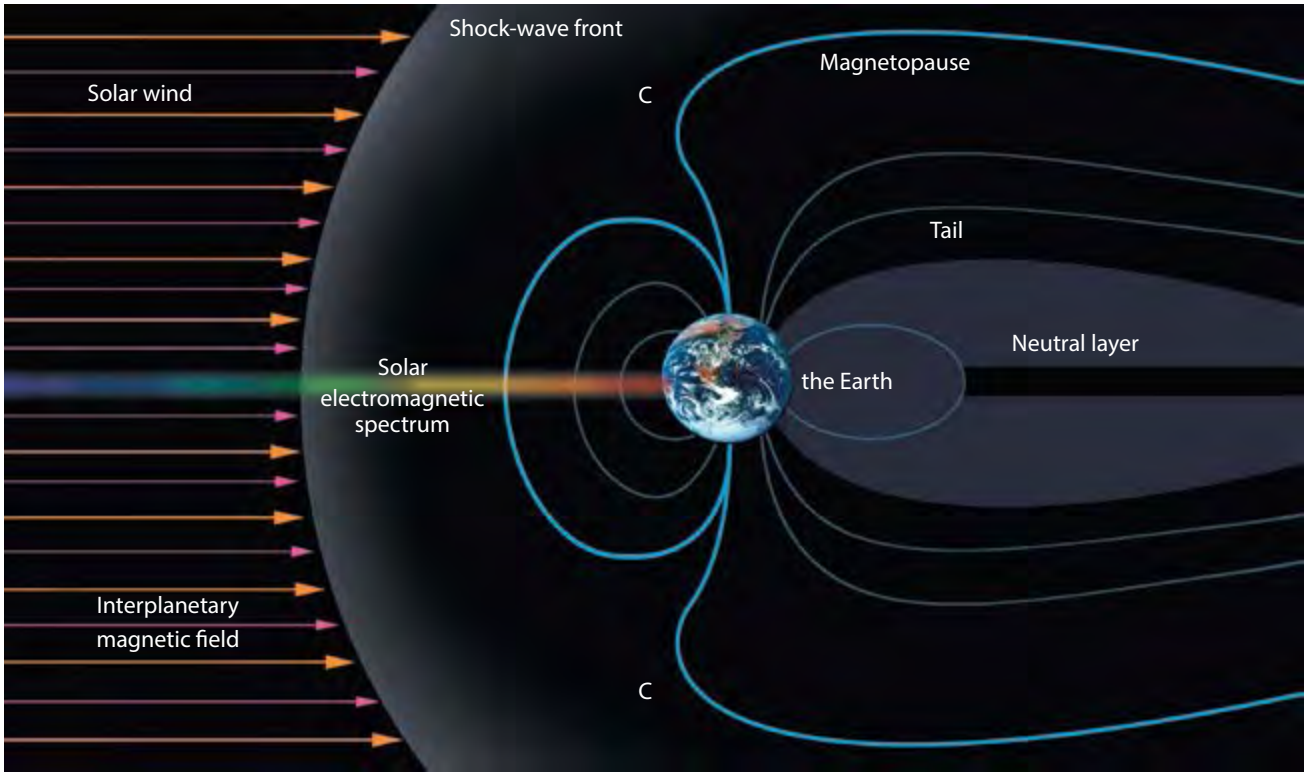


Fig. 7.7. The structure of the Earth's magnetosphere

lights), disturbance of radiowave propagation, trigger currents on the Earth, disrupt radio communications, disable satellite systems, affect GPS, damage electric transmission lines and high-latitude facilities (such as the Trans-Alaska Pipeline System). The flux of solar photons only indirectly affects the state of the magnetosphere due to the dynamic processes that connect it to the lower layers of the Earth's atmosphere, where electromagnetic radiation plays an important role.

Aurora Borealis is the glow of the upper atmospheric rarefied layers at an altitude of 90–1000 km due to the interaction of high-energy particles of the "solar wind" (electrons and protons) with oxygen and nitrogen of the atmosphere. Their collision leads to the transition of oxygen and nitrogen molecules to a high-energy state. Return to the initial equilibrated state leads to the emission of light quanta, i.e. Aurora Borealis (Fig. 7.8).

Auroras are observed in the high auroral ovals, surrounding the Earth's magnetic poles, most often in spring and autumn during the vernal and autumnal equinoxes. They coincide in their higher peaks with 27-day solar rotation and 11-year solar variability.

The color of Aurora Borealis depends on its intensity (I–IV points): the greater intensity (III–IV points), the more color in the glow: yellow-green (oxygen), less often — red and purple (nitrogen). The Aurora lasts from several tens of minutes to several days.

Aurora Borealis can be caused by a nuclear explosion in the upper atmosphere or by rocket emissions.

Thus, the geomagnetic field is a powerful factor in protecting the Earth from various space influences. Academician M. V. Keldysh noted in this regard: "The Earth has a special position because it is protected by a magnetic field, similar to armor, which does not allow charged particles close to the Earth. The Moon does not have such a "protection", as well as Mars or Venus. The Earth has a special position in this regard — it is an armored planet".

Of particular importance is the phenomenon of the magnetosphere, such as the activity of the geomagnetic field. Geomagnetic activity is a complex of various phenomena observed on Earth and in surface space. It has a significant impact on human (Fig. 7.9).

As previously noted, the Earth is surrounded by a constant magnetic field, which is created by flows of ionized mass in the liquid core of the Earth (internal causes) and accounts for 94 % of the total geomagnetic field. An alternating magnetic field is placed on a constant magnetic



Fig. 7.8. Aurora Borealis. Source: *ozzophotography.com*

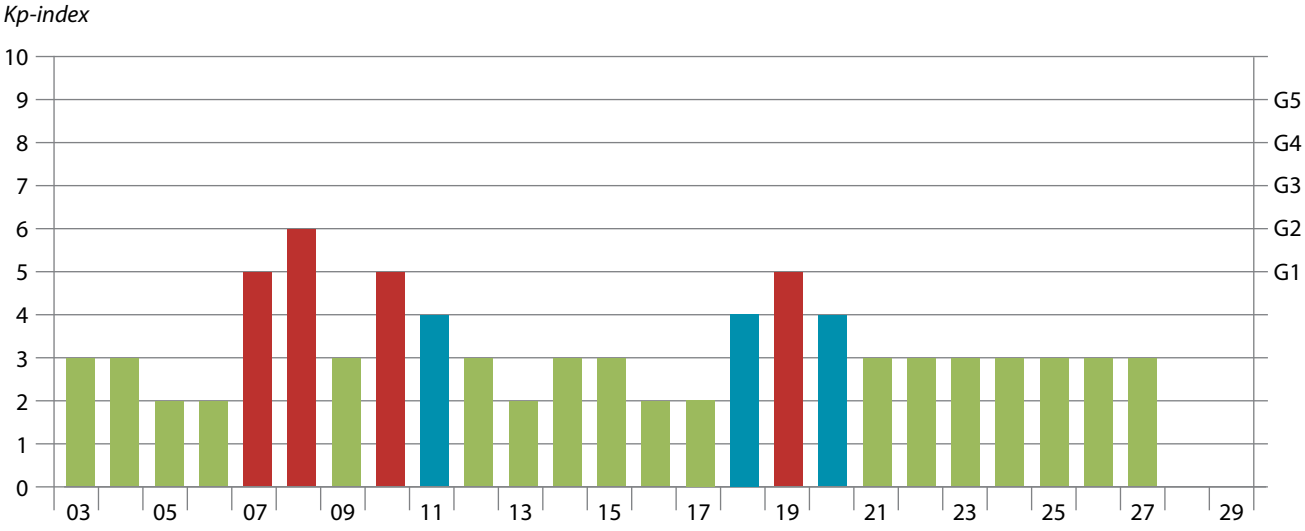


Fig. 7.9. Geomagnetic storms in October 2018

field. An alternating magnetic field is created by external causes: corpuscular fluxes of the solar wind, consisting of hydrogen nuclei (protons), electrons, neutrons, and so on. These fluxes flow out from the active areas of the Sun and the deep of outer space. The alternating magnetic field accounts for about 6 % of the total geomagnetic field.

Due to the influence of the high-power Sun's activity (chromospheric and "proton" flares), magnetic storms occur in the Earth's magnetosphere. The Laboratory of X-ray Astronomy of the Sun of the P. N. Lebedev Physical Institute (LPI) outlines the following magnetic storms according to a rating power scale (1–5):

- G_1 — minor storm (G_1 level);
- G_2 — moderate storm (G_2 level);
- G_3 — strong storm (G_3 level);
- G_4 — severe storm (G_4 level);
- G_5 — extreme storm (G_5 level).

Levels G_1 and G_2 typify the Earth's magnetosphere as "quiet". They are green on the forecast graphs (Fig. 7.9). Level G_3 characterizes the magnetosphere as "excited" (blue, orange). And levels G_4 and G_5 are characterized as a "magnetic storm" (red on the graphs).

Magnetic storms can cause various heliometeotropic reactions in humans: in some people — malaise, migraine, cephalgia, sleepiness, idiopathic fatigue, arterial blood pressure fall, and, on the contrary, in others, — emotional arousal, increase in arterial blood pressure, aggression attacks and insomnia. With strong magnetic storms, the cardiovascular accidents increase: angina attacks, myocardial infarction, cerebrovascular disturbances, etc.

In order to prevent these complications (when forecasting strong magnetic storms), the certain recommendations should be followed: avoid stress and strenuous physical activity, control emotions, take a rest day, more sleep, spend more time outdoors, avoid (or sharply limit) the alcohol, coffee, sugar and salt, greasy or fried foods, drink more water, green tea, dried or fresh fruit drinks, limit the use of smartphones, computers.

In marked symptoms of heliometeotropic cardiovascular, endocrine and nervous diseases, the physician prescribes appropriate chemotherapeutic and/or physiotherapeutic preventive treatment for such patients.

For the past 10 years, lights in the form of long pinkish ribbons of up to 1.000 kilometers are occurred over Canada. The mechanism of their occurrence is basically different from Aurora Borealis, so they were dissimilarly termed — "Steve" (Fig. 7.10). Probably, Steve's lights are due to processes in the Earth's ionosphere, but it is not accompanied by a strong increase in the flow of charged particles.

7.4. Earth's radiation belts (Van Allen radiation belts)

Smaller energy particles enter the magnetosphere during magnetospheric substorms. Most of the particles are con-



Рис. 7.10. Steve's radiance over Canada

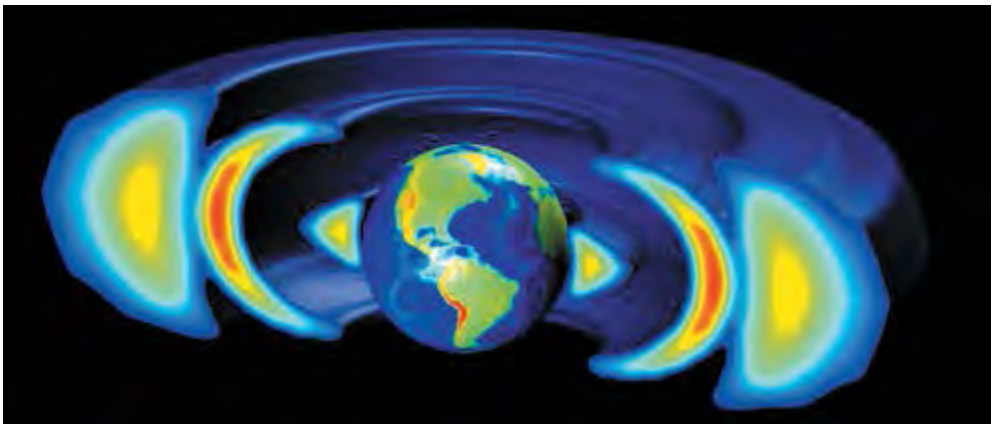


Fig. 7.11. Earth's radiation belts *(Van Allen radiation belts)*

tained in the radiation belts of the Earth at an altitude of 800–4800 km, 8000–10.000 and 14.000–16.000 km, where their maximum concentration is observed (Fig. 7.12).

In radiation belts, particles move along the lines of force of the magnetosphere in a helical path from the positive side (plus), and electrons are slightly swerved to the east and protons — to the west. In this way, radiation belts, catching charged particles, keep out them to the Earth's surface, reduce the overall level of ionizing radiation on the Earth's surface, support the preservation of modern life forms on Earth.

7.5. The effect of solar radiation on the Earth's atmosphere

The solar electromagnetic spectrum (Fig. 7.12 and Table 7.1) enters into various forms of interaction with the Earth's atmosphere (Fig. 7.13 and Table 7.2).

High-energy components of the solar electromagnetic spectrum — γ-rays, X-rays and short ultraviolet rays interact with oxygen in the stratosphere forming ozone, which at an altitude of 18–30 km forms the ozone layer of the atmosphere:

$$O_2 \longrightarrow O + O$$

$$O + O + M \longrightarrow O_2 + M$$

$$O_2 + O + M \longrightarrow O_3 + M$$

h — Planck's constant which equal to 6.626×10^{-34} J * s
v — frequency of the radiated wave, Hz.

Ozone decay reactions in the atmosphere:

$$O_3 + O \longrightarrow O2 + O2$$

$$O_3 \longrightarrow O_2 + O + heat$$

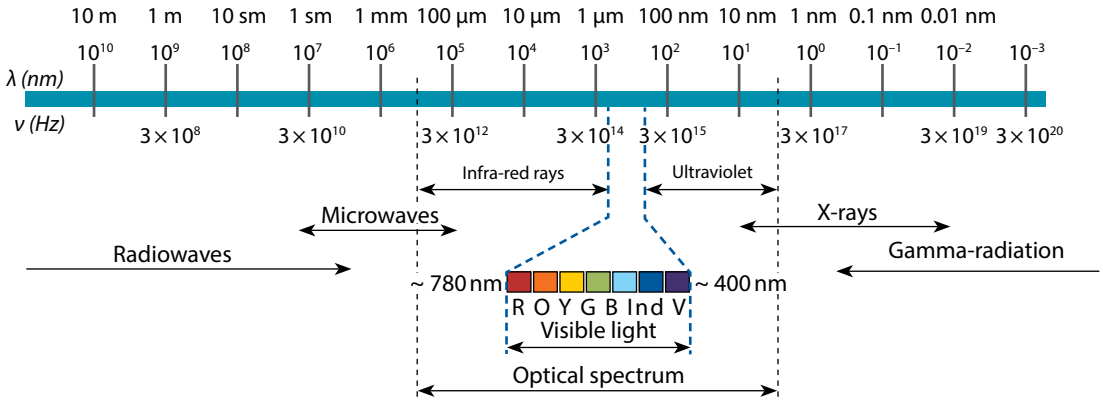


Fig. 7.12. Electromagnetic spectrum of solar radiation

Table 7.1. Electromagnetic spectrum of solar radiation

Components of the solar spectrum	Wave length, nm
Radio frequency range	> 100,000
Far-infrared region	100.000–10.000
Infrared region	10.000–760
Visible (optical) region	760–400
Ultraviolet region	400–120
Extreme ultraviolet region	120–10
Soft X-rays	10–0.1
Hard x-rays (γ-rays)	< 0.1

Low energy medium- and long-wave ultraviolet rays, reaching the Earth's surface, interact with various pollutants of the surface layer of the atmosphere (primarily, with vehicle exhaust gases), forming photochemical (Los Angeles) smog (Table 7.3).

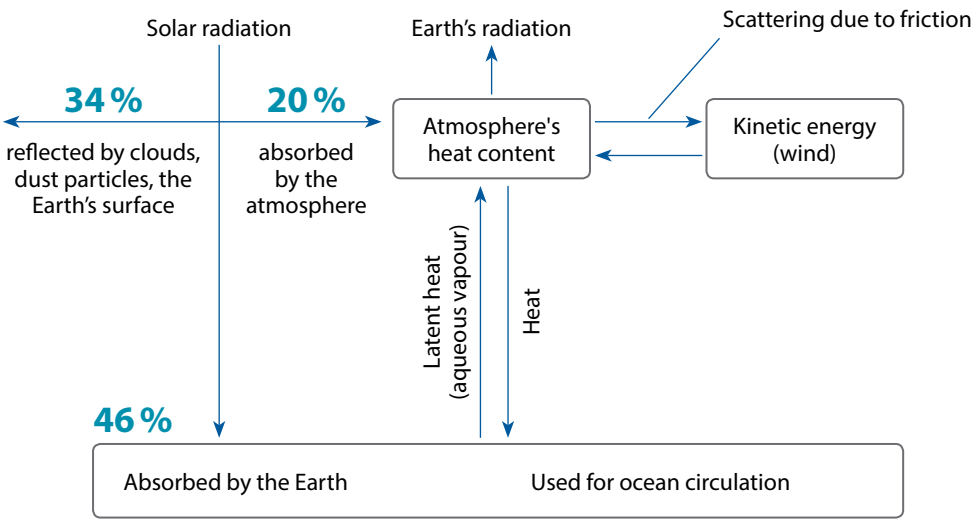


Fig. 7.13. Distribution of solar energy on the Earth's surface

Table 7.2. Interaction of solar radiation with the Earth's atmosphere

Weather conditions	Components of solar radiation		
	ultraviolet radiation (250–400 nm)	*visible radiation (400–750 nm)*	*near-infrared radiation (750–4000 nm)*
Clear	Scattering, absorption by oxygen	Scattering and absorption by aerosol	Absorption by water vapor, attenuation by aerosol
Cloudy	Scattering in the clouds, absorption by oxygen	Scattering in the clouds, absorption by aerosol	Scattering in the clouds, absorption by water vapor and cloud particles

Table 7.3. Atmospheric reactions of photooxidation under the influence of ultraviolet radiation

Reactions	Pollution forming rate, mg/m^3/year
Wave length < 400 nm	
$O_2 = O + O$	very high, about 26
$O_3 = O_2 + O$	high, about 2.6
$2NO + O_2 = 2NO_2$	low, 0.002–0.004
hydrocarbons + NO_2 or NO–NO_3, aldehydes, peroxyacetylnitrites, peroxybenzenenitrites, carbonyl compounds, aerosols	from low to high, from 0.02 to 2
olefins (C_2–C_5) — $O_2 + O_2$–O_2 = aerosols, $H_2SO_4 + O_3$, other oxidants, carbonyl compounds	from low to high, from 0.02 to 2
$SO_2 + ½O_2 = SO_3$	very low, 0.08
Wave length < 310 nm	
$O_3 = O_2 + O$	low, about 0.2

8 CHAPTER SOLAR RADIATION. INTERACTION WITH THE EARTH'S BIOSPHERE. USE OF SUN RAYS FOR DISEASE PREVENTION AND AIR, WATER AND OBJECTS SANATION

V. G. Bardov, S. T. Omelchuk, N. V. Merezhkina, G. P. Bardov

8.1. Influence of solar radiation on the Earth's biosphere

The electromagnetic components of solar radiation reaching the Earth's surface also interact with the biosphere.

The processes that occur in biological systems during the absorption of radiation energy are called photobiological. They are classified into three main groups:

1. Photosynthesis of carbohydrates, fatty acids, amino acids, purine and pyrimidine bases, chlorophyll pigment in green plants, bacteria, algae, which could be a source of life on Earth:

$$6CO_2 + 12H_2 \xrightarrow[\text{Chlorophyll}]{\text{Light}} C_6H_{12}O_6 + 6H_2O + 6O_2 + 674\ \text{kcal}$$

2. Processes (animal vision, phototaxis, phototropism and photoperiodism of plants) that support the regulation of plant growth and development, animal behavior, i.e. the perception of information about the environment.
3. Processes that result in damage to the living structure, destruction of biologically important compounds and, as a consequence, the suppression of the vital functions of the organism.

Other photobiological processes are available, but less understood: the stimulating effect of light on the development of animals; photoreactivation (elimination of the damaging effect of ultraviolet radiation in the case of sequential irradiation of cells with visible light); too feeble glow of tissues during biochemical reactions. Photobiological processes are based on photochemical reactions: photoionization, photoreduction and photooxidation, photodissociation, photoisomerization, photodimerization.

Photoionization is the liberation of an electron by a photon of radiation outside the molecule resulting in the formation of ions or free radicals. Photoreduction and photooxidation are the transfer of an electron from one molecule to another, consequently, one molecule is oxidized, and the other is reduced. Photodissociation is the process of a molecule dissipation into ions under the action of a photon of radiation. Photoisomerization is a change in the spatial configuration of a molecule under the influence of visible radiation of its structure. Photodimerization is the formation of a chemical bond between molecules caused by photons of radiant energy.

In this way, the photochemical reaction is accompanied by either the loss or acquisition of an electron, or the destruction of the molecule. This leads to a change in chemical properties of the molecule, for example, the protein loses its enzymatic ability.

The course of any photochemical reaction has two stages: light and dark. The light stage is the absorption of a radiation photon by molecules, which is then excited.

Excitation is the process of storing energy by molecules. The electrons of the molecule involved in the absorption of photons move from the ground energy level to a higher level. The total energy of the molecule increases by the amount of energy of the absorbed photon. At the same time, excitation is a reversible process. In a very short space of time (10^{-12}–10^{-8} s), a molecule can expend the stored energy in heat or a luminescence photon emission, or pass into a triplet state, transferring energy to another molecule (energy migration). In most cases, the excited molecule enters into photochemical reactions with surrounding molecules. By receiving or donating an electron, the excited molecule is converted into a radical, ion or radical ion, i.e. into a primary reductant or primary oxidant.

Next comes the dark stage. Primary reductants or oxidants, that contain unpaired electrons and electrons with high cosmic activity on external orbits, enter into

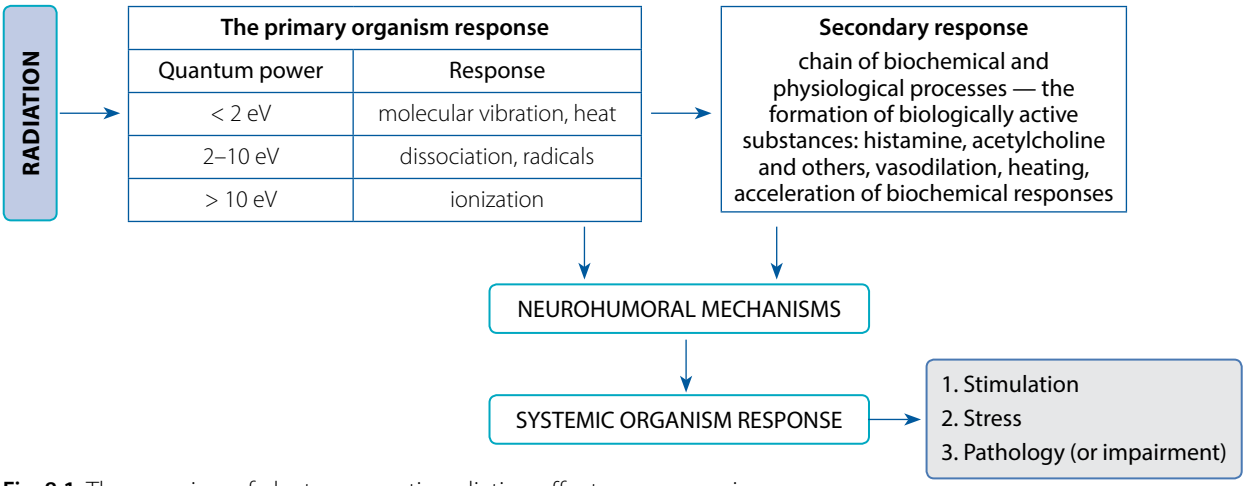


Fig. 8.1. The overview of electromagnetic radiation effect on an organism

biochemical reactions in the dark, changing them. This leads to a change in the general physiological state of the organism and the completion of any physiologic action (oxygen release during photosynthesis, the movement of leaves in plants towards the Sun, the death of the organism). According to the basic law of photochemistry, photochemical action is exerted by visible radiation absorbed by any biological system. The absorption capacity of the system is determined by the following factors:

1. The total amount of energy absorbed or the number of photons absorbed per unit of time that determine the rate of the photochemical process.
2. The intensity of the processes depends on the substance optical density, i.e. the absorption spectrum of visible radiation with different wavelengths; the type of radiation, wavelength and photon energy (Table 8.1) determines it.

The nature of the photobiological process depends significantly on the ability of radiation to penetrate through the human skin (Table 8.2). This is particularly the case with regard to the most biologically active ultraviolet radiation.

The permeability of different skin areas depends on the thickness of the stratum corneum. Radiation with a wavelength of less than 210 nm does not penetrate through this layer, and with a length of 200–250 nm — cause erythema. Radiation with a wavelength of 250–270 nm passes through the epidermis granular layer and causes pigmentation and erythema in the papillary dermis; 270–320 nm — penetrates the vascular layer, causing hyper-pigmentation and erythema, stimulates the sebaceous activity and skin nerve endings. Radiation with a wavelength of 320–390 nm penetrates through the dermis, causing pigmentation more often without erythema, 390 nm — reaches the subcutaneous tissue, causing a thermal effect and cutaneous flushing due to the increased cutaneous blood flow.

Table 8.1. Dependence of the photon energy of solar radiation on the wavelength

Radiation	Wavelength, nm	Photon energy, eV
infrared	100 000–760	0.64–1.66
Visible		
red	760–620	1.66–1.92
orange	620–590	1.82–1.94
yellow	590–560	1.94–2.06
green	560–500	2.06–2.34
blue	500–480	2.34–2.48
indigo	480–450	2.48–2.71
violet	450–400	2.71–3.11
Ultraviolet		
region A	400–320	3.11–3.90
region B	320–280	3.90–4.43
region C	280–200	4.43–6.21
vacuum	200–10	6.21–12.48

Thus, the biological effect of the main components of the solar spectrum reaching the Earth's surface is different, because it depends on the above conditions (Table 8.3).

Table 8.2. The penetrating ability of the solar radiation components in human skin (%)

Tissue layer	Layer thickness, mm	Ultraviolet radiation, μm			Visible radiation, μm			Infrared radiation, μm		
		0.21	*0.3*	*0.37*	*0.4*	*0.55*	*0.75*	*1*	*1.4*	*3.6*
Epithelial layer of the skin	0–0.25	100	92	48	20	15	20	25	56	80
	0.25–0.5	—	8	49	25	5	10	5	16	20
Connective layer of the skin	0.5–2.0	—	—	3	55	75	40	48	20	—
Subcutaneous tissue layer	2.0–25	—	—	—	—	5	30	22	8	—

Table 8.3. Biological effect of components of the solar electromagnetic spectrum

Radiation type	Primary action	Biological effect
Infrared	Deep thermal	Increase in skin metabolism, intensification of the UV radiation effects
Visible	Deep thermal, slight photochemical	Light perception, tonic effect
UV-A	Photochemical	Low general stimulating effect, pigment-forming (chromogenic) effect
UV-B	Photochemical	Strong pigment-forming (chromogenic) effect, low antibacterial effect, cholecalciferol synthesis
UV-C	Photochemical	General stimulating effect, strong bactericidal action, synthesis of cholecalciferol

8.2. The effect of components of solar radiation on organism

8.2.1. Biological effect of infrared rays

Infrared (thermal) radiation is a major part of the solar electromagnetic spectrum. Infrared radiation reaches the Earth's surface with a wavelength of 760–3000 nm, which trapped longer by the atmosphere. Under surface conditions, the direct infrared radiation of the Sun has an average photon output equal to 0.5–1 eV. Encountering molecules and atoms of various substances, radiation intensifies their vibration motions and causes a thermal effect. It penetrates the atmosphere, the water and soil, through the window glass and clothes.

It is the energy of infrared radiation in the form of uneven heating of the Earth's surface and evaporation of moisture that induces the movement of air and water masses, global system of winds, cyclones and anticyclones, warm and cold streams, diversity of climatic zones, weather conditions, also indirectly affects the life of animals, plants and human health.

The shortest infrared radiation with a wavelength of 760–1000 nm penetrates through tissues, including the cranial bones, to a depth of 4–5 cm. Radiation with a longer wavelength acts superficially. In the case of local exposure on tissues, infrared radiation in some degree accelerates biochemical reactions, enzymatic and immunobiological processes, cell growth and tissue regeneration, enhances bioluminescence and blood flow. The intensity of the subcutaneous tissue and internal organs heating decreases due to blood circulation, but the temperature of the blood and lymph increases.

The human body (internal organs, skeletal muscles) produces and emits infrared radiation through the skin and even clothing. Radiation cooling can lead to colds and exacerbation of diseases of the musculoskeletal system, internal organs. Thus, infrared radiation promotes thermoregulation of the body through thermogenesis and thermolysis.

The effect of infrared radiation in the case of absorption due to small values of photons is mainly manifested by deep or surface heating of tissues up to thermic fever

(or sunstroke), by the increase of blood flow in vessels and increased metabolism.

There are also a low photochemical effect of infrared radiation, especially in the case of dyes, the impact on the formation of reflexes in the cerebral cortex, the development of cataracts.

Active breakdown products, formed by infrared radiative effect on the skin, and nerve impulses from the skin spread the local effects of radiation on the body. Such influences (nervous and humoral) normalize the tonicity of the autonomic nervous system, relieve excessive tension, weaken the muscle and blood vessel tone, have analgesic and antiphlogogenic effects. Due to this, infrared radiation is used in medical practice.

8.2.2. Biological effect of visible rays

Visible (or light) radiation from the Sun has a wavelength of 400–760 nm and a photon energy of 1.66–2.75 eV.

Solar radiation creates a maximum illumination intensity on the horizontal surface of about 10.000 lux. If the Sun is above the horizon, the total illumination of the Earth's surface decreases to 1000 lux, and with lunar illumination — to 0.2 lux.

Visible radiation forms a range of colors. Depending on the wavelength in the direction from the infrared to ultraviolet spectrum of solar radiation, the main colors are the following: red, orange, yellow, green, blue, indigo (or deep blue) and violet. Visible radiation of the Sun determines the photosynthesis of plants, which creates organic matter in nature, phototaxis and bioluminescence, specifically affects the visual organ, for which it is an adequate stimulus.

Visible radiation penetrates through the skin into the human body to a depth of 2.5 cm. It has a local effect manifested by intensification in some degree of biochemical processes, immunobiological reactivity, photoreactivation, increased of internal tissue glow locally or through the blood flow. Human and animal blood plasma with a volume of 100 ml at a temperature of 37–40 °C emits about 10.000 photons per day. Visible radiation increases the excitability of the cerebral cortex, increases hypophysis secretion and metabolism, has a signal or conditioned-reflex value.

In the long-wave red area, visible radiation has an effect close to the effect of infrared radiation, i.e. it causes a thermal effect, and, in the shortwave violet area, it is close to the effect of ultraviolet radiation with photochemical effects: erythema, suntan, bactericidal, especially in the presence of photosensitizers.

Color has a great importance in human life: violet and indigo (or deep blue) control the neuropsychological sphere and facilitate in dropping-off to sleep, blue has a sedative effect, green — indifferent (or neutral), but it can activate digestive processes, bright yellow — irritating, red — excitatory. Blue color aggravates the depression state, and pink provokes a state of abnormal excitement.

8.2.3. Biological effect of ultraviolet rays

Ultraviolet radiation is very important for medical science and practical healthcare, as it can cause both salutary effect on humans and animals, and negative effect (Fig. 8.2).

The whole spectrum of ultraviolet radiation is divided into three areas that differ in their biological activity (resolution of the II International Congress on Phototherapy and Photobiology, 1932):

- region A — ultraviolet radiation with a wavelength of 400–315 nm (synonyms: long-wave ultraviolet radiation, near ultra-violet radiation, black light);
- region B — 315–280 nm (medium-wave ultraviolet radiation, radiation that causes tanning);
- region C — 280–210 nm (short-wavelength radiation, far ultra-violet radiation, bactericidal radiation).

Solar radiation with a wavelength shorter than 200 nm (vacuum region of ultraviolet radiation, vacuum ultraviolet radiation) on the Earth's surface has no significant biological effect, because it is absorbed by the atmosphere.

Due to scattering and absorption by the unpolluted Earth's atmosphere, radiation with a wavelength of 290–400 nm reaches the Earth's surface. However, due to the intense atmosphere pollution observed recently over large industrial cities, radiation with a longer wavelength reaches the Earth's surface.

Artificial light sources (gas-discharge light sources — mercuric, xenon, intermittent (or pulsed), fluorescent, carbon, quartz, and halogen lamps, oxygen-water and plasma torches, which give a line continuous spectrum), can provide a wide range of ultrasonic radiation.

The energy of ultraviolet radiation is absorbed by cellular proteins, nucleic and aromatic acids. Depending on the energy of the photon, charged atoms and molecules-ions, free radicals are formed, which due to their charge are involved in the migration of energy, i.e. in subsequent photobiological processes.

Depending on the amount of energy received, the following processes take place:

- photosynthesis — more persistent substances are formed;
- photolysis — the disintegration of nucleic acids in places of weak interatomic bindings;
- protein denaturation due to changes in the charge of atoms and molecules, reduction in size, loss of biological activity, causing formation of coarsely dispersed fractions.

Long-wave ultraviolet radiation more often causes photosynthesis, and short-wave — protein denaturation. These processes are naturally combined.

The mechanism of ultraviolet radiation influence on a human body is complex and various (Fig. 8.2). There are three main interrelated processes: biophysical, humoral and neuroreflexive. The ultraviolet radiation has the following effects on the body: photoelectric effect, secondary photoluminescent, mitogenetic radiation and photochemical effect. This leads to the activation of biochemical processes, changes in the ionic composition, electrical charges of cell colloids, their dispersion, which, in turn, affects the cells activity. Consequently, biologically active substances (histamine, acetylcholine, serotonin, etc.) are formed, as well as the activity of some enzymes (histaminase, tyrosinase, hydrogenase, etc.), and functions of organs and tissues are changed. This gave rise to the so-called histamine theory of the effects of ultraviolet radiation on humans.

Some researchers believe that protein breakdown products, including histamine and histamine-like substances, stimulate the nerve endings located in the skin and mucous membranes. This contributes to a complex of complex reflex responses, among which the humoral effects of breakdown products are combined with neural influences.

The amount of biologically active substances depends on the intensity of ultraviolet radiation and the area of irradiated skin. These substances change the microcirculation, permeability of tissues, get into the blood channels. As a result, especially due to a complex vasomotor reflex, when its arc in the case of correction of the cerebral cortex is closed in the hypothalamic area, a primary local effect is developed — photoerythema, i.e. an inflammatory reaction of the skin.

Then the accumulation of biologically active substances in the blood, due to the complex transformational change of neurohumoral status with the participation of different parts of the autonomic nervous system, a chain of secondary reactions is developed: increased conditioned reflex reaction at low and moderate doses of ultraviolet radiation with normalization of the relationship between stimulants and inhibition, the next activation of

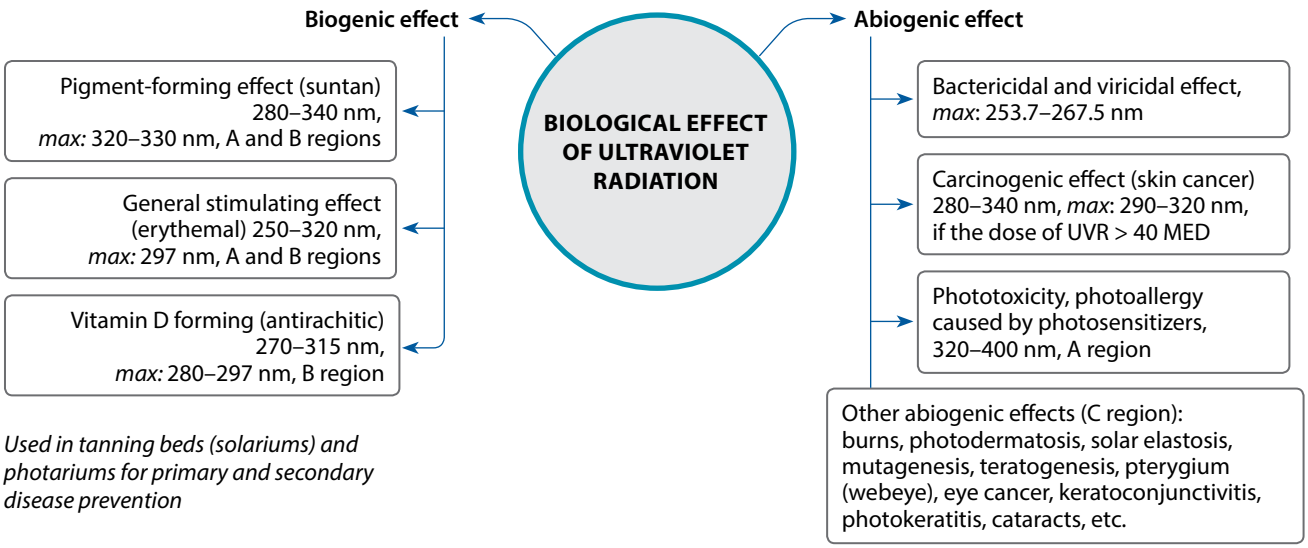


Fig. 8.2. Biological effect of ultraviolet radiation

the sympathetic-adrenal system and the development of body adaptation to this effect, stimulation of trophic function of the sympathetic part of the autonomic nervous system, increased oxygen consumption, activation of enzyme systems, increased oxidative phosphorylation and aminotransferase activity of mitochondria of various organs, increased activity of other enzymes (histaminase, amylase, lipase, phosphatase), stimulation of the metabolism of microelements that are parts of enzymes, increasing organism resistance to infections, exposure to chemical and physical factors of the environment.

Effects of ultraviolet radiation are classified into biogenic (vitamin D-forming or antirachitic effect, erythemal or general stimulating effect, suntan or pigment-forming effect) and abiogenic (bactericidal, mutagenic, allergenic, carcinogenic effects).

The biogenic effect of ultraviolet radiation is manifested only at certain, physiologically associated, specifically small doses of radiation.

Vitamin D-forming effect of ultraviolet radiation. Calciferols are a group of compounds formed in the human body from cholesterol derivatives of — ergosterin and 7-dehydrocholesterol (calciferol provitamins). Cholecalciferol (vitamin D_3) is synthesized in human skin under the influence of ultraviolet radiation. 7-dehydrocholesterol, which enters the skin through the blood flow with the help of serum lipids (its carriers), is concentrated in the Malpighian layer of the epidermis. The maximum concentration of this provitamin is found in keratins and sebaceous glands.

Calciferols are involved in calcium-phosphorus metabolism, which provides permeability of the intestinal mucosa for calcium ions, its absorption and digestion, as well as reabsorption of phosphates in the nephron tubules. Calcium determines the permeability of cell membranes and participates in blood clotting. It is a plastic material for bone growth. Phosphorus is included in nucleic acids, phosphoproteins, and many cell constituents. Calciferols reduce the activity of alkaline phosphatase, which increases with hypovitaminosis or avitaminosis D (vitamin D insufficiency), to restore calcium content due to bone calcium. Thus, calciferols regulate the accumulation of calcium and phosphorus salts in bones, i.e. normalize bone mineralization, influences the citric acid metabolism, which also participates in the processes of general metabolism (regulation of nervous system excitability, use of proteins and minerals from food, elements of enzyme oxidation). In the case of hypovitaminosis or avitaminosis D, there are pathological changes in the human body: blood clotting disorders, muscle weakness (in children — pendulous abdomen and, further, poor head and neck control), increased bone fragility arising from calcium depletion, ossification disorders, myopia.

Calciferol enters the human body with food (the daily need of an adult is 2–5 mg), and it is formed in the skin from provitamins under the influence of ultraviolet radiation.

Penetrating the skin, ultraviolet radiation activates 7-dehydrocholesterol, from which the cholecalciferol (provitamin) is synthesized. This photochemical reaction occurs in the skin in the stratum spinosum (spinous layer) and stratum basale (basal cell layer) of the epidermis, and after 15–20 minutes, the content of provitamin reaches a maximum. The formation of cholecalciferol in the skin is limited by the conversion of its excess into biologically passive photoproducts — tazesterol-3, and most often — lumesterol-3. This process is considered to be one of the main links in the regulation of the cholecalciferol formation in the skin. Subsequent to the concentration of provitamin becomes maximum, the increase of intensity and duration of ultraviolet radiation has no significant effect on its level in the irradiated area of skin. The content of the provitamin in the case of human skin irradiation with medium-wave ultraviolet radiation does not exceed 10–15 % of the initial level of 7-dehydrocholesterol.

Another factor that has impact on provitamin photosynthesis is skin pigmentation. It does not affect the maximum possible concentration of cholecalciferol, but inhibits the conversion of 7-dehydrocholesterol to provitamin, and therefore increases the time required (up to 3 hours) to reach its maximum concentration.

In case of insufficiency or deficiency of ultraviolet radiation, there are disorders of phosphorus-calcium metabolism in the form of hypovitaminosis or avitaminosis D. Avitaminosis D causes 90 % of calcium and 60–70 % of phosphorus to be unassimilated. However, the urinary excretion of these ions is continued even in the absence of their entry into the body.

The value of ultraviolet radiation for vitamin D status of the body is confirmed by data on the increase in the incidence of rickets, decrease in the content of cholecalciferol metabolites in the blood of adults after the autumn-winter period, when the duration and intensity of natural ultraviolet radiation is reduced.

Ultraviolet insufficiency and manifestations of hypovitaminosis D are observed in the form of disorders of phosphorus-calcium metabolism in sailors and employees working in closed space (without sunlight), a content reduction of 25-(OH)D^3 in the blood of submariners.

Treatment and prevention of hypovitaminosis D is provided by the use of pharmaceuticals with cholecalciferol. It is obligatory to combine medicines with ultraviolet radiation.

Excessive intake of the vitamin with food can lead to hypervitaminosis accompanied by hypercalcemia, apathy, weight loss, accumulation of calcium salts in various organs and tissues, the development of urolithiasis (or Kidney stone disease). Hypervitaminosis D due to ultraviolet radiation is not observed.

For prevention of rickets, ultraviolet radiation is more preferable and natural type of treatment than artificial pharmaceuticals with vitamin D complex. The main reason for this conclusion is the fact that under the influence of ultraviolet radiation the body synthesizes cholecalciferol using own resources, while pharmaceuticals can lead to allergies. Aside from prevention of hypovitaminosis D, ultraviolet radiation promotes the formation of other antirachitic substances in the body, which structurally differ from the vitamin.

A threshold dose for the antirachitic effect is the erythemal irradiation dose of ultraviolet radiation: 83 – 111 W / ($m^2 \times h$) at a wavelength of 297.6 nm, which is equal to 1/8–1/10 of the minimal erythema dose (MED). Ultraviolet radiation with a lower dose has no preventive effect. There are indications that the ultraviolet radiation effect by erythemal radiation dose equal to 1167 W / ($m^2 \times h$) is sufficient for the treatment of patients with rickets.

General stimulating effect of ultraviolet radiation (Table 8.4, Table 8.5). This type of biogenic effect of ultraviolet radiation begins with erythema, which is occurred in 8–20 hours after irradiation with erythemogenic ultraviolet radiation and resolves in 1–4 days. Symptoms on the skin: redness, hot to the touch, minor pain, swelling and edema. If the dose of ultraviolet radiation is high, there is a severe form of erythema — sunburn in the form of blisters. In this case, edematous fluid (transudate) is accumulated exfoliating the epidermis and forming blisters or even necrotic zones. After a few days, the skin darkens and sloughs. Ultraviolet radiation has an erythemal effect in the wavelength range 250–320 nm. In this case, a double peak is observed at maximums of 250 and 297 nm and minimum of 280 nm.

Therefore, the amount of ultraviolet radiation required for the development of erythema varies depending on the wavelength, because different areas have different erythema efficiency.

Considering the wavelength and qualitative features, short-wave ultraviolet radiation produces erythema faster, and such erythema is less intense in color than erythema caused by medium-wave ultraviolet radiation (wavelength is about 297 nm). Erythema that develops during exposure to long-wave radiation is nonspecific because it is not caused by cholecalciferol metabolites, but by vasodilation due to increased heat generation. Long-wave ultraviolet radiation enhances the erythematosus effect of short-wave ultraviolet radiation (when they are combined).

The erythema mechanism has not been definitively clarified. However, it has already been established that under the influence of ultraviolet radiation in the papil-

Table 8.4. General stimulating effect of ultraviolet radiation (experiment)

Ultraviolet radiation supply for rabbits	Myocardial area	Activity of respiratory and glycolysis enzymes in the myocardium of rabbits with experimental myocardial infarction on the background of different UV supply			
		SDH	*LDH*	*NAD DH*	*NADPH DH*
Ultraviolet radiation deficiency	Myocardial infarction area Peri-infarction area Uninvaded (noninvolved) area	— ++ — ++; +++	+ ++ +++ ++ +++	—; + ++ — ++; ++ +++	— + — + ++
Ultraviolet radiation optimum	Myocardial infarction area Peri-infarction area Uninvaded (noninvolved) area	— ++; ++ +++ +++; +++ ++	+ ++; ++ +++ ++; +++ +++	—; + ++; ++ +++ +++ ++	—; + ++ + + ++; ++

Note: SDH = succinate dehydrogenase, LDH = lactate dehydrogenase, NAD DH = nicotinamide adenine dinucleotide dehydrogenase, NADP DH = nicotinamide adenine dinucleotide phosphate dehydrogenase

Table 8.5. General stimulating effect of ultraviolet radiation of patients (UV exposure)

Content of outpatient conservative treatment	A hypertensive patient population without UV exposure in the hospital (n = 90)		A hypertensive patient population with UV exposure in the hospital (n = 89)	
	1 year before hospital treatment	*1 year after hospital treatment*	*1 year before hospital treatment*	*1 year after hospital treatment*
Medication treatment throughout the year	3 3.3 % 100.0 %	21 23.3 % 700.0 %	4 4.5 % 100.0 %	14 15.7 % 350 %
Medication treatment during adverse seasons	47 52.2 % 100.0 %	61 67.8 % 129.8 %	54 60.7 % 100.0 %	59 66.3 % 109.3 %
Medication treatment during the period of health state deterioration	33 36.7 % 100.0 %	8 8.9 % 27.6 %	25 28.1 % 100.0 %	16 18.0 % 64.0 %
No medication	7 7.8 100.0 %	— 0.0 % 0.0 %	6 6.7 % 100.0 %	— 0.0 % 0.0 %

lary dermis (with blood vessels), histamine, kinins, prostaglandins E_2 and E_{2a}, nucleotide byproducts are formed. They provide a complex chain of biochemical processes of erythemal effect.

The intensity of erythema depends on a number of factors. It increases in the case of irradiation of sensitive skin on the abdomen and back (it is more sensitive than on the extremities), especially in children, during menstruation, pregnancy, thyrotoxicosis, allergic diseases, in the winter-spring period, in people with less skin pigmentation. If the dose of ultraviolet radiation at the beginning of irradiation does not exceed 1 MED, the erythemal effect of radiation has a significant stimulating effect, which is widely used for preventive care and therapeutic purposes.

General stimulating effect of ultraviolet radiation:

- increase in the content of total amino acid nitrogen;
- increase in the level of albumins and gamma globulins;
- stimulation of the mononuclear phagocyte system and bone marrow;
- normalization of the protein spectrum of blood and hemocytogenesis — the amount of hemoglobin, erythrocytes and leukocytes increases;
- intensification of the cell resistance, activity of internal respiration enzymes, microsomal hepatic enzymes, mitochondria, hexokinase, phosphofructokinase, pyruvate kinase;
- increase in the content of ATP (adenosine triphosphate) and 2.3-diphosphoglycerophosphate in erythrocytes, which indicates the activation of glycolysis and increase in the degree of blood saturation with oxygen;
- intensification of phagocytic activity of leukocytes, bactericidal properties of blood and skin, production of agglutinins in immunized animals;
- decrease in the level of cholesterol and tyrosine in the blood serum;
- increase in glucose tolerance, activity of the genital glands and galactosis;
- stimulation of sympathetic-adrenal and pituitary-adrenal systems;
- increase in the secretion of many hormones;
- growth of gas exchange and general tolerance in children, non-specific resistance of organism to infections and to toxic, carcinogenic substances, ionizing radiation, etc.

Small doses of ultraviolet radiation activate the processes in the cerebral cortex, increase mental capacity, muscle tone and physical endurance, rest efficiency.

Erythema doses of ultraviolet radiation stimulate the growth of angioblasts, activate the formation of conjunctive tissue, and facilitate the skin epithelialization used in the wound and ulceration healing, especially in the case of delayed healing. The decrease in pain sensitivity is due to a decrease in the sensitivity of skin receptors and the

emergence of a new excitation source (dominant) in the central nervous system, which by the type of negative induction extinguishes the disease-related dominant.

The *pigment-forming effect of ultraviolet radiation* is manifested by the formation of melanin pigment in the cells of the lower layer of the epidermis — melanoblasts — from the amino acids tyrosine, dioxyphenylalanine, adrenaline breakdown products and the migration of melanin into the surface layers of the skin.

Melanin is the main pigment in human body. It is responsible for color of hair, eyelashes, iris. Melanin has an influence on skin color. It protects cell nuclei as well as internal organs from overheating by infrared radiation, which penetrates deep (up to 40 mm) under the skin, and visible radiation. When photons of ultraviolet radiation are absorbed by molecules of proteins, nucleic acids and other organic compounds, as mentioned above, the decay and splitting of molecules occur. In this case, ions, free radicals, biologically active substances are formed. They react with other molecules, supplementing and intensifying the damage. This reaction is stopped by polymeric melanin molecules with a network structure. Melanin molecules, which have the properties of stable free radicals, retain and neutralize the fragments of molecules destroyed by ultraviolet radiation, do not let them into the blood and the internal environment of the body. This protective property of melanin is used for preventive protection of human body from ionizing radiation and during treatment for radiation sickness.

The ability of ultraviolet radiation to cause tanning depends on the wavelength and has two rises: the first — in radiation with a wavelength of 280–340 nm and a maximum at a wavelength of 320–330 nm, the second — with a wavelength of 240–260 nm.

Darkening of the skin caused by ultraviolet radiation can appear immediately (immediate darkening) and slow (persistent darkening). Accordingly, the tan can be immediate or delayed (or true melanogenesis).

Immediate tanning is a protection skin mechanism from the damaging effects of ultraviolet radiation. It appears after 5–10 minutes of skin exposure to the Sun or long-wave ultraviolet radiation, as well as visible radiation, reaches a maximum in an hour. 30 minutes after the cessation of radiation, it begins to disappear and, after 3–8 hours, becomes barely noticeable.

The delayed tanning becomes noticeable after 73 h after exposure to ultraviolet radiation in regions A and C and short-wave visible radiation of high power [more than 17.7 ± 8 J / ($cm^2 \times min$)]. Delayed tanning retains more than a year.

In the process of phylogenesis and ontogenesis, effective means of protection against excessive exposure to ultraviolet radiation have been formed in human. These include thickening of the skin and pigmentation. Approximately 3 days after ultraviolet irradiation, the rate of cell division of the irradiated area increases resulting in an increase in the thickness of all layers of skin, except pigmented stratum, and the protective index (ratio of erythemal sensitivity of tanned and non-tanned skin) is 2/3. Its value for tanned skin in combination with thickening of the epidermis can increase to 60. In addition, the upper layers of the skin and areas of sweat secretion contain urocanic acid, which adsorbs ultraviolet radiation with a wavelength of 290–310 nm. The greater sensitivity of wet skin to the effects of ultraviolet radiation is due to washing away and reducing the urocanic acid content in the skin.

Abiogenic effect. Burns, photodermatosis, solar elastosis, mutagenesis, phototoxicosis, photoallergy, pterygium (webeye), eye cancer, keratoconjunctivitis, photokeratitis, cataract should be considered abiogenic, i.e. adverse effects of ultraviolet radiation on humans. The antimicrobial effect of UV rays is also a relatively adverse factor.

The *bactericidal effect of ultraviolet radiation* is significant (Table 8.6, Table 8.7), because the absorption spectrum of radiation by nucleic acids, which are the basis of the bacterial cell and virus, probably correlates with the spectrum of lethal and mutagenic effects of ultraviolet radiation. In addition, the curves of bactericidal effect, inhibition of cell division and growth almost entirely congruent with the absorption curves of ultraviolet radiation by nucleic acids.

Thus, denaturation and photolysis of nucleic acids, which are the most important components of the hereditary background, the formation of thymine dimers and cross-links between DNA strands lead to the cessation of cell division and growth, and in large doses — to their death.

Table 8.6. Bactericidal effect of ultraviolet radiation

Wavelength of UV rays, nm	400–380	330–300	280–260	260–240	240–220	220–210	210–200
Time for coliform bacteria destruction, s	960	920	4	2	20	30	120

Table 8.7. Characteristics of artificial sources of ultraviolet radiation

Lamp type	Radiant flux, %				Erythemal flux, μer* (microer)	Bactericidal flux, μbact/cm²**	Luminous flux, lm
	Visible area	Ultraviolet radiation					
		UV-A	*UV-B*	*UV-C*			
EUV-15	20	45	35	0	110	84	70
DRT-1000	44	19	22	15	16 500	39 500	32 000
BUV-30	18	2	2	78	30	4 500	150

Notes:
** er (erythemal flux unit measure) = monochromatic radiation flux of 1 W with a length of 297 nm.*
*** bact (bactericidal flux unit measure) = bactericidal flux of monochromatic radiation of 1 W with a wavelength of 255.5 nm.*

After ultraviolet irradiation, the bacteria are first excited, i.e. their vital activity is promoted. They lose the ability to multiple repair and to form colonies due to imbalance of nucleic acid metabolism (bacteriostatic or bacterial growth-inhibiting effect). Finally, protein coagulation leads to bacterial destruction.

The bactericidal effect of ultraviolet radiation depends on a number of circumstances. Radiation absorbed by nucleic acids, proteins, primarily DNA, has a significant bactericidal effect. The causes of bacterial destruction are lethal mutations, loss of ability to replicate for at least one DNA molecule, transcription abnormality. One of the main direct causes of bacterial cell destruction is the inactivation of the biosynthetic apparatus responsible for the synthesis of vital DNA, RNA and protein molecules. The intensity of UV radiation plays a certain role — concentrated radiation has more intensive effect than diffuse radiation. New bacteria (after mitosis) are more sensitive to ultraviolet radiation.

Staphylococci, streptococci, influenza viruses, vibrio cholera, mycobacterium tuberculosis, fungi and their spores, coliform bacterium, and other pathogenic and saprophytic microorganisms die or change their properties under the influence of ultraviolet radiation. Ultraviolet radiation destroys diphtheria, tetanus, dysentery, typhoid fever, and staphylococcus aureus toxins. The most efficient and fastest way to destroy microorganisms is radiation with a wavelength of 253.7–267.5 nm. On both sides of the UV spectrum, the bactericidal efficiency decreases. To destroy bacteria by radiation with a wavelength of 280–210 nm, it is necessary to irradiate for 20–30s, if the wavelength is in the range of 210–200 nm — for 120 s, and for radiation with a wavelength of 330–300 nm — for 1920s.

Solar ultraviolet radiation effect is a very important factor for self-purification of air, rivers and seas.

The bactericidal effect of ultraviolet radiation is used to sterilize the air in health care facilities, to disinfect toys, dishware, tools, water, food, and to inactivate viruses during the producing of vaccines, etc.

The presence of ultraviolet radiation with a wavelength of less than 297 nm is near-zero in solar radiation that reaches the Earth's surface, because it is absorbed by the atmosphere. Therefore, to obtain it on the Earth, artificial sources (bactericidal lamps) are used. They are used for disinfection of premises and various products. This radiation is unfavorable in the ultraviolet radiation sources intended for irradiation of animals and humans. Not more than 5 % of such radiation from the total spectrum is allowed in artificial sources of ultraviolet radiation.

Carcinogenic effect. Prolonged exposure to ultraviolet radiation from the Sun or artificial sources in doses that significantly exceed the threshold dose of erythemal radiation causes burns, dermatitis, alteration, collagen degradation, the development of erosions, ulcers, benign and malignant tumors (of epidermoid and mesenchymal nature). Ultraviolet radiation in the region of 280–340 nm has a carcinogenic effect. However, if the shielding effect of the stratum corneum is weak, radiation with a wavelength of 365 nm also shows carcinogenic activity.

Canceration is possible only when the initial erythema dose exceeds the MED by 40 times or more and continues to increase beyond the adaptation of organism. Based on this, we can conclude that there are no grounds for adverse effects of preventive ultraviolet radiation.

It is now believed that UVR-induced carcinogenesis has a number of successive factors, which are the result of photodamage of genetic material. The erroneous DNA repair has been found to increase the incidence of oncogenesis causing DNA changes. This leads to increased

chromosomal aberrations and mutations, increased rate of transformation of healthy cells into cancer ones, triggering the detection of latent tumor viruses capable to intensificate the cancer cell growth. Errors that occur during DNA repair in the early stages of oncogenesis seem to be the most probable mechanism that leads to cancer.

The study findings on the solar radiation influence, especially its ultraviolet component, on the skin cancer formation can be represented in the form of such associative links (WHO, 1984):

1. Link with the irradiated skin areas. In fair-skinned people, skin cancer occurs most often in the areas of the body that are most exposed to solar radiation — the head, neck, hands, forearms, legs (in women).
2. Link with the UV protection. In races with dark skin, in which the pigment filters ultraviolet radiation, skin cancer is very rare and not on exposed surfaces. Sunburn and skin cancer occur on the same tissues, and radiation is known to cause burns. People who are most liable to skin cancer can easily get sunburns. Fair-skinned people of Celtic origin are more liable to skin cancer and sunburn than people of the Romance group.
3. Link with the solar radiation dose. Among fair-skinned people, skin cancer most often occurs in those who spend more time outdoors.
4. Link with the solar radiation intensity. The incidence of skin cancer among fair-skinned people increases with the nearing to the equator. This is associated with increased intensity of solar radiation, including ultraviolet.
5. Link with ultraviolet radiation in laboratory studies. Skin cancer in mice can be caused by repeated exposure to the same spectrum of radiation that causes sunburn in humans.
6. Link with low capacity to repair DNA damaged by ultraviolet radiation. In people with a recessive form of xeroderma pigmentosum and defects in DNA repair, skin cancer develops particularly rapidly. Such people are sensitive to light, and solar ultraviolet radiation can cause tumors in them. They often die from skin cancer in early childhood and adolescence.

Case fatality rate from non-melanoma skin cancer, which is caused by ultraviolet radiation and is the most frequent, is 1 %, and this rate from malignant melanoma is more than 40 per 100.000 population.

Recently, mathematical models have been proposed that reveal the dependence of skin cancer incidence on solar ultraviolet radiation. Despite the inaccuracies, according to the optimal model, a 5 percent increase in the solar ultraviolet radiation in the erythema spectrum can lead to an increase in the incidence of skin cancer in people over 60 years of age, who are liable to it, by 15 %.

Phototoxicity leads to the skin damage by visible radiation in the presence of photosensitizers; not caused by the mechanism of allergic reaction. The mechanism of the phototoxic reaction has not been definitively clarified. It can be caused either by a photosensitizer molecule (exogenous) alone, or by a complex of chemical and cellular elements that are excited by the absorption of light, forming triplet compounds or free radicals, or both.

Photoactivated (or photodynamic) active substances, when excited, can form peroxides, oxidize the biological substrate and transmit excitation to this substrate. After that, photosensitizing molecules return to their initial state without structural changes resulting in the development of phototoxicosis. It is characterized by erythema or even edema, which appears a few minutes or hours after ultraviolet radiation. It is accompanied by hyperpigmentation and peeling. An example of such erythema is sunburn. Phototoxic erythema clinically differs from other types of erythema in the following characteristics: onset during or immediately after ultraviolet radiation exposure; erythema may be accompanied by "farinaceous formation", and disappears after 5–6 hours; pigmentation is minimal.

Types of photosensitizers:

- endogenous — due to metabolic disorders (porphyrin);
- exogenous — in the form of pharmaceuticals. Exogenous photosensitizers are classified by type of exposure:
  - through skin contact (cosmetic agents: perfumes, colognes, lotions containing essential oils and psoralen, lipstick containing a fluorescein derivative, creams and haircare products with derivatives of coal tar, some plants that cause phytophotodermatitis (such as Citrus hystrix or Persian lime), pharmaceuticals containing phenosin, sulfanilamides, halogen-substituted salicylanilides, etc.);
  - through systemic medications entering the body (thiazide-type diuretics, sulfanilamides, sulphonylureas, phenothiazines, chlorpromazine (in particular, dimethylchlorotetracycline), antibiotic (in particular, dimethyl-chlortetracycline) etc.).

The spectrum of action of phototoxic substances are in the range of 320–400 nm.

Response in humans to ultraviolet radiation exposure, in the presence of photosensitizers, can be phototoxic or photoallergic.

Photoallergy is the ability of the skin to give a reaction, usually pathological, to visible radiation alone or in the presence of a photosensitizer. In this case, the photosensitizer promotes the formation of a photohapten, which covalently binds to the corresponding carrier molecule and creates a complete antigen. The carrier may be macromolecules of protein, polypeptide, mycopolypeptide, mucopolysaccharides, etc. present in the skin.

Once developed, photoallergy can manifest itself as a reaction even to visible radiation. Apparently, a small amount of photoantigen remains in the skin and, under the influence of ultraviolet radiation with a wavelength of 320–400 nm, causes a reaction of circulating antibodies or a response at the cellular level.

Photoallergy is rare in occurrence. It is clinically characterized as an immediate urticaria or a delayed eczematous or papular reaction similar to contact dermatitis. As with phototoxicosis, photoallergy causes specific rashes.

The most common photoallergens are 3.5-dibromosalicylanilide, salicylanilide, 4.5-dibromosalicylanilide, tribromosalicylanilide, hexachlorophene, butionol, trichlorocarbanilide.

8.3. Sunlight deprivation, clinical signs, diagnosis and preventive measures

The intensity of solar radiation reaching Earth's surface depends on a large number of natural and anthropogenic factors: geographic latitude, time of year, time of day (these factors determine the solar elevation), topographic relief, air pollution, climate, weather, etc.

Cloud cover, especially when it is low with a high density, clouds, fog, high humidity, dusty or smoggy atmosphere are the factors that significantly reduce the intensity of solar radiation as a whole, especially ultraviolet radiation.

In the mountains, an increase in altitude (above sea level) affects the intensity of ultraviolet radiation — it is increased by 3–4 % per 100 m or 15 % per 1000 m. Ultraviolet radiation is significantly absorbed by regular window glass: near the open window its intensity is 50 % of the external intensity, and near the closed — 2–3 %. In pure water, the intensity of ultraviolet radiation decreases with each meter of depth by 14 %.

Clothes can block from 50 to 100 % of ultraviolet radiation: a white shirt transmits 20 %, lightweight fabrics — about 50 %. Solar ultraviolet radiation reaches a maximum intensity between 10 a.m. and 14 p.m. This period accounts for 60 %, and for the period between 9 a.m. and 15 p.m. — 80 % of the daily amount of ultraviolet radiation. A person in the shade of a house is exposed to less diffused radiation from half the sky, which is equal the intensity of the total solar radiation.

Prolonged sunlight deprivation or its insufficiency due to geographical, seasonal, atmospheric and other specifics of the settlement, the nature of work activities, diseases, etc. leads to the development of syndrome of ultraviolet insufficiency or sunlight deprivation.

Sunlight deprivation is manifested by the following abnormalities:

- stunted growth and development of children;
- aberration of phosphorus-calcium and mineral metabolism;
- skin capillary fragility;
- the presence of fresh cases of rickets;
- dental caries development;
- decreased activity of oxidative enzymes (succinate dehydrogenase, myeloperoxidase, glycerophosphate dehydrogenase);
- decreased complement-fixing titer, phagocytic activity of leukocytes, and acid stability of erythrocytes
- degradation of immunologic reactivity indicators;
- abnormality of a disease course;
- increase in blood lipolytic activity, reflex excitability, pain sensitivity;
- suppression of bile acid synthesis in hepatocytes;
- weakening of inhibitory processes in the central nervous system.

To diagnose an ultraviolet insufficiency, various methods are used that reflect the metabolic condition and take into account the medical history. In view of this, the sensitivity of the skin to ultraviolet radiation, the activity of serum alkaline phosphatase, the content of inorganic phosphorus and ascorbic acid in the blood are determined. The most probable indicator of ultraviolet insufficiency is an increase in the activity of alkaline phosphatase, which originates from osteoblasts or hepatocytes, placental cells and adrenal glands. It is involved in the adenosine triphosphoric acid and phospholipid metabolism.

At different latitudes of the Earth, the ultraviolet supply of the population is different. The total annual number of erythema doses of natural ultraviolet radiation is 911 at the latitude of Kyiv, 2200 — Vinnytsia. The farther north the area of residence is situated, the longer the period of UV radiation shortfall. In the northern latitudes, severe climatic conditions force people to wear

warm clothing, through which solar radiation does not penetrate, for almost the whole year round. This fact in combination with the natural ultraviolet deficiency increases sunlight deprivation. Natural causes come with anthropogenic: air pollution by dust, smoke, soot, mining works, confined space works, night shifts, ill-designed planning of residential and public premises, insufficient size of windows and glass, the use of window glass that absorbs 90–95 % of ultraviolet radiation, the use of window blinds, curtains, drapes, painting the walls of the premises yellow. All these conditions increase sunlight deprivation.

Recently, healthcare practice includes the implementation of ultraviolet deficiency prevention. Accumulated experience in the use of ultraviolet radiation is turned to improve performance, prevent occupational diseases, compensate for the ultraviolet deficiency among employees, improve the living conditions and kind of work that leads to sunlight deprivation, and improve the health and performance of athletes.

To compensate for the ultraviolet deficiency, the natural ultraviolet radiation is primarily used (even in the cold season and at low solar elevation). In this regard, the following measures are carried out: cleverly designed layout of premises and settlement development providing at least three hours of insolation through windows of all living spaces, increase in insolation for indoor space using window glass transparent to solar ultraviolet radiation, use special shielded trestle beds (couches) or cabins with polyethylene coating. In this case, it should be taken into account that the biological effectiveness of solar radiation in the North is 2–4 times lower than in the South.

During periods of "biological darkness" (solar radiation has no ultraviolet rays) or "biological twilight" (at noon the intensity of the total erythemal flux of ultraviolet rays as a part of solar radiation does not exceed 10–12 mer/m^2), ultraviolet irradiation by artificial radiation sources (sunlamps or erythema lamps) is conducted. For this purpose, photarium is created (Fig. 8.3, Fig. 8.4), and sunlamps are inserted in the device for lighting, especially in child welfare institutions, industrial enterprises. A positive effect of ultraviolet irradiation of children with selective fluorescent sunlamps was obtained.

During preventive irradiation, erythema irradiation levels are determined by the daily dose, which is 0.125–0.75 minimal erythema doses. This is the so-called "preventive" dose of ultraviolet irradiation. Some researchers identify the ultraviolet irradiation optimal dose equal to 0.5 MED.

Due to its health-promoting effects, ultraviolet radiation is widely used in the practice of health care facilities, in animal husbandry, plant growing.

8.4. The use of solar radiation for the prevention and treatment of diseases

A considerable amount of information indicates that irradiation with ultraviolet radiation of natural (as part of solar radiation — an important element of human habitat in the process of ontophylogenesis) and artificial origin (in photariums) (Fig. 8.3 and 8.4) has a positive effect. Its preventive effect is especially important in relation to the most common and life-threatening diseases of the blood circulatory system. Experiments proved that in animals that received a preventive regimen of ultraviolet radiation of natural and artificial origin, the course of experimental renal hypertension, myocardial infarction, coronary heart disease, myocarditis and other diseases of the circulatory system differs markedly from the course of similar diseases in unirradiated animals of control group. Due to the ultraviolet optimum, the animals had a delayed increase in arterial tension (hypertension reached a maximum later in 0.5–1 month), the maximum values of which were 20–40 % lower than in the animals of the control group; mortality in the case of myocardial infarction was 2–3 times lower, the pulse rate was much less rapid, the parameters of the electrocardiogram, tissue respiration in the myocardium, etc. changed.

In people with diseases of the circulatory system, after preventive ultraviolet radiation, the following positive changes were observed: the recovery of excitation–inhibition ratio in cerebral cortex, improvement in a functional status of autonomic nervous system, positive changes in the activity of a series of enzymes, increase in content of hemoglobin in blood, decrease in arterial tension in the case of hypertension, improved indicators of the functional status of the cardiovascular system, reduction in anginal attack, hypertensive crisis, myocardial infarction and stroke cases, normalization of lipid, mineral and especially phosphorus-calcium metabolism and permeability of cell membranes, increase in anticoagulative blood function, etc.

However, the positive effect of ultraviolet radiation can be achieved mainly in health resort conditions and only in patients with uncomplicated diseases. In these conditions, 5–7 % of people with circulatory system dis-

eases can be accommodated and then only for 24 days a year. Therefore, there is a need to introduce into the practice of health care (cardiology health centers and clinics) for the preventive purpose of available and effective practices of preventive ultraviolet irradiation of natural and artificial origin for persons with cardiovascular diseases (while at home or in usual work conditions).

Helioprophylaxis of diseases of the circulatory system in Ukraine using natural ultraviolet radiation. The territory of Ukraine in the context of the solar radiation intensity (both integrated flux and its ultraviolet component) belongs to the zone of ultraviolet comfort. This zone is located between 57.5 and 42.5° north latitude. There is no "biological darkness", which is characterized by the complete absence of biologically active short-wave ultraviolet radiation.

"Biological twilight" with minimal, inefficient values of bioactive solar radiation is observed only in the northern regions of the zone during December — January. Biologically active solar radiation is detected in the southern regions of Ukraine throughout the year.

Thus, on the territory of Ukraine, helioprophylaxis of hypertensive disease may be necessary in the northern regions during March — October, and in the southern regions during February — November.

In the process of sunbathing, the human body receives direct, scattered (in the atmosphere) and reflected (from surrounding objects, surfaces) ultraviolet (1 % of the solar spectrum), infrared and visible radiation (99 %). This process is also influenced by physical factors of ambient air (temperature, humidity, air velocity) and objects (radiation temperature). Therefore, such baths are solar-air, and the period of mass primary ultraviolet prevention of natural origin, carried out outside of special health resorts, is limited to June — August in the northern regions of Ukraine and May — September — in the southern regions.

Sun-air baths are taken in aerosolariums and on health resort beaches with the eliminated conditions of hypothermia or thermoplegia and the radiation equivalent-effective temperature in the range of 16–30 °C.

During primary prevention, a person lay down on a couch (trestle bed) which oriented along the flow of direct solar radiation. The head should be in a shadow from a special sunshade or sunawning, and the eyes should be protected with smoky lens sunglasses. In the northern regions, when the Sun is above the horizon, people can take sun-air baths in the upright position.

Irradiation should be carried out after a light breakfast, but not in the fasted state or immediately after a heavy meal. Reading or sleeping during irradiation is not recommended. The dose of erythema irradiation should be evenly distributed between the anterior, posterior and lateral surfaces of the body. Solar preventive irradiations should be preferably carried out in the morning and in the evening. It is possible to combine sunbathing with sports games and physical exercises. After irradiation, a person should rest in the shade.

Primary helioprophylaxis of diseases of the circulatory system is provided in doses. Considering the small doses of ultraviolet radiation required for secondary prophylaxis and the fact that patients can receive these prophylactic doses in the summer while staying outdoors for 40–60 minutes, secondary helioprophylaxis of these diseases is not performed.

Preventive ultraviolet irradiation of artificial origin. To prevent sunlight deprivation by ultraviolet radiation of artificial origin, various irradiators ("solariums" — photariums) are used, in which the source of ultraviolet radiation is a sunlamp (erythema lamp). Such lamp does not generate undesirable short-wave ultraviolet radiation — shorter than 285 nm (Fig. 8.3 and 8.4).

The method of ultraviolet irradiation is the same for any type of irradiators. After determining the erythema dose, irradiation is performed according to the following regimen under the constant conditions. The irradiator is placed over the couch, on which the person lies during irradiation, at a distance of 50 cm from the irradiated surface (back or abdomen). If after determining the MED there is a need to change the distance from the lamp to the irradiated surface, then the appropriate calculations is performed.

After placing the person on the couch and turning the irradiator away from him/her, the lamp should be connected to a power supply (power switch) and turned on. Irradiation should begin by turning the irradiator toward the irradiated surface, 10–15 minutes after the lamp is turned on, when the irradiation mode is set, the maximum radiation of the lamp will be reached and the filaments will heat up — sources of infrared radiation. This enhances the favorable effect of ultraviolet radiation.

The skin on the abdomen and back should be subjected to ultraviolet radiation treatment. To perform this procedure, a room space is required to be well-ventilated for easy removal of ozone, which is formed during the process. Personnel in the room during irradiation and the irradiated person should protect their eyes with tinted glasses.

Considering, that the irradiated person is dressed in light underwear, the parameters of room's microclimate



Fig. 8.3. Horizontal photarium. Source: *bombia.eu*



Fig. 8.4. Vertical photarium. Source: *sunkiss.lt*

should be observed during irradiation: air temperature — 20–22 °C, air humidity — 40–60 %, air velocity — about 0.3 m/s, radiation temperature — 18–22 °C.

Ultraviolet radiation dosage. There are several methods of UV radiation dosing (conditions considered):

1. Duration of irradiation, min.
2. Intensity of ultraviolet radiation, W/m^2.
3. Individual sensitivity of the skin to ultraviolet radiation (by the means of special devices).

For primary and secondary prevention of diseases during dispensary observation of diseased and healthy people who are in usual working and living conditions, it is better to dose the radiation in minutes, calculated by determining the erythema dose of ultraviolet radiation. Erythema dose is the minimum dose of ultraviolet radiation, which is expressed in minutes of irradiation, which after 8–20 hours on the skin of a non-tanned person will cause a mild, even and distinct erythema (threshold erythema).

With a view to determine the minimal erythema dose (MED), a biodosimeter DB-2 is used, proposed by I. F. Gorbachev and D. Dalfeld.

The general regimen of ultraviolet prevention is on the example of the circulatory system diseases (Table 8.8). For primary and secondary prevention of cardiovascular diseases, ultraviolet radiation cycles are performed 3–4 times a year. The duration of each cycle is one month, and the intervals between cycles are 2–3 months. Given the seasonal biological dynamics of exacerbation of these diseases, preventive cycles of ultraviolet irradiation should be provided in October, December, February, and April. In the warm season, the erythema dose can be obtained at noon in 15–20 minutes.

Therefore, to obtain a preventive dose of ultraviolet radiation equal to 1/8–1/2 of the erythema dose for a person dressed in light clothing that transmits 20–60 % of the Sun's ultraviolet radiation, it is sufficient to spend 30–60 minutes outdoors at noon.

Since the helioprophylaxis scope is limited by the warm season, the main method of prevention of circulatory system diseases is the ultraviolet irradiation of artificial origin.

After the erythema dosage for a particular person in specific conditions of irradiation in the above-mentioned months of "biological twilight", appropriate cycles of primary and secondary prevention are conducted. The anterior and posterior surfaces of the body should be irradiated (half the calculated dose for each surface). In some cases, irradiation should be started with a reduced and gradually increasing erythema dose: increased skin sensitivity to ultraviolet radiation observed in the spring,

Table 8.8. Prevention of the circulatory system diseases under the effect of ultraviolet radiation (min)

Preventive regimen days	Primary prevention	Secondary prevention
1	1/8	1/10
2	1/8	1/10
3	1/8	1/10
4	1/4	1/8
5	1/4	1/8
6	Rest	Rest
7	1/4	1/8
8	1/2	1/6
9	1/2	1/6
10	1/2	1/6
11	3/4	1/6
12	Rest	Rest
13	3/4	1/4
14	3/4	1/4
15	1	1/4
16	1	1/4
17	1	1 /4
18	Rest	Rest
19	11/2	1/2
20	11/2	1/2
21	11/2	1/2
22	11/2	1/2
23	11/2	1/2
24	Rest	Rest
25	2	1/2
26	2	1/2
27	2	1/2
28	2	1/2
29	2	1/2

prolonged absence of UV radiation (work in the North), some diseases including those accompanied by elevated level of bile pigments and hematoporphyrin in blood, long-term use of some pharmaceuticals (iodine pharmaceuticals, sulfanilamides, antibiotics and mercury-containing substances).

As the body's need for ascorbic acid increases during ultraviolet radiation, it is necessary to prescribe vitamin preparations (ascorbic acid, multivitamins) for irradiated person at the rate of 150 mg of acid per day. The effectiveness of ultraviolet irradiation is furthermore increased if cholecalciferol previtamins (as part of multivitamins), calcium and phosphorus pharmaceuticals or products that contain them in sufficient quantities (milk, cheese, egg yolk, etc.) is used.

Primary UV prevention is carried out in apparently healthy humans of various ages, affected by circulatory disease risk factors (genetic predisposition, neurasthenia, hypercholesterolemia, chronic psychoemotional trauma, kidney disease, eclampsia, exanimation or blast injury in the past, endocrine disorders, hypodynamia, overweight, smoking, abusive drinking behavior, etc.).

Contraindications to primary ultraviolet prophylaxis are acute phase or exacerbation of internal diseases, pulmonary tuberculosis in the active phase, eczema in the exacerbation period, hemorrhagic tendency, toxic diffuse goiter, renal tuberculosis, glomerulonephritis, malaria, stage III circulatory failure, malignant tumor, cachexia, photosensitivity.

Secondary prevention of ultraviolet radiation is carried out in patients with disease incipience in remission period. Contraindications to secondary ultraviolet prophylaxis are the disease exacerbation in the form of hypertensive crises, frequent angina attacks, acute progression of cerebral accident (stroke), myocardial infarction, sharp deterioration of health, headache, increase in arterial blood pressure (above normal levels) and other symptoms indicating a deterioration in the patient condition, as well as all the above contraindications to the primary ultraviolet prevention of the circulatory system diseases.

Obligate principles of primary and secondary ultraviolet prevention are rational medical examination of patients, medical supervision over irradiation process, continuity in the work of hospital-based and family physicians, well-timed cessation of irradiation in case of complications, optimization of the whole set of measures, especially in the secondary disease prevention — work-rest distribution, sensible nutrition, preventive and conservative treatment on an outpatient basis.

The application of a method of natural and artificial ultraviolet irradiation in a set of therapeutic measures and its proper organization are important factors of primary and secondary disease prevention.

8.5. Use of solar and artificial ultraviolet radiation for sanitation of air, water and objects

Ultraviolet radiation has been successfully used to reduce the number of microorganisms, especially in indoor air. Due to the effect of ultraviolet radiation under the condition of efficient air circulation, bacterial contamination of the premises is reduced by 70–90 % and more. This requires the radiation energy to be equal to 1.5–6 μW / m^2. Ultraviolet radiation with a wavelength of 250–270 nm is most effective for inactivation of microorganisms. The bactericidal effect of radiation is manifested at a distance of not more than 2 m at a relative humidity of 40–70 %. In the case of high humidity, the efficiency of radiation decreases. On dark surfaces treated with ultraviolet radiation, microorganisms remain 10–20 % more than on light ones. In the shade, for example, under the table board or on the back of the tool, ultraviolet radiation has no influence. It penetrates into the upper layer of liquid and begins to irritate the eyes and skin a few minutes after the start of irradiation. After 2–6 hours, acute conjunctivitis is developed in the irradiated person. It takes 5 to 6 hours to eliminate such inflammatory state. It should also be taken into account that ultraviolet radiation causes ozone formation. Ozone is a factor of adverse effects and toxic even in small concentrations. Therefore, in healthcare facilities, medical staff need to use devices without forming ozone.

There are direct and indirect ultraviolet irradiation. For direct irradiation, ultraviolet irradiators are mostly installed in the upper third of the room. They are fixed relatively close to the workplace and pointed towards the floor. Indirect irradiators are pointed towards the ceiling.

Only persons in protective glasses and clothing are allowed to remain in the room during direct irradiation. Therefore, direct irradiation is most often performed at night, for example, in surgical units, in the infant-feeding units, in the waiting room and in physician's offices (when there is no care encounter), in microbiological laboratories, in rooms for bottling of serums, vaccines, antibiotics and other pharmaceuticals or in boxes of tissue preservation. Ultraviolet radiation primarily damages the air

microorganisms. As a significant part of microorganisms that fly in the air settles without artificial ventilation after 4 hours, it is recommended to turn off ultraviolet irradiators only 4 hours after the start of their use. The effect of ultraviolet radiation should not be exaggerated.

Calculation of the optimal number of ultraviolet irradiators for the premises depends on their size and power.

Direct ultraviolet radiation is also carried out in the form of ultraviolet gateways. An ultraviolet "curtain wall" about 30 cm wide prevents the circulation of microorganisms in air between two rooms or between separate sections of one room.

An ultraviolet irradiator can also be used to reduce the number of microorganisms in the circulating air. The air is sucked out of the room, irradiated and through the filters is fed back into the room. Such ultraviolet recirculators are now widely used in premises with throngs of people (for example, in kindergartens, etc.).

To prevent indoor air pollution by air conditioners, the water must be kept clean in them. Currently, this is the main problem during the operation of air conditioners. However, air conditioners after mechanical treatment contain 10^4–10^6 microorganisms in 1 ml. None of the studied disinfectants based on chlorine aldehydes or amphotensides significantly reduces the number of microorganisms in the water of air conditioners. There were moreover cases of irritation of the mucous membranes by air from air conditioners. Ultraviolet irradiators, which were placed in the path of water circulation between the pump and the treatment chamber, allow reducing the number of microorganisms for several months in the case of systematic monitoring of the technical condition of air cleaners, underwater channels and filters.

Ultraviolet irradiators are used for the treatment of filter surface, covered with dust or clean, to trap microorganisms from the air in equipment with turbulent and conventional ventilation. The filter must be irradiated for two hours per day for the purpose. Ventilation equipment at this time continues to work.

Ultraviolet disinfection of clothing, such as white coats placed in the ultraviolet gateways, is ineffective. At the same time, ultraviolet irradiators successfully reduce the contamination of magazines and other literature in health care facility premises, such as waiting rooms. However, each sheet should be irradiated, and it takes a lot of time.

Ultraviolet irradiators must always be clean, because the layer of dust in them significantly reduces the energy of radiation. They need to be replaced after 76.000 hours of operation, i.e. about 10 years after daily four-hour operation. If this period of operation has been exceeded, such ultraviolet irradiators cannot effectively reduce the number of microorganisms in the air, even by reducing the distance from the radiation source to the irradiated object. Therefore, in this case, it is possible to increase the radiation intensity only by increasing the duration of the irradiation or changing the irradiator.

To evaluate the effectiveness of ultraviolet radiation, the microbial inoculation of the air is performed before and after irradiation. It helps to determine the degree and ratio of efficiency. Air sanitation is considered effective if the degree of sanitation efficiency (percent decrease in the number of microorganisms in 1 m^3 of air after ultraviolet irradiation) is not less than 80 %, and the ratio of efficiency, which shows how many times the number of microorganisms was reduces per 1 m^3 of air, is not less than 5.

Bactericidal effect of ultraviolet radiation is widely used for disinfection of tools, dishware, toys, water (Fig. 8.5–8.9), food, viral inactivation in the vaccine production.

Solar ultraviolet radiation is an extremely important factor in the self-purification of atmospheric air, water of natural reservoirs.

8.6. Adverse consequences of human excessive insolation and their prevention

Prolonged exposure to ultraviolet radiation from the Sun or artificial sources in doses significantly exceeding the



Fig. 8.5. Ultraviolet water disinfection system. Source: *process-cooling, com*



Fig. 8.6. Sanitation of air in the operating room with suspension bactericidal lamps



Fig. 8.7. Sanitation of air in the operating room with vertical mobile bactericidal irradiators

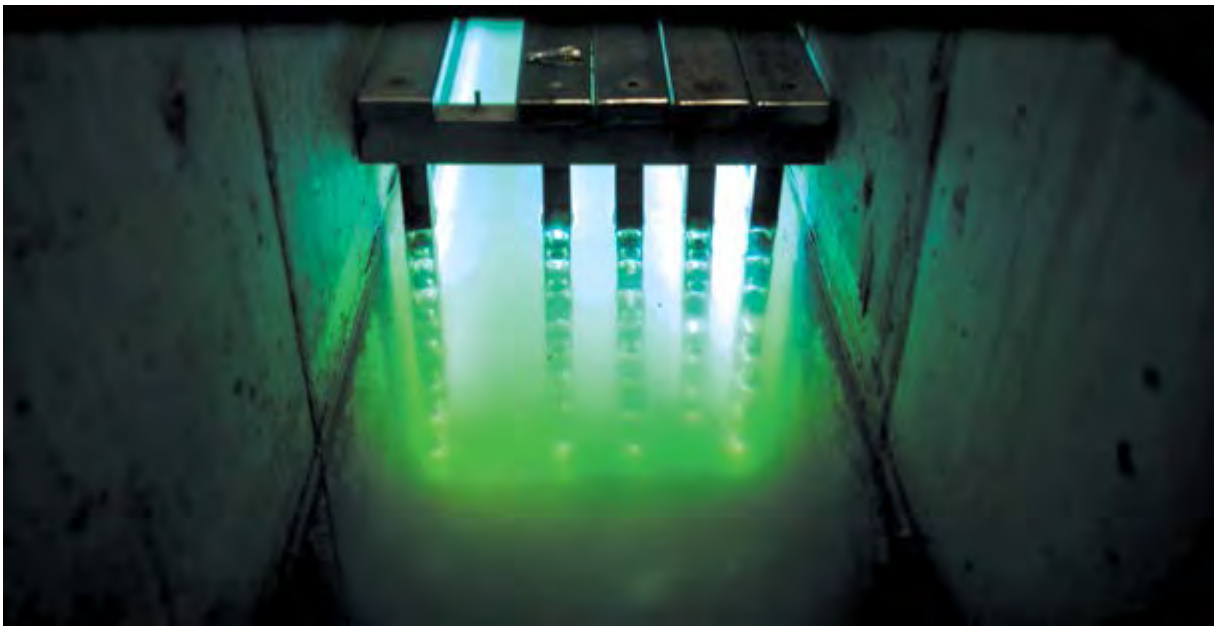


Fig. 8.8. Ultraviolet water disinfection system. Source: *mlive.com*



Fig. 8.9. Ultraviolet water disinfection system. Source: *kyst.no*

threshold dose of erythema radiation causes burns, dermatitis, alteration, collagen degradation, development of erosions, ulcers, benign and malignant tumors (of epidermoid and mesenchymal origin) (Table 8.9). Ultraviolet radiation in the region of 280–340 nm has a carcinogenic effect. However, if the shielding effect of the stratum corneum is weak, radiation with a wavelength of 365 nm also shows carcinogenic activity.

The development of malignant tumors is possible only when the initial erythema dose is 40 or more times

Table 8.9. Adverse reactions of the person at re-irradiation by components of a solar spectrum

Type of radiation	Adverse reactions to excessive irradiation
Infrared	Sunstroke, heat stroke, burns in acute irradiation; cataract due to chronic irradiation
Visible	Sunstroke, blinding, photodermatitis due to acute irradiation; photodermatitis, eczema, hyperkeratosis, skin cancer due to chronic irradiation
Ultraviolet	Ultraviolet erythema, photoophthalmia, electroophthalmia, burns, photodermatitis, exacerbation of chronic diseases due to acute irradiation; exacerbation of chronic diseases, photodermatitis, eczema, hyperkeratosis, skin cancer due to chronic irradiation

higher than the MED and continues to increase beyond the adaptation of organism. Based on this, it can be concluded that there are no grounds for adverse effects of preventive ultraviolet radiation.

8.7. Hygienic importance of solar radiation

Summarizing the above, we can conclude about the considerable hygienic value of solar radiation for the planet Earth:

1. The corpuscular flux of the "solar wind" forms three radiation belts around the Earth.
2. Fluctuations of the "solar wind" during the "active Sun" determines the increase in the activity of the Earth's magnetic field, i.e. the occurrence of geomagnetic storms and pulses.
3. Infrared rays of solar radiation provide the planet Earth with vital climatic conditions.
4. Visible rays of solar radiation due to the processes of photosynthesis provide the formation of oxygen and nutrients (proteins, fats, carbohydrates, vitamins) vital for animals and plants.
5. Visible rays of solar radiation provide a human with 80 % of information about the environment.
6. According to the theory of Academician M. O. Oparin, life on the planet Earth originated due to the combined action of infrared, visible and longwave ultraviolet rays of solar radiation, the accumulation of mineral "coacervates" in the "primordial soup".
7. Long and medium ultraviolet rays of solar radiation in regions A and B provide biogenic effects on the human body: pigment-forming, general stimulating and vitamin-forming.
8. Short ultraviolet rays of region C, X-rays and gamma rays provide abiogenic (abiotic) biological effect on living organisms: bactericidal, virucidal, carcinogenic, embryotoxic, teratogenic, phototoxic, photoallergic, ionizing (radiation sickness), etc.

9 CHAPTER HYGIENIC IMPORTANCE OF WEATHER. HYGIENIC ASPECTS OF PREVENTION OF HELIOMETEOROTROPIC REACTIONS

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Throughout the ages, people have shown interest in the weather, because both well-being and human life have depended on it. The weather and climate effects have been various. For example, the harsh and dramatic nature forces destroyed homes, caused field erosions and crop destructions. People cursed storms and hurricanes, which took hundreds and thousands of lives, and, in contrast, basked in the warm of early spring, thanked nature for fertile summer and heaven-sent rains that are vital for crops.

Since the earliest times, human has tried to control the weather by praising and, at the same time, conjuring it. Harsh weather was attributed to the evil will of the gods.

Sorcerers of primitive tribes were the mediators between tribe and gods. They were rainmakers and tried to make the turbulent weather quiet. In a case of a long-duration drought, the sorcerer imitated the rain by sprinkling water and even imitated the wind howling. Although the rituals of tribes were different, the essence was the same. For example, a pit was dug on a flat surface for rituals in the center of the tribal settlement. Some sacred animal was placed in it. Most often it was a dog. The animal was buried in the ground so that the head was above the surface. Hot water or oil was poured into the ear. The poor animal was howling with pain. People wanted the rain god to hear the howl of the animal, weep with pity, and abundantly watered the ground with the long-awaited rains.

Ancient peoples had their gods of weather. In Greek mythology, this was Zeus, the supreme god of Olympus. A thunderclap was considered as a sign given by Zeus before sending rain. During a long-duration drought, the Greeks came to the Acropolis and prayed Zeus for rain. The Roman "twin" of Zeus was the god Jupiter. The Romans worshiped Jupiter as the god of rain and thunder. Other ancients also had their own gods of rain and thunder. Among the Scandinavians it was Thor, and among the early Slavs — Perun (the god of thunder).

And it seems that human should be ease at adaptation to the weather, foresee and even change it. However, this is not the case.

People judge the weather not by books and textbooks, but from their own experience — how it affects their daily lives, how they perceive its whims. People's judgments about the weather largely reflect the individual differences of a person's response to the environmental conditions and are often subjective. At times, virtually all of us are concerned with the weather. It is a permanent talking point, but we know by no means everything about it.

9.1. Weather and its definition

Natural factors (weather and climate), in which the human has been evolved, constantly and variously influence the life of each person and humanity as a whole.

The first mention on the biotropic effects of climate and weather on the human body are found in ancient literature: since ancient times (Hippocrates, Galen, Celsius) it is known that the onset, course and solution of many diseases depend on climatic conditions. There were also evidences of about the use of climatic and weather factors for therapeutic and prophylactic purposes. In the Treatise on *Airs, Waters, and Places*, Hippocrates (4th century BC) pointed out that: "Whoever wishes to pursue properly the science of medicine must proceed thus. First he ought to consider what effects each season of the year can produce; for the seasons are not at all alike, but differ widely both in themselves and in the influence on a diseased person during their changes". Hippocrates made periodic meteorological observations and kept terms with meteorologists and astronomers. In his seven books on epidemic diseases, he considered the role of meteorological conditions before describing each specific disease.

The ancient Greek physician Diocles of Carystus (4th century BC) has divided the year according to weather conditions into six periods, during each of which there should be a different way of life. The renowned rhetorician and physician of ancient Rome Asclepius of Bifinia (2nd century BC) believed that weather conditions should be taken into account in a case of bloodletting. Aulus Cornelius Celsius (1st century BC) advised to swap the climate in event of certain diseases for warmer one (in each case of disease), and Galen (2nd century BC) recommended the use of climates of mountains and deserts for the treatment of lung diseases.

In the Middle Ages and the Renaissance, bioclimatology knowledge were developed in Europe. In some legal systems of the 9th century (Frisian laws) and the 13–14th centuries (East Frisian laws) imposed a heavy fine on people guilty of bodily damage if the inflicted wounds left weather-sensitive scars after healing. The papers of P. Hohenheim (Paracelsus — 16th century), T. Sydenham (17th century), K. Leibniz (18th century), K. Humboldt, K. Gufeland, M. Schonlein, S. P. Botkin, P. Ackermann, M. Pettenkofer (19th century), D. Missenara, P. Dorno, O. L. Chizhevsky, M. Pettersen, P. de Rudder, M. M. Voronin, D. Assman, G. P. Danishevsky, B. V. Bogutsky, M.O. Gavrikov (20th century) contain information about the influence of weather and climate on the course of somatic and epidemic human diseases.

Recently, medical science and practice are increasingly focused on the various aspects of human ecology, including natural factors such as weather and climate. There are consequently separated special sciences: medical geography, bioclimatology, biometeorology, heliobiology, balneology, etc. It is understood that the use of these sciences in medical practice will provide an effective assistance in the treatment and prevention of cardiovascular, nervous, respiratory, infectious and other diseases.

Weather is a set of physical and chemical properties of the surface layer of the atmosphere in a relatively short period of time (hours, days, weeks).

Thus, the weather is a variable phenomenon.

9.2. Weather-forming environmental factors

Weather is considered as a holistic natural phenomenon, which is formed due to the relationship of natural and anthropogenic factors. Weather-forming *natural factors* are the solar radiation, underlying surface, circulation of air masses and ocean circulation. *Anthropogenic factors* play a certain role in the formation of weather: air pollution, deforestation, creation of artificial water reservoirs, agricultural hydraulics and land reclamation, irrigation, etc.

9.3. Weather characteristic factors

The weather is characterized by an aggregate of the following phenomena and factors:

1. Heliophysical:
   - *Solar radiation intensity:*
     - total and erythemal UV radiation;
     - sunshine duration.
   - *Solar activity:*
     - sunspots;
     - active regions;
     - chromospheric flares;
     - ionizing radiation.
2. Heophysical:
   - geomagnetic field density;
   - geomagnetic activity;
   - geomagnetic storms and impulses.
3. Electrical state of the atmosphere:
   - atmospheric electric field density;
   - electrical conductivity of the air;
   - atmospheric ionization;
   - electromagnetic oscillations (atmospherics).
4. Meteorological:
   - air temperature;
   - air humidity;
   - atmospheric pressure;
   - wind speed and direction.
5. Synoptic:
   - cloud coverage;
   - precipitation.
6. The chemical composition of the surface layer of the atmosphere:
   - oxygen concentration;
   - carbon dioxide concentration;
   - air pollution load.

9.4. Overall scheme of weather formation on the planet Earth

Solar energy reaching the Earth is distributed as follows: about 19% is absorbed during passage through the atmosphere, about 34% is reflected back into space from

the upper surface of clouds and the Earth's surface, the remaining 47 % (after some scattering) is absorbed by the Earth's surface and converted into heat (Fig. 9.1). Thus, a fifth part of solar energy directly heats the atmosphere, but the major part of the energy that heats the atmosphere comes from the heated Earth's surface.

The atmosphere unevenly heats up in different parts of the globe (depending on latitude): the greater the distance from the equator to the pole, the greater the angle of inclination of solar radiation to the plane of the Earth's surface, and hence, less energy per unit surface area, and less heating. The atmospheric heating also depends on the nature of the underlying surface: the water of the oceans or seas, continental ground, bare ground, verdure ground, snow surface of the Polar Regions, terrain relief and other factors.

This distribution of solar thermal energy has led to the formation of a belt of extra warmed up surface at the equator of the Earth, and extra cold — at the poles. If the heat was not moving (with water and air masses) from the equator to northern latitudes, the winter temperature near the Earth's surface at the poles would be –90 °C. The temperature of middle latitudes would be much lower. Evaporation, which increased by 1/3, and heat release during condensation, which increased with the same extent, would turn the equator into a zone of severe thunderstorms, tropical downpours and hurricanes. However, due to strong sea and air currents there is a redistribution of equatorial heat on the Earth's surface. Under the influence of trade winds, water moves along the equator forming the Equatorial ocean current. Moving from the west coast of Africa, it carries water to the east coast of America, where it splits into two branches: the Gulf Stream, which moves to the northeast, and the South American, which moves along the coast of South America. In the Pacific Ocean, there are only the peninsulas of Asia and the Sunda Isles on the path of the Equatorial current, so the northern branch (the Kuroshio Current), is stronger. There are also cold currents (the Labrador Current).

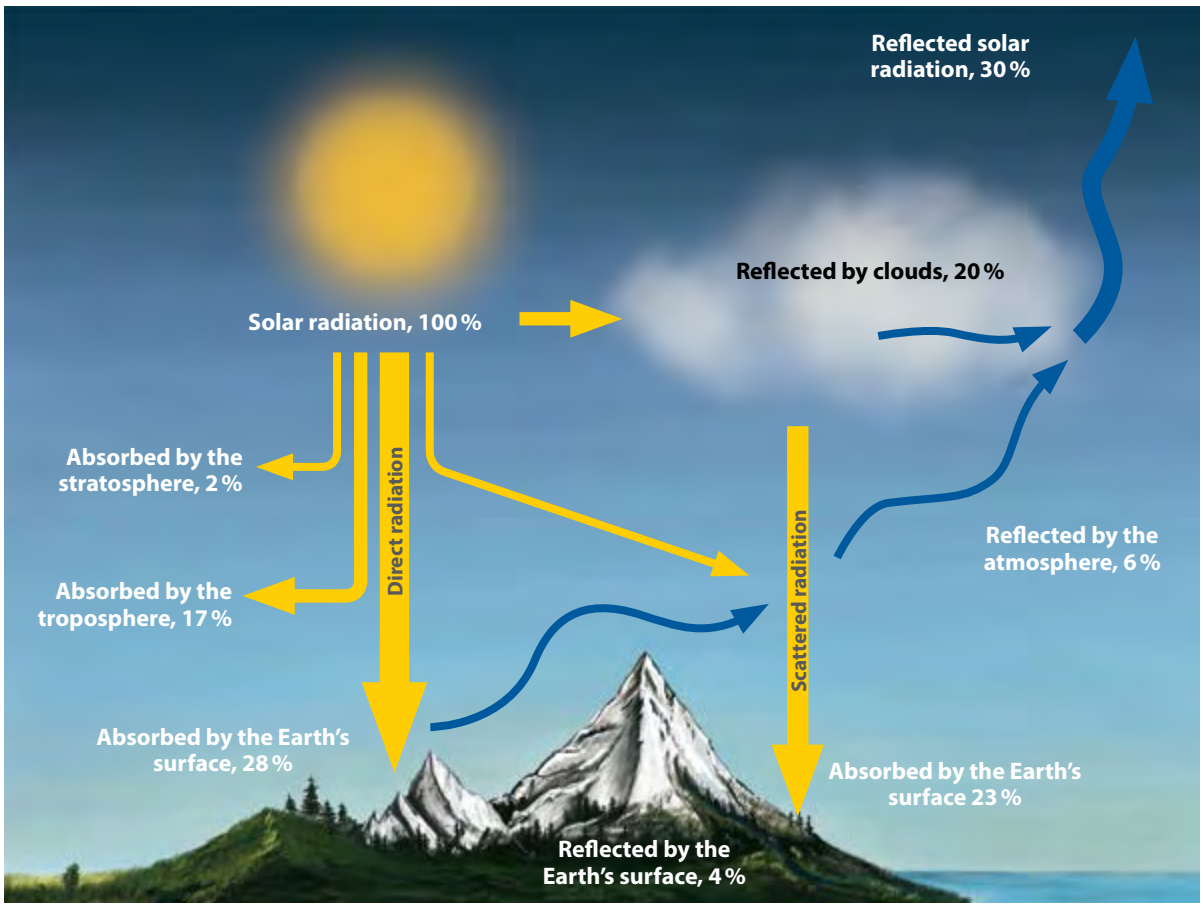


Fig. 9.1. Distribution of solar radiation between the Earth and the atmosphere

Ocean currents have a significant impact on the formation of climate and weather in almost all parts of the globe.

Equally important is the planetary atmospheric circulation, which is much more complex than the oceanic. The equator receives the most amount of solar heat. This is the place where the surface of land and ocean heats up more than in other latitudes. At the poles, due to the small ingress of solar heat and its significant reflection by snow and ice fields, the air is the coldest.

The peculiarities of the temperature distribution in the troposphere cause a low-pressure area to be formed in its lower layers near the equator and a high-pressure area — near the poles, while in the upper layers of the troposphere the pressure distribution is reversed. As a result, in the high layers of the troposphere, the atmospheric pressure changes significantly in the direction from the equator to the poles, and the most — in the middle latitudes of the temperate climate.

If the Earth was stationary, the air in the upper troposphere would move to the poles, and in the lower — would return back to the equator. There would be a closed circulation between the equator and the poles. However, the force of the Earth's rotation (the Coriolis force) diverts air masses in the Northern hemisphere to the east, and, at approximately 30° latitude, south wind changes direction and becomes westerly. In the area between 30° and 40° north latitude, air masses move down and form a subtropical high-pressure zone.

The baric gradient, which consequently increases in the lower layers of the troposphere, between the subtropics and the equator, causes an airstream directed to the equator, which is also affected by the divertive force of the Earth's rotation. Thus, in the northern hemisphere, an air current of northeastern and eastern directions is formed — the northeastern trade wind. This trade wind, along with the Coriolis force, predetermines the ocean currents mentioned earlier. Between the subtropics and the equator, a closed regional circulation is formed, which is also relating to trade winds.

Between the subtropical zone and the high-pressure polar region formed by cold air, a low-pressure zone (baric depression) appears in temperate latitudes. From both the pole and the subtropics, the pressure decreases toward temperate latitudes. Therefore, the subtropical air masses are directed to temperate latitudes, and, under the influence of the divertive force of the Earth's rotation between 40° and 60° north latitude, there is a clearly formed zone of westerly winds (or westerlies).

Masses of air entering the temperate latitudes of the northern hemisphere from the Arctic Basin (or North Polar Basin) also deflect and appear between 65° and 70° north latitude already in the form of northeast and even east winds (or easterlies). In temperate latitudes, the coming air masses rise to the high layers of the troposphere, where they move in the opposite direction partly to the high-pressure polar zone and partly to the subtropical zone. Thus, there are two closed circulations — circulation of polar latitudes and circulation of temperate latitudes.

Different closed circulations, bumping into each other more or less closely, form a general circulation, called planetary circulation (Fig. 9.2). In the upper atmosphere, the general circulation has a rather complex structure. However, the presented scheme is sufficient to understand the meteorological processes (described below).

9.5. Air masses. Weather fronts, cyclones, anticyclones

The atmosphere consists of separate air masses, which are part of the surface layer of the atmosphere and extend over an area of tens, hundreds or more square kilometers. Each air mass is characterized by a combination of meteorological conditions. Under certain conditions of radiation, air masses with certain properties are formed over a homogeneous underlying surface. These properties are the temperature, humidity, pressure, etc. They change rapidly at the boundary of two different air masses. Accordingly, there are warm and cold, dry and humid, marine and continental air masses. Thus, the following air masses are distinguished by the four main geographical zones of their formation: arctic (or polar), temperate (or middle), tropical and equatorial. Furthermore, there are also marine and continental air masses, depending on the source region — over sea or terrestrial area.

Due to the uneven heating of different areas of water plane and land, topographic features, Earth's rotation and other factors, air masses are constantly moving. These factors change the air masses that were previously over the certain area, and, therefore, cause a change in weather.

Polar air masses are cold and dry at any season of the year, tropical — warm and humid. Marine air masses are moderately cold in summer and relatively warm and mild in winter, but they always has high humidity. Continental air has the opposite particularities. The gas composition of air masses also differs. The polar air is extremely pure, and tropical air contains many solid particles, including

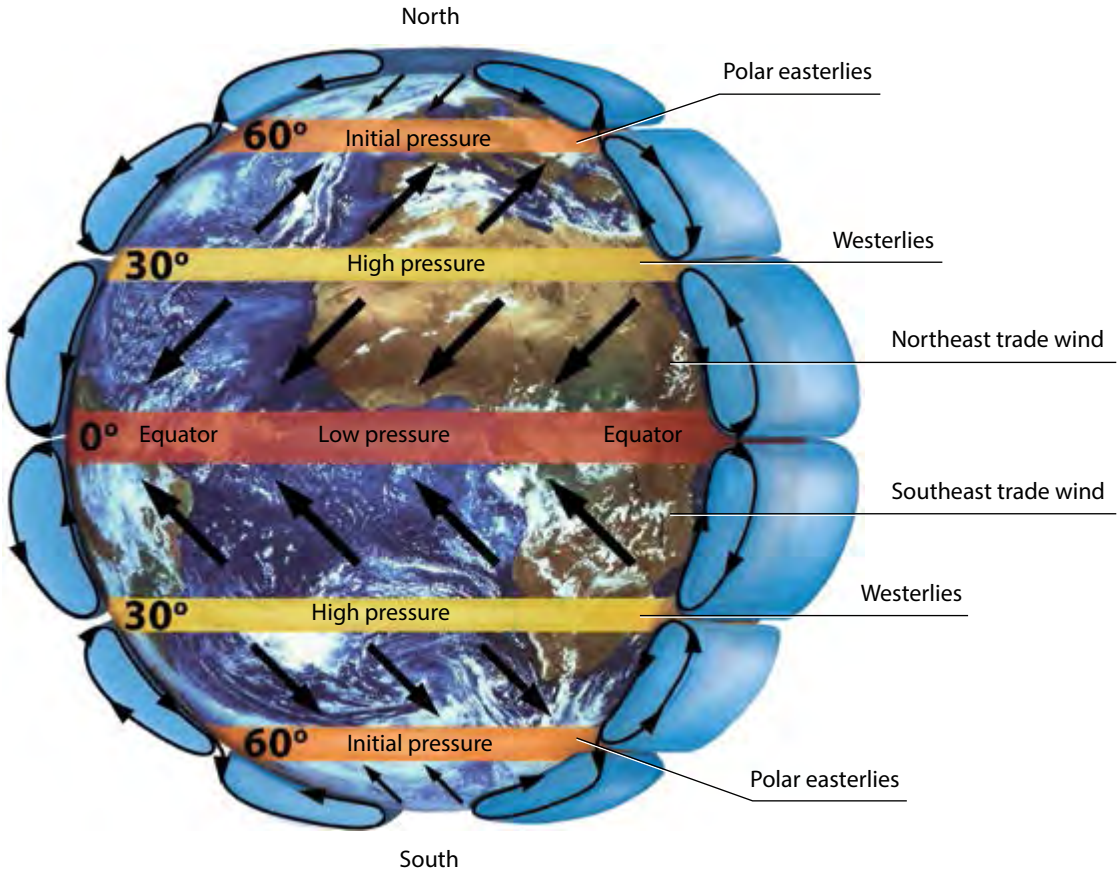


Fig. 9.2. Schematic representation of the general circulation of the Earth's atmosphere

heavy ones. The marine air has iodine and other mineral matter, and the continental air has inorganic and organic matter that enter the air from the vast steppe zones.

Air masses change on average every four days, but can change during the week (winter continental air). Continental air masses predominate in winter, marine — in summer.

The most rapid change in the weather state with a sharp change in the parameters of meteorological elements during the day is observed due to the passage of the front — the boundary layer between two air masses with different properties. The surface of the front is always inclined. There are sharp changes in temperature, wind, humidity and pressure. The front line passes in the place of intersection of frontal surface with the Earth's surface. The front speed can reach 60 km/h. A lot of accumulated information allows to consider the weather of the front type as an intensive physiological stimulus.

There are warm, cold and occluded fronts (Fig. 9.3).

If the front line moves towards the cold air, which recedes in the form of a wedge and frees up space for warm air, which, in turn, rises up the slope of the cold air, such a front is called warm. With upward warm air current, its adiabatic cooling and condensation of steam, contained in moist warm air, take place. Subsequently, clouds are formed: scarf, cirrostratus, altostratus, and nimbostratus. Of the latter, rain falls before the front. It rains for a long time and continues after the passage of the front, while there is an upward movement. Then the rain stops, and the clouds dissipate. The temperature behind the front rises; the wind changes direction from south and southeast, which he had before the front, to southwest and west.

If the front line is shifted towards warm air, there is a blunt wedge of cold air, in front of which warm air recedes and moves up, the front is called cold.

In the area of the cold front, the cold air flows under the warm and pushes it up at a sharper angle. This front has much stronger ascending air currents. Cumulonimbus clouds with intense precipitation and thunderstorms are formed here, followed by nimbostratus clouds with less precipitation, and then altostratus and cirrostratus clouds without precipitation.

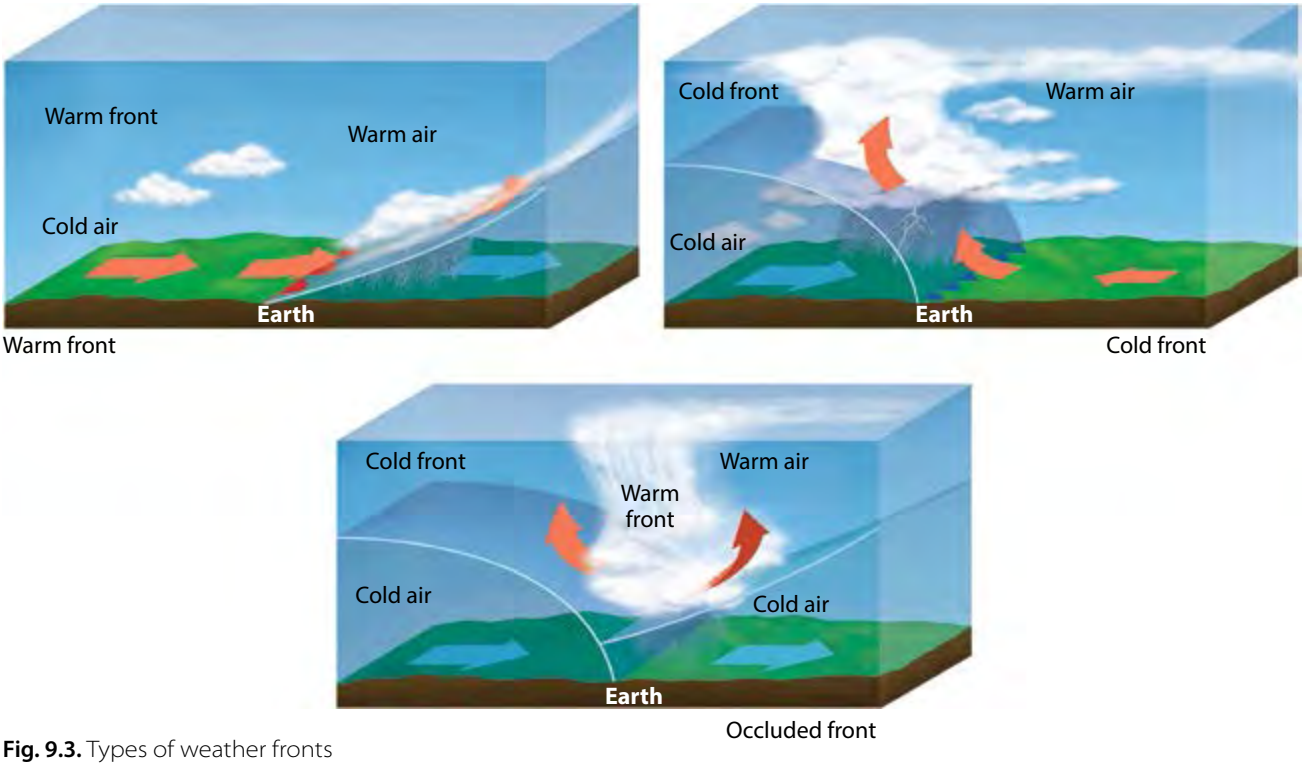


Fig. 9.3. Types of weather fronts

As the cold front moves faster than the warm one, it can get closer to the latter and even catch up with it. After that, warm air is forced up, where it spreads. Thus the *occluded front* is formed.

In the troposphere there is a constant confrontation of warm and cold currents. The passage of the front and the change of air masses are usually combined with the formation of one of two main types of meteorological states of the atmosphere — a cyclone or anticyclone.

Cyclone is an area of reduced atmospheric pressure equal to 2–3 thousand km in diameter, which goes down from the periphery to the center and upwards from the Earth's surface. The circulation of air currents, i.e. winds, in the cyclone occurs counterclockwise in the northern hemisphere (Fig. 9.4) and clockwise — in the southern hemisphere (Fig. 9.5). The weather in the cyclone area is quite unstable with large differences in temperature, pressure, with high humidity, precipitation, and with high electrical conductivity of air and a decrease in the gradient of the Earth's electric field (voltage gradient). The influx of the cyclone causes warming, drop in barometric pressure, increased clouds and precipitation. After the passage of the cyclone, the rainfalls stop, and the atmospheric pressure rises. There is a fall in temperature and clearing. Cyclones that pass over Central Europe are often occluded.

In tropical regions, other types of cyclones are formed. They have the form of deep atmospheric concavity with a diameter of 80 to 500 km. A tropical cyclone occurs in the tropics over the oceans and brings stormy and the most destructive weather on Earth. A tropical storm is called as a hurricane in the West India and Southern USA, cyclone — in the Indian Ocean, typhoon — in the South China Sea, begwiz in the Philippines, and villa-villa — in the Northern Australia. The speed of tropical cyclones can exceed 120 m/s. Most of them cause significant floods and destruction. Meteorologists give names for tropical cyclones: Betsy, Karel, Hazel, Elizabeth, etc. (Fig. 9.6).

Tornado (from the Spanish "*tornar*" — to turn) is an atmospheric phenomenon that is a rapid whirlwind with a diameter of 50 km and a height of 10 km. It extends from a cumulonimbus cloud to the surface of water or land. Tornadoes can be of various shapes — a column, cone, wine glass, barrel, tube, sand glass, "devil's horns", etc., but most often, they have the shape of a rotating trunk, tube or funnel hanging from the mother cloud.

The occurrence of tornadoes is associated with local atmospheric inhomogeneity, collision of air masses inhomogeneous in humidity and temperature, warm (below) and cold (above) layers of air and strong crosswinds during stormy weather.



Fig. 9.4. Photo of a cyclone from a satellite in the northern hemisphere. Source: *nasa.gov*

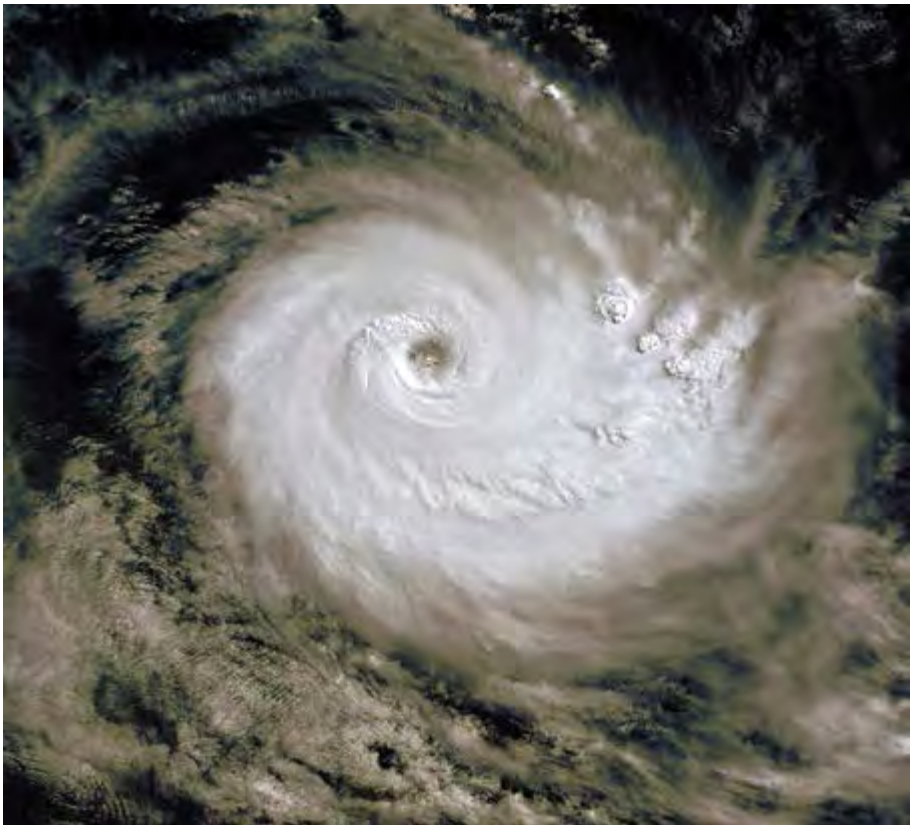


Fig. 9.5. Photo of a cyclone from a satellite in the southern hemisphere. Source: *nasa.gov*



Fig. 9.6. The impact of tropical cyclone. Source: *wikimedia.org*

Reduced pressure inside the tornado creates a "pump effect", i.e. the absorption of ambient air, water, dust, objects, people and animals inside the funnel (Fig. 9.7). This effect also leads to the knocking down of roofs and the destruction of houses that are caught into the middle of the tornado. Tornadoes often cause damage to the urban infrastructure (they can move even large objects, for example, cars) (Fig. 9.8).

Tornadoes often are formed on tropospheric fronts — on the boundaries of the interface in the lower 10-kilometer atmospheric layer, which separate air masses with different wind velocities, temperatures and humidity. In the region of the cold front, the atmosphere is particularly unstable and forms a tornado in the mother cloud and many turbulent vortices below it, which rotate rapidly.

Thunderstorms occur in most of the globe, except the regions with subarctic and arctic climates. However, tornadoes can accompany only those thunderstorms that are at the junction of weather fronts.

The largest number of tornadoes is recorded in the North America, especially in the central part of the United States, the less — in the Eastern United States.

The second region of the globe where there are conditions for the formation of tornadoes is Europe.

Thus, tornadoes are mainly observed in the temperate zones of both hemispheres, from about the 60th parallel to the 45th parallel in Europe and to the 30th parallel in the United States. Tornadoes are also recorded in Eastern Argentina, Southern Africa, Western and Eastern Australia and a number of other regions, where the conditions for collisions of atmospheric fronts can also occur.

The largest number of tornadoes, 148 in one day, occurred on April 3–4, 1974, over the Southern United States.

The highest speed of tornadoes was recorded on April 2, 1958, near Wichita Falls, Texas. It was 450 km/h.

The highest wind speed near the Earth's surface was recorded during the tornado in Oklahoma and Kansas (USA), on May 3, 1999. It was 511 km/h.

The largest tornado in the history of observations occurred in Oklahoma (USA) during a series of tornadoes in the second half of May 2013.

The speed of air movement in the "walls" of the tornado can exceed the speed of sound (1300 km/h), and the pressure in the center can drop even to 500 mm Hg and below.



Fig. 9.7. The tornado with mother cloud. Source: *scmp.com*



Fig. 9.8. Destruction along the path of the tornado. Source: *dailybeast.com*

The longest-running tornado was recorded on May 26, 1917, in the United States. The Mettun tornado swept across the United States territory of 500 km in 7 hours and 20 minutes, killing 110 people.

The strongest tornadoes were recorded in London, the British Isles, and on December 14, 1810 in Portsmouth.

The tornado in Shatursh, Bangladesh, was listed in the Guinness Book of World Records on April 26, 1989, as the most tragic in all of human history. Residents of this city, having received a warning about the approaching tornado, ignored it. As a result, 1,300 people died.

In Ukraine: on May 26, 1948, a tornado with a diameter of about 30 m flew over the villages of Bilogorivka and Berestove in the Donetsk region. The tornado hit a passenger train and flung down 7 train carriages from the railway line.

On May 11, 2016, a tornado was recorded between the villages of Plotycha and Ivachiv Dolishnii, as well as on the outskirts of Ternopil.

Anticyclone is a high atmospheric pressure area with a diameter of 5–6 thousand km, in which the horizontal circulation of air flows is most often clockwise in the northern hemisphere, and vice versa in the southern hemisphere. The vertical airflow in the anticyclone occurs from the center to the periphery and from top to bottom (Fig. 9.9, Fig. 9.10).

Anticyclones bring mostly clear weather. They comes before each series of cyclones. The air diffluence in the anticyclone makes conditions for clearing between the cyclones. Due to the fact that in winter the Earth's surface is very cold, and the downflows of warm air cannot reach Earth, the air temperature can be extremely low in the center of a stable zone of high pressure. In summer, conversely, the warm air partially descends directly to the Earth and, due to the strong influence of solar radiation, becomes even warmer. In both cases, clear weather is provided by air downflow.

In summer, anticyclones cause periods of warm and even hot weather, as well as short-term heavy rainfalls, sometimes with hail and thunder. In winter, they bring clear and frosty or cold cloudy weather with snowfall and long-duration radiation fog. The link between high atmospheric pressure and fair weather (going by a standard barometer) is not always observed. Anticyclones provide stable, but not every time pleasant and clear weather. In the center of the formed anticyclone, the weather will be calm and windless.

In addition to weather fronts, cyclones, anticyclones, the main thermobaric processes also include monsoons and trade winds.

Monsoon is a wind that prevails in many tropical areas, occurs on the shores of seas and oceans due to the

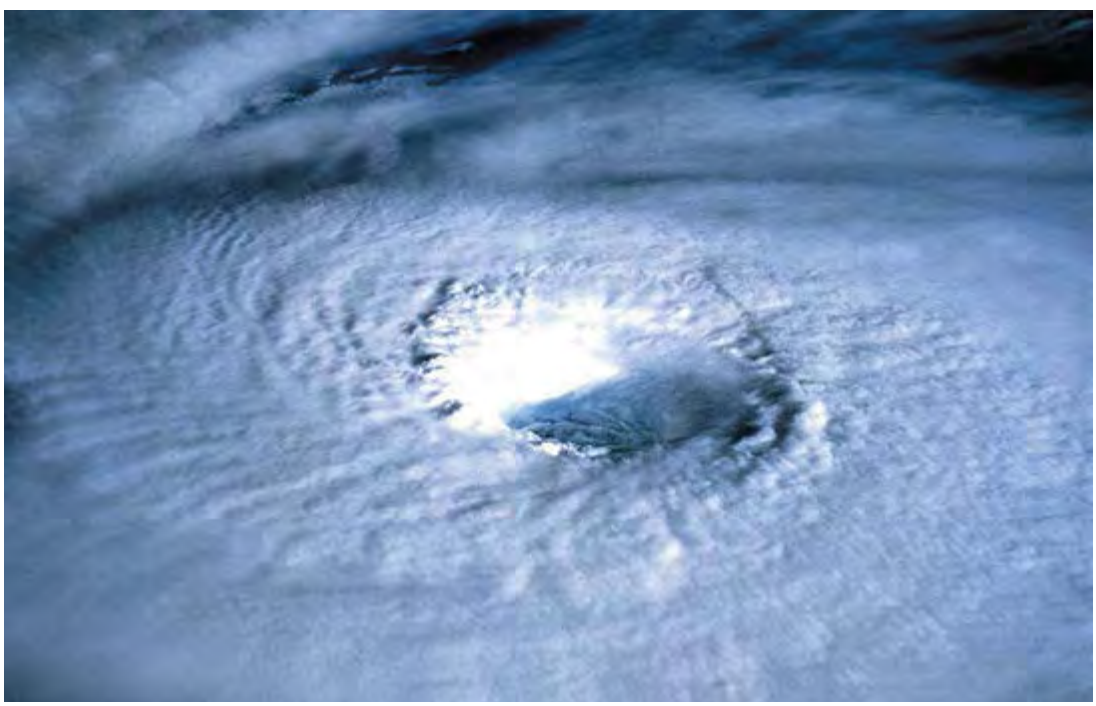


Fig. 9.9. Satellite photography of anticyclone. Source: *nasa.gov*

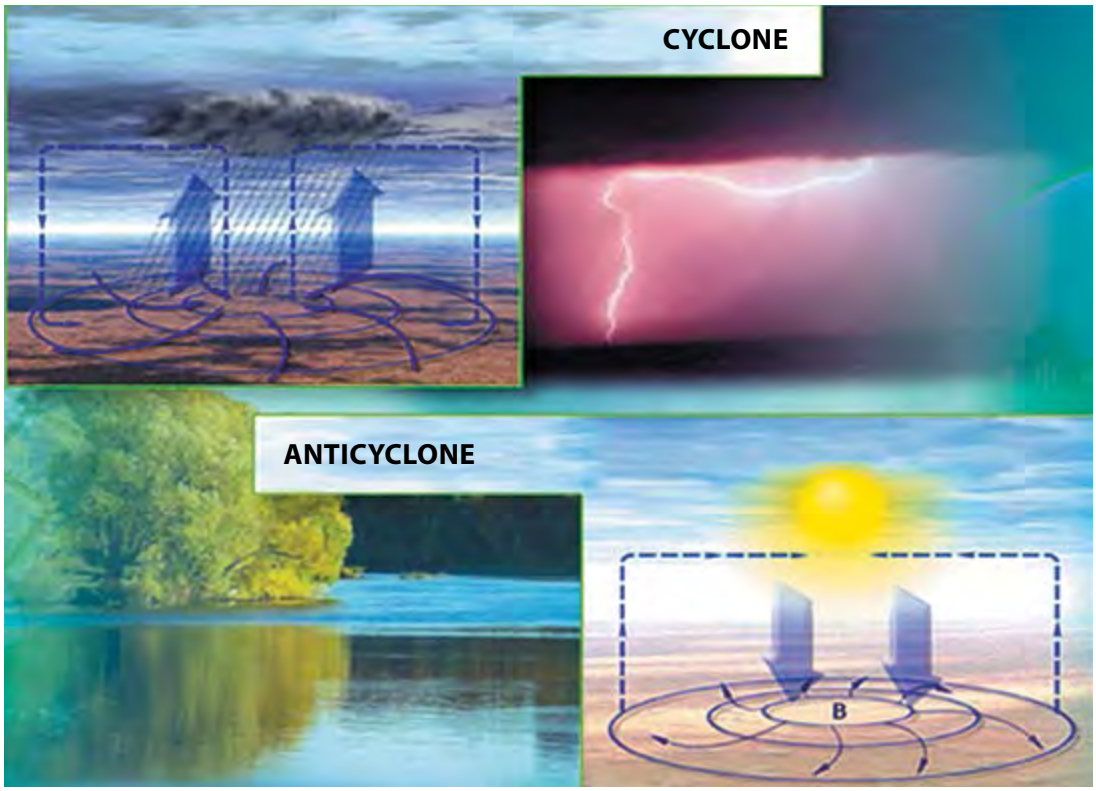


Fig. 9.10. Demonstrative comparison of a cyclone and anticyclone

constant temperature difference on the continents and oceans (Fig. 9.11).

Trade winds are winds that occur near the equator, where vertical air currents move from northeast to southwest, covering a distance of 30–35° latitude to the equator.

9.6. Direct impact of weather on the human body

Weather affects the physiological state of human in direct and indirect way. The direct way is carried out by impact on human heat exchange through separate meteorological factors or their combination. Hot and windless weather with high humidity causes stress on thermoregulatory mechanisms, other physiological changes and can lead to overheating of the body (or thermoplegia). Relatively low temperature, high humidity, strong wind can contribute to an increase in cold-related diseases, pneumonia, sore throat, acute inflammatory renal diseases, peripheral nervous system diseases, etc. In the case of a combination of meteorological factors that cause hypothermia (severe frosts with windy weather or relatively low air temperature and humidity), cold injury can occur, and the combination of low air temperature with high humidity mainly leads to cold injury of the lower limbs.

Weather conditions are important in the epidemiology of infectious diseases. For example, hot weather create the conditions that contribute to the occurrence of bacteriogenic food-borne diseases (toxicoinfections, toxicosis).

9.7. Indirect impact of weather on health due to distortion of the dynamics of air pollution. Smog

The hygienic significance of the weather is not limited to its impact on human health, which is manifested by more or less severe heliometeotropic reactions. It can also affect indirectly through other adverse environmental factors. A vivid example is the phenomenon of *temperature inversion*.

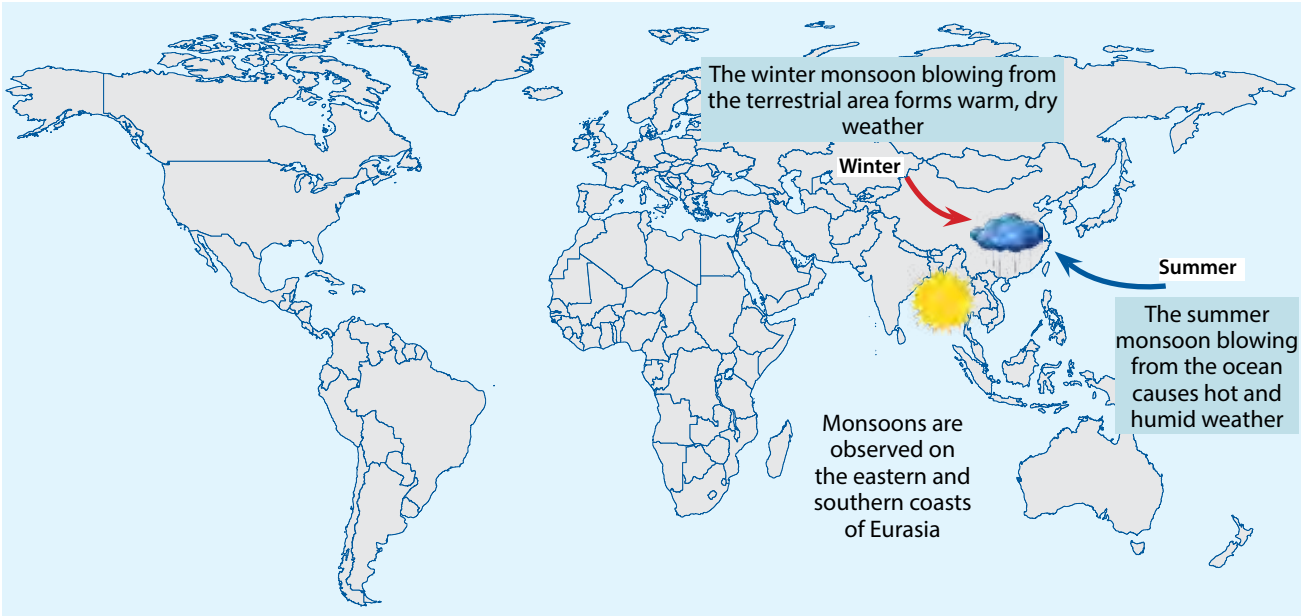


Fig. 9.11. Monsoon formation

Under normal conditions, the air temperature decreases with a distance from the Earth's surface. With a rise of 100 m upwards, the air temperature decreases by 0.7 °C. In the case of a stable anticyclone, due to the movement of vertical streams of cold air, the temperature may be distorted in the following way: when approaching the surface of the Earth, the temperature will rise, not decrease. This distortion of the atmospheric circulation has a rather negative effect on the dynamics of the spread of air pollution. There are many cases when intensive emissions of industrial enterprises within the conditions of windless weather and temperature inversion are almost not diffused in the atmosphere (atmosphere self-purification), but concentrated near the Earth's surface. As a result, in the settlements that were close to the sources of pollution and were in the center of the anticyclone, a toxic fog was appeared — the so-called smog which caused mass respiratory, circulatory diseases, a sharp increase in case fatality rate (London, Los Angeles, New York, Tokyo).

Smog is a poisoned mixture of smoke and gaseous waste from chemical plants with fog or no less poisoned mixture of fuel combustion products in vehicle engines and refuse-fired plants with dust and other types of urban air pollution (without fog). There are the following types of smog:

1. London-type moist (sulfurous) smog (Fig. 4.23–4.25, Fig. 9.12).
2. Los Angeles-type photochemical smog (Fig. 4.26–4.28, Fig. 9.13).
3. Alaskan-type ice smog (Fig. 4.34, Fig. 9.15).
4. Volcanic smog (Fig. 4.29–4.33, Fig. 9.14).
5. Forest fires smog (Fig. 4.35, Fig. 4.36).
6. Chemical agricultural smog (Fig. 4.9).

Industrial smog prevails in large industrial areas. It is the result of incomplete combustion of liquid and solid fuels. Photochemical smog occurs in places of accumulation of vehicles under the action of sunlight, which activates photochemical reactions in exhaust gases.

Industrial and photochemical smog damage the respiratory epithelium, provoke inflammation of the bronchi (bronchitis), reflex bronchospasm, facilitate the penetration of allergens into the respiratory tract, accelerate the destruction of surfactant. Studies have shown that chronic bronchitis is more spread in the cities located in the areas of high industrial pollution, and bronchial asthma — in the cities with severe air pollution with exhaust gas.

Interest in such phenomena has long been known. As early as 1909 and 1912, Chalmers described cases of toxic fog in Glasgow. At this time, extremely high mortality rates were registered in the city from diseases of the cardiovascular and respiratory systems. Smog can cause high mortality of people, especially the senior citizens and patients with chronic non-specific pulmonary diseases. In London, more than 4,000 people died of smog in two weeks in 1952. In the following years and espe-



Fig. 9.12. London-type smog. Source: *bakclass.com*



Fig. 9.13. Photochemical smog. Source: *senate.ca.gov*



Fig. 9.14. Volcanic smog. Source: *independent.ie*



Fig. 9.15. Ice smog. Source: *termos.bg*

cially these days, smog is observed in many countries around the world.

Smog is a signal of air pollution level in cities, i.e. this signal shows that air pollution level exceeds a limit and may bring an adverse public health effect.

Weather-forming factors such as wind structure (direction, speed) are also of great hygienic importance. They are associated with the intensity and nature of the noise and air pollution (dust, smoke, gases).

Cloudy weather sharply reduces the ultraviolet radiation intensity (by 40–70 % and more). Increased humidity exacerbates the negative effects of air pollution, for example, it facilitates the conversion of sulfur oxides into the sulphuric acid aerosol, nitrogen oxides — into nitric acid aerosol.

All of the above substantiates the importance and possibility in principle of forecasting of air pollution trend based on meteorological forecast with the subsequent use of air pollution forecast of any locality for appropriate preventive measures.

Unfavourable temperature conditions (high or very low temperature) worsen working conditions at open platforms. Specifically, this concerns construction and installation workers, forest laborers, etc.

Thus, weather conditions may have a significant and sometimes negative impact on human health, work, life and recreation. Therefore, they should be taken into account when planning and implementing preventive measures. In particular, medical workers have an important task — to develop criteria and a system of medical weather forecasting and subsequent prevention of heliometeotropic reactions.

9.8. Indirect effects of weather on health via unbalance of human biological rhythms

The indirect effect of weather on the human body is due primarily to the action of so-called aperiodic changes in weather conditions, which conflict with the usual human rhythms of physiological functions.

It is commonly known that the formation of the modern organic world and, in particular, human took place in the cyclical dynamics of external factors — the rhythmic change of time, day and night, seasons, light level, and etc. In conjunction with such types of rhythmicity of natural phenomena as the reaction of adaptation, there are rhythmic changes in biological processes — biorhythms.

Biorhythms (can be traced back to the Greek terms, *bios* and *rhuthmos* — "life" and "regular recurring motion, rhythm") — are periodic changes in the intensity of physiological and mental processes over time.

The classification of biorhythms is the following:

- circadian biorhythms (diurnal changes of body temperature, activity and rest, sleep and keeping awake, dynamic changes of metabolic processes, CNS lability, etc.);
- monthly (circalunar) biorhythms associated with the rhythm of the Earth's rotation around the Sun and the Sun around its axis (for example, monthly, 27–28-day ovarian cycle);
- seasonal, i.e. annual, or circannual biorhythms (changes in hormonal activity, gastric acid secretion, metabolic processes), etc.

These biorhythms arose in response to natural cyclical changes in habitat factors, and therefore they are called adapted (Fig. 9.16, Fig. 9.17).

Recently, much attention has been paid to the study of the influence of circadian (daily) and seasonal periodic changes in weather conditions on the rhythms of physiological processes in humans. The circadian rhythm of physiological processes, efficiency and responsiveness of an organism is well studied. The insight into the adaptive significance of biological rhythms was formed, and, specifically, they reflect the cyclical dynamics of the surrounding world for the benefit of the organism. If a person's daily regimen, i.e. his vital functions, is consistent with the cycles of external conditions, this contributes to vital activity and performance capability. On the contrary, the mismatch of the rhythm of vital functions and cyclical changes in external conditions affects life, impairs performance, and in some people — causes health deterioration. This is observed in the case of improper organization of work and personal daily regimen in institutions with three shifts (telegraph services, hospitals, industrial enterprises, etc.). An impaired productivity, neurosis type disorder called desynchronosis, has occurred in people when flying high-speed aircraft over long distances from east to west or from west to east with a change of 8–10 time zones. Some pilots even had to be suspended from work on such airlines.

9.9. Heliometeotropic reactions of healthy and sick people, pathogenesis and classification

Human has generally adapted to the rhythmic changes in the intensity and nature of the climate and weather as-

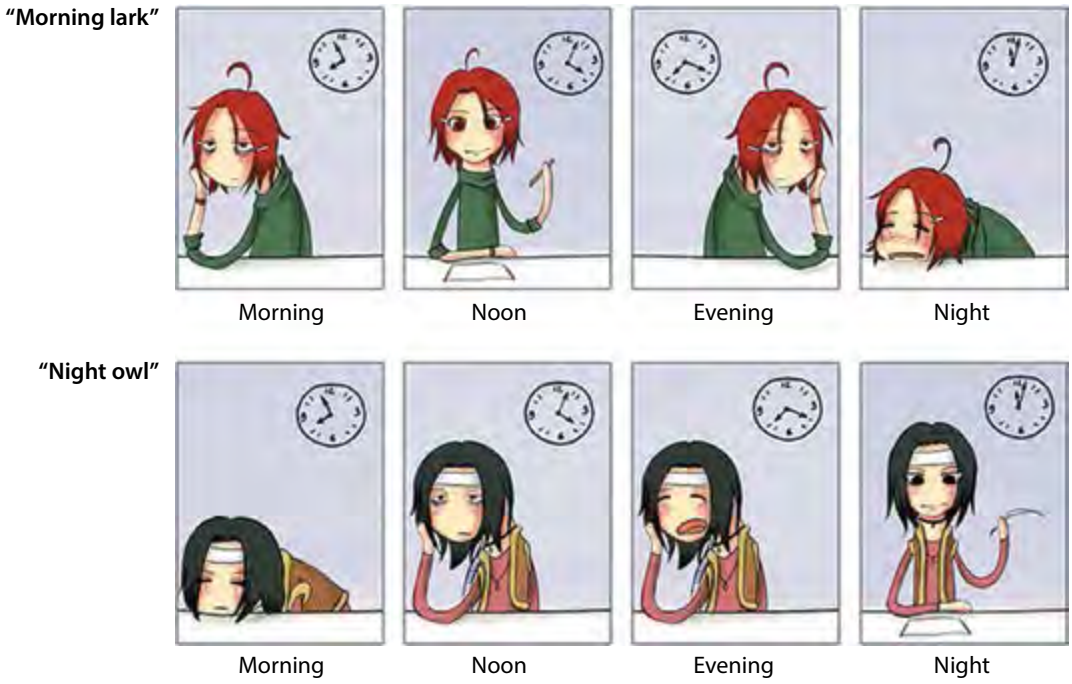


Fig. 9.16. Circadian biorhythms

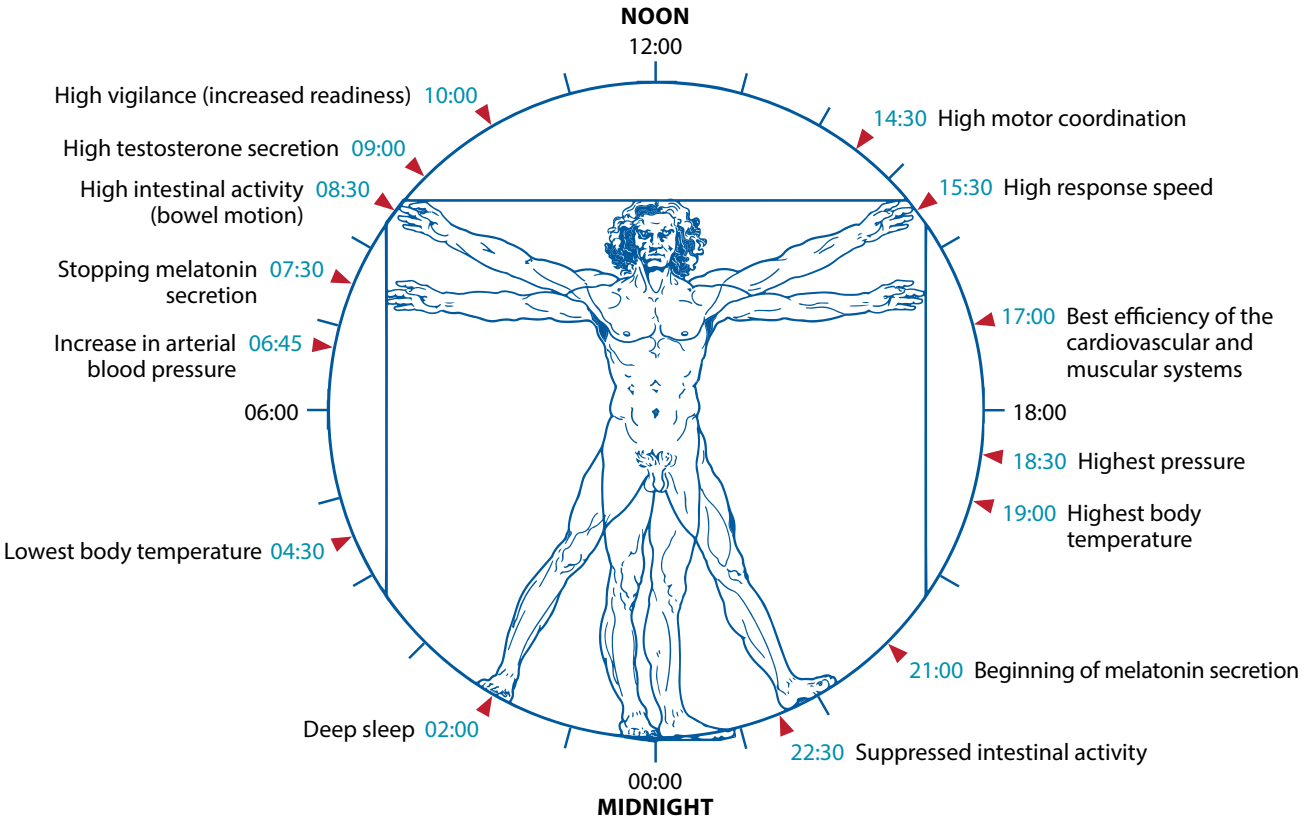


Fig. 9.17. Schematic representation of circadian biorhythms

sociated with the day/night and seasonal changes. Most people perceive such changes without any negative manifestations. Another reaction is observed under the influence of aperiodic abrupt changes in weather, which depend on changes in air masses or the impact of heliogeophysical factors. In this case, most healthy people with well-developed physiological mechanisms of adaptation do not notice disorders associated with weather changes in their health or physical condition. Such people are usually healthy, more disease-resistant. They are often called meteo-resistant.

However, there are people, often diseased, sensitive to weather changes. These are the so-called meteo-labile or meteo-sensitive people (meteodependents). The number of meteo-labile patients depends on the type of pathology, age, type of mental (higher nervous) activity and varies among different cohorts in a wide range — from 10–30 to 80–100 %. In meteo-labile people, adverse weather changes cause various and sometimes life-threatening manifestations in the form of heliometeotropic (meteotropic) reactions.

Heliometeotropic reactions are a combination of objective and subjective changes that are unfavorable for human health and performance capability, which occur in the body due to weather patterns.

The heliometeotropic reaction is not a nosological unit with a clearly defined symptom complex. The nature of this reaction and its manifestations depend on the type of disease, type of mental activity, initial state of the organism, work and life peculiarities.

In most meteo-labile people, unfavorable weather causes breakdown of overall well-being, sleep disorders, anxiety, faintness or dizziness, impaired productivity, rapid fatigability, as well as rapid blood pressure changes and chest pain, etc. In such cases, the pharmaceutical sensitivity changes (often decreases, which is dangerous).

It is established that unfavorable weather has a negative effect on the course of many diseases of the cardiovascular, respiratory, endocrine systems, digestive tract, skin, eyes, neuropsychiatric and others.

A typical heliometeotropic reaction is the so-called phantom pain (or stump neuralgia) in people with amputated foot, hand, joint pain in patients with arthritis (usually in elderly people with arthritis).

Unfavorable weather has a particularly strong effect on patients with pathology of the cardiovascular system. Numerous studies conducted in different countries, as well as observations made in Kyiv and other cities of Ukraine, are indicative of that due to unfavorable weather, which is manifested by the development of so-called biotropic meteorological situations or changes in solar and geomagnetic activity, the frequency of the following adverse effects statistically increases: acute myocardial infarction, hypertensive crises, strokes, angina attacks, also the course of these diseases worsens, mortality increases.

G. M. Danishevsky defined heliometeotropic reactions as clinical deconditioning syndromes (maladaptation), i.e. meteoroneurosis of maladaptation origin. The key point in the pathogenesis of the heliometeotropic reaction is the inclusion of the autonomic and central nervous systems. Then humoral mechanisms join and there is a reaction-response — heliometeotropic reaction. The basis of heliometeotropic reactions in cardiovascular patients are vasomotor reflexes (angiospasm, heart acceleration, increase in arterial blood pressure, etc.) and changes in the blood system (inhibition of fibrinolysis, increased blood clotting ability, development of blood clots). These changes, in particular, provoke thrombosis, myocardial malnutrition, ischemia or myocardial infarction.

Manifestations of heliometeotropic reactions are various, but they all share the common feature — simultaneously occurrence in many patients under the same general meteorological situation. The point to note is that the same meteorological situation (weather) causes a more clearly defined heliometeotropic response in more individuals when adaptive resources in them are reduced, for example, due to seasonal fluctuations in ultraviolet or vitamin supply, undernutrition, respiratory diseases, overfatigue, etc.

There are three links in the health effect mechanism of natural and preformed physical environmental factors:

1. The initial reaction of a physical factor with a biological substrate.
2. Various metabolic changes.
3. Stabilization of metabolism.

There are three phases of heliometeotropic reaction development: I — phase of clinical and physiological adaptation to atmospheric and physical fluctuations; II — phase of hypersensitivity to various weather changes, which is manifested by changes in the level of neuropsychological and immunological reactivity; III — phase of maladaptation to the weather, which is manifested in healthy but meteo-sensitive people with a certain weather-somatic syndrome, in patients (diseased people) — subclinical and clinical reactions and exacerbation of diseases.

Classifications of heliometeotropic reactions:

1. Type I — heliometeotropic reactions with subjective perception.

2. Type II — with objective perception.
3. Type III — with significant manifestations and complications in the form of cardiovascular accidents.
4. Cerebral syndrome, cardiac syndrome, asthmatic syndrome and asthenoneurotic syndrome with a predominance of vegetovascular disorders (all syndromes go through two phases: regulatory phase and phase of persistent changes).
5. I degree, mild heliometeotropic reactions — in the form of complaints of a general nature; mainly the symptoms of the psycho-emotional sphere;
   II degree, marked heliometeotropic reactions — subjective disorders and marked changes with the CNS symptoms onset;
   III degree — severe heliometeotropic reactions — severe vascular crises.

According to H. Selje (1973), the organism responds to changes in climatic conditions under conditions of normal physiological activity primarily by nonspecific reactions, which are manifested by the general stress of the organism (anxiety stage of the general adaptation syndrome). In this case, the activity of some physiological systems of the body increases, and the level of metabolic processes changes along with this self-regulatory system "hypothalamus — hypophysis — adrenal cortex" plays the main role in the mechanism of the corresponding reaction. However, the nonspecific and specific influence of the factor is important depending on the features of the pathological process.

Adverse environmental factors can affect the cerebral cortex and subcortex, and through it — the entire vasomotor system. It cannot be ruled out that in the presence of the *locus minoris resistentiae* in the vasomotor system the first symptom will develop exactly in the localization with appropriate conditions.

9.10. Prevention of heliometeotropic reactions: permanent, seasonal, urgent

Adverse weather conditions can be prevented by appropriate measures. These are conditioning of an organism (developing resistance to cold), the correct choice of clothes, improvement of living and working conditions, normalization of a microclimate in industrial, hospital and other premises; measures to reduce the impact of weather when working outdoors (agriculture, construction, etc.).

Organizational prevention measures include the following: registration of meteo-sensitive patients both at the site and in the hospital, with the identification of high-risk individuals; organization of medical weather forecast on the basis of weather forecasts of meteorological stations of the Hydrometeorological Service of Ukraine; notification of health care facilities about the medical weather forecast.

The whole variety of direct measures for the prevention of heliometeotropic reactions can be systemized in three groups:

1. Increasing non-specific resistance of the body by conditioning — outdoors time, air and sun baths, bathing, wet wiping, use of natural and artificial (photarium) ultraviolet radiation, course of vitamin administration.
2. Sparing regimen for the body — bed rest, partial bed rest or modified bed rest, limiting or repeal of climatic or physiotherapeutic procedures, reschedule of elective operations or treatment and diagnostic procedures, restriction of movement regimen, rational organization of work, life and rest with proper use of annual leaves, referral of patients to night health resorts, climate change during adverse seasons.

In addition to regimen measures, the sparing of the patient's body is achieved by creating wards (climatized rooms) with artificial microclimate — biotrons, wards with stable ionic regime — ionotrons, equipment that regulate the microclimate in the premises (air conditioners), favorable microclimate of cities with green planting, construction of fountains, etc.

3. The use of specific and nonspecific chemotherapeutic agents — sedatives, antihypertensives, antispasmodics, neuroleptics, etc.

Pharmacological prophylaxis is carried out in two main ways — regular intake of low doses of pharmaceuticals in the most unfavorable months in this climate area (the so-called seasonal prophylaxis) and prophylactic course of administration in periods and days with adverse weather, based on a long-term or short-term medical meteorological forecast.

Seasonal prevention of heliometeotropic reactions is carried out in the seasons characterized by the most harmful combination of climatic and heliogeophysical components of the environment. In most cases, such seasons are the months of autumn — winter — spring period. However, in order to achieve the maximum effectiveness of seasonal prevention in each climate zone, it should be carried out in specific periods adopted in particular region in accordance with the zoning of Ukraine,

proposed by the Ukrainian Weather Bureau for weather forecasts and storm warnings.

Seasonal disease prevention is recommended to be carried out in 2–3-month courses depending on the duration of the unfavorable period for a particular region. These courses of pharmacological and/or physiotherapeutical prophylaxis take place 10–15 days earlier and last for periods with the most unfavorable climatic weather conditions. The pharmacological alternatives and dosage are individualized depending on the state, type and course of disease, hemodynamic type of the nervous system functional status, drug tolerability profile, the presence of contraindications.

In periods of particularly unfavorable weather conditions, short preventive courses are carried out for 10–14 days. These courses are prescribed to patients who are both under dispensary observation and in a hospital or health resort. The basis for such courses (they are conducted for persons not covered by seasonal prevention and elective prevention) is an unfavorable (monthly or decade) weather forecast. During short prevention courses, the same pharmaceuticals as in the case of seasonal prevention should be used.

Urgent prevention of heliometeotropic reactions covers primarily patients in a cardiac hospital, health resort, etc., i.e. where medical staff has the opportunity to carry out appropriate treatment and preventive measures urgently, based on current daily information about the weather and its forecast for the nearest time. It is expedient to carry out this prophylaxis not to all patients, but only to meteo-sensitive ones. Physician detects such patients at the time of arrival at a health care facility by collecting meteorological medical history of a patient or monitoring the dynamics of objective and subjective indicators depending on weather conditions during treatment.

In case of unfavorable weather conditions, prevention of heliometeotropic reactions should include movement restriction of inpatients and health resort patients, set of therapeutic measures aimed at preventing of the disease exacerbation. Pharmaceuticals (according to the medication regimen adopted in a health care facility) in therapeutic doses should be prescribed for 1–2 days before the unfavorable weather, throughout the period with such weather and for 1–2 days after the formation of favorable weather with the control of objective and subjective functional indicators.

In the case of moderately biotropic weather, in addition to a set of therapeutic measures, which are carried out according to the usual regimen, this regimen should be strengthened or other pharmaceuticals should be additionally prescribed.

Resistance to heliometeotropic reactions and their course depend on the oxygen supply of the body, which must be taken into account during medical prescriptions (oxygen cocktail, oxygen baths, etc.).

The microclimate of the hospital ward is important in the prevention and treatment of meteo-sensitive patients. The best way to optimize such a microclimate is to transfer the patient to the "biotron" type ward with a stable microclimate. If this is not possible, other ways to improve the microclimate should be used — local and domestic air conditioners, which are installed directly in the wards, overheating prevention, air exchange intensification, etc. Although such measures do not influence on the atmospheric pressure level, they can support other meteorological elements — temperature, humidity and air movement, oxygen content, positively affecting the microclimate of the rooms, normalizing physiological processes, increasing the body's resistance.

9.11. Medical weather classification

Since the discovery of human meteopathology, physicians have repeatedly tried to classify the weather, to determine its gradations and the gradients of the separate elements that form the weather and with which the heliomeotropic reaction risk is associated to varying degrees. Many researchers have tried to identify and determine the correlation of mortality, disease exacerbations with the absolute values of separate weather elements: air temperature, atmospheric pressure, humidity, general illumination, cloud coverage, precipitation, wind, atmospheric electricity, air ionization, number and size of sunspots, intensity of chromospheric flares on the Sun, geomagnetic storms, etc. However, other researchers have denied such a simple link. It was further proposed to consider the magnitude of differences in separate components of the weather as a criterion for medical weather forecasting. Gradually, researchers concluded that human is affected not by one or two weather elements, but by a whole weather complex. Therefore, the search for complex characteristics of the degree of weather biotropicity began. This was followed by a growing number of complications due to the use of a large number of indicators. Thus, some researchers and practicing physicians have proposed to use thermobaric (pressure-and-temperature)

formations as meteorological units: cyclone, anticyclone, weather fronts. However, it turned out that if, for example, an anticyclone helps to improve the patient's state, but cyclone, on the contrary, can deteriorate the patient's state. A similar contradiction was found in the case of using other weather classifications.

The recent studies have proven high practicability of the V. F. Ovcharova weather classification for medical weather forecasting and subsequent prevention of heliometeotropic reactions. This classification takes into account the dynamics and intensity of circulating processes in the atmosphere, large number of different micrometeorological situations, the degree of variability and the trend of the main meteorological elements.

Weather classification (Ovcharova V. F. et al.):

1. Stable indifferent.
2. Unstable, passing from indifferent to "spastic" type.
3. "Spastic" type.
4. Unstable "spastic" type with elements of "hypoxic" type.
5. "Hypoxic" type.
6. Unstable "hypoxic" type with elements of "spastic" type of weather.
7. "Spastic" type weather passing to stable indifferent.

Each weather type corresponds to certain meteorological situations. Hygienic assessment of the biotropicity of each weather type is carried out taking into account the degree of interdiurnal variability of meteorological elements.

There are 5 degrees of variability: very weak or indifferent, weak, moderate, variable, very variable. Indifferent variability characteristics: the diurnal atmospheric pressure varies within ± 0.25 kPa (2.5 mbar), air temperature — ± 2.5 °C, absolute humidity — ± 0.5 mbar, relative humidity — ± 10 %, oxygen content — ± 2.5 g/m^3. If the variability is weak, the variation range can be 2 times larger, if moderate — 4, variable — 8, very variable — more than 8 times.

This classification has advantages over the previous ones as it can be used in almost all non-mountainous terrain regions of the middle latitudes after a regional biotropic assessment, i.e. after the linkage to local conditions. The weather of spastic and hypoxic types is unfavorable for patients at any degree of interdiurnal variability of meteorological elements and unstable type in case of moderate, variable and very variable degrees of interdiurnal variability. Such weather in Ukraine is observed during 28–31 % of a whole year. In the rest of the year, the weather is favorable or moderately biotropic for these patient populations.

However, this classification does not take into account the influence of solar and geomagnetic activities. Solar activity affects the human body indirectly due to the changes in the Earth's magnetic field intensity and some other parameters. Its influence is usually similar to the influence of adverse weather conditions. Along with this, its specifics is that the adverse effect is not caused by the absolute magnitude of the geomagnetic field intensity, but mostly by strong geomagnetic storms or other abrupt field changes (60 % or more from the initial level) under the both increase and decrease conditions. Solar activity has the greatest effect in the late winter and spring months, when the body's adaptive resources are reduced. The combination of unfavorable meteorological and heliophysical conditions causes the most significant heliometeotropic reactions.

Thus, today there are well-defined criteria for medical forecasting, i.e. medical interpretation of meteorological forecasts which is manifested in the prediction of the impact of the expected weather on humans.

9.12. Medical and meteorological forecasting

The components of the system for the prevention of heliometeotropic reactions are:

1. Determination of weather that adversely affects the course of disease, i.e. medical weather classification.
1. Medical interpretation of weather forecast, i.e. medical and meteorological forecasts.
2. Development of a system of preventive measures for patients based on the weather forecast.

Taking into account that the meteorological lability of patients with various diseases is very high, for example in the case of the cardiovascular system diseases, it is 20–90 %, and in average — 60–70 %, it is obvious that medical weather forecasting and prevention of heliomeotropic reactions will not only make it possible to save and prolong the lives of millions of patients, but also to preserve their performance capability. This means a great economic benefit.

The management of the prevention of heliometeotropic reactions, the use of weather data for the prevention and treatment of patients with heliometeotropic reactions are mandatory requirements for full medical care for these patients both in the hospital and during outpatient care.

The system of appropriate measures covers:

1. Obtaining, registering, analyzing and medical interpretation of latest information on current and forecast weather conditions.
2. Notification on medical weather forecast and recommendations regarding the treatment and prevention measures.
3. Implementation of a set of measures for the treatment and prevention of heliometeotropic reactions.
4. Analysis and generalization of the observational results in order to improve the prevention of these reactions.

Various institutions carry out observations over the weather conditions and heliogeophysical variations: the Hydrometeorological Service of Ukraine, which includes stationary and observation stations, hydrometeorological observatories, mobile stations and laboratories (on marine vessels, airplanes, etc.), the State Hydrometeorological Committee of Ukraine, the Main Geophysical Observatory, etc. In addition to the Hydrometeorological Service, agrometeorological, bioclimatological and other laboratories conduct meteorological observations. Along with meteorological data, the results of observations of the solar activity manifestations and geomagnetic field intensity changes are critical for a comprehensive assessment of weather conditions and forecasting. The Main Astronomical Observatory of Kyiv University, astronomical observatories and geomagnetic stations of the Ukrainian National Academy of Science, etc. make such observations.

The results of meteorological and heliogeophysical observations are recorded in special journals of current record, and then summarized and published, respectively, in the meteorological monthly publications of Hydrometeorological Service, bulletins "Solar Data" ("Solnechnye Dannye") of the Main Astronomical Observatory, "Space Data" ("Kosmicheskie Dannye") of the Institute of Geophysics, etc.

The main source of operational information on weather and geophysical conditions in the settlement are local meteorological and geomagnetic stations. Obtaining this information, its subsequent delivery to medical institutions, guidance and coordination of work on the prevention of heliometeotropic reactions are centralized on a settlement scale. For this purpose, the meteo-preventive office is organized at the health departments of the regional, city or district state administration or at one of the hospitals. A responsible employee is a doctor or a nurse (medical assistant), whose responsibilities include obtaining and registering information about weather conditions, their preliminary generalization and supplying information for engaged employees.

The dedicated health care worker contacts the local meteorological center by phone or in person on a daily basis or directly the weather bureau office and meteorological station (if there is no meteorological center) and receives information about the weather conditions and forecast for the coming day. The primary data is recorded in a registration book, and the summarized data is recorded in the appropriate book for the notification and forecasting purposes.

Before the daily round, the physician becomes familiarized with information about weather conditions and their medical assessment. Based on this information (it can be supplemented or changed during the day), physician makes am appropriate adjustments to the patient's treatment regimen, additional prescriptions, cancels or prescribes procedures, gives the instructions to transfer individual patients to the intensive therapy wards, wards with artificial microclimate, etc. Pharmacological prescriptions and other recommendations for the prevention and treatment of patients with heliometeotropic reactions are recorded in the medical history. Weather conditions are taken into account not only for meteorologically labile patients, but also for all critically ill patients, for whom adverse weather is a risk factor. In this case, the medical and meteorological forecast made by a specialist is the main reference point, not the personal perception of the weather, which may not coincide with the degree of its biotropicity. Weather, often perceived as calm, stable, sunshine, has significant biotropic properties depending on factors that are not perceived subjectively.

In order to assess the effectiveness and continuous improvement of prevention and treatment of patients with heliometeotropic reactions, the observational results are analyzed and summarized. This work is performed based on purposeful study of case histories and their comparison with the weather conditions book using modern methods of correlation, variance and other types of mathematical analysis.

10

CHAPTER

HYGIENIC IMPORTANCE OF CLIMATE. ACCLIMATIZATION

N. V. Merezhkina, V. G. Bardov

10.1. Climate, concept definition

Each area has its own weather conditions and certain boundaries within which the weather can change. Thus, in Ukraine the air temperature in summer has never been above +45 °C (in the shade), and in winter — below -40 °C. In Ukraine, there is always the alternation of day and night, and, in the Arctic Circle, there is a half-year cold polar night in the winter half of the year. The children of equatorial countries have never seen snow, but, in Europe, there have never been tropical downpours, which are usual for the southern latitudes. In the middle of an Arctic summer day, the Sun is low with barely warm rays, while, in the equatorial and subtropical latitudes, the Sun is close to the zenith, and its rays carry huge amounts of heat to the Earth's surface.

Why does the Sun's heat is distributed so unevenly? What are the differences in the weather of northern and southern latitudes?

Back in ancient Greece, people knew that such differences are due to the diverse climate, which depends primarily on the latitude of the area, i.e. the angle at which sunlight falls on the Earth's surface. However, observations have shown that the climate of a particular area depends not only on the angle of the solar rays to the horizon. Climate is nowadays understood as a set and sequence of weather conditions and weather phenomena over a long period.

Climate is a long-term weather regimen naturally repeated in a certain area. Therefore, climate is one of the characteristics of the geographical environment, specifically, its meteorological characteristic.

10.2. Climate-forming factors

As the most important component of the natural environment, climate affects the patterns of human economic activities, household activities, sanitary living conditions, health, rate and patterns of morbidity. The presence of pathogenic agents and disease carriers in the environmental mediums largely depends on the climate, which is associated with the geographic distribution of many diseases. Therefore, climatic conditions are taken into account when developing hygienic recommendations for public (residential units, hospitals, health resorts, etc.) and industrial construction, sensible nutrition, clothing, footwear, work-rest distribution, upbringing of the younger generation, prevention of nosogenesis and exacerbation of various diseases. Hippocrates in "Aphorisms" pointed to the different course of diseases in different climatic conditions and recommended climate-therapy for therapeutic and health purposes, which has now become widespread. Medical geography successfully develops by studying human health and patterns of disease spread in different geographical areas subject to social conditions.

Climate-forming factors. Climates of various areas are different — from extremely high temperature to quite low. There are humid, dry, etc. climates. The diversity of climatic zones is extremely large. By studying the climates of different areas, scientists sought to find out what causes determine the climate of an area. These causes are called climate-forming factors. The most important factors that form the climate in a certain area are:

- latitude of an area (the angle of the sun rays, length of day/night/seasons, the amount of solar heat, etc.);
- sea level elevation (the atmospheric transmittance for sunlight, air temperature and density, etc. depend on an elevation), topographic features and type of land surface (dryness or moisture of the soil, forest or herbaceous cover, snow cover, the angle of slope which forms the conditions of precipitation runoff, and the tilt angle of the sun rays to the Earth's surface);
- peculiarities of air mass circulation (air currents that transfer and change the weather);
- distance from the oceans and seas, etc.

10.3. Climate characterizing components

Indicators that characterize the climate should identify long-term processes. Therefore, they are average indicators.

Climate characterizing factors

These are the average indicators determined over a year-long period:

- air temperature;
- air humidity;
- atmospheric pressure;
- amount of precipitations;
- wind speed and direction;
- amount of solar radiation;
- number of clear and cloudy days;
- light climate (or photoclimate);
- duration of winter;
- depth of soil freezing.

The weather patterns are essential in climate characterization at different seasons. One of the indicators is the weather instability index:

$$K = a/b,$$

Notice: a — quantity of days of weather changes;
b — total quantity of days in a certain period (season, year).
K index exceeding 0.5 is considered unfavorable.

10.4. Climate classifications

All the diversity of climates observed on the Earth's surface can be narrowed down to a relatively small number of climate types.

Living conditions, plant development, human activity depend on climate patterns, therefore, the climate of the same place can be described with different characteristics and from different points of view. For example, for specialists who study rivers, the climate of the area is convenient to determine by the type of rivers in this area and the characteristics of water supply sources of the rivers. By contrast, specialists who study vegetation determine the climate of the area by the predominant type of plants.

The modern climate is the result of the interaction of a large number of both terrestrial and cosmic factors over millions of years. Its main feature, formed by the evolution of climatic conditions, is the creation of clearly defined climatic zones (or belts). Each climatic zone has 4 main types of climate: continental, maritime, due to different influences of terrestrial areas and seas, and the climate of the western and eastern coasts of the continents arised due to atmospheric circulation and sea currents.

In geography, it is customary to differentiate climate by natural conditions, which are a consequence of climate. Taking into account the main climatological indicators (temperature, pressure, humidity, precipitation, light climate, wind regime, etc.) and the geographical location of the area on the globe, there are seven main climatic zones (Fig. 10.2):

- tropical (0–13° latitude, average annual temperature 20–24 °C);
- hot (13–26° latitude, 16–30 °C);
- warm (26–39° latitude, 12–16 °C);
- temperate (39–52° latitude, 8–12 °C);
- cold (52–65° latitude, 4–8 °C);
- harsh (65–78° latitude, 0...–4 °C);
- polar (69–90° latitude, –4 °C and below).

Thus, the climate of the equatorial zone is formed under the conditions of intense solar radiation, cloudless weather, and significant evaporation. The accumulation of moisture is supported by its transfer with trade winds from the tropical regions of the ocean. Evaporation in the equatorial zone on the oceans and continents is the same, and therefore the continental type of equatorial climate is similar to the oceanic.

Frequent rains and thunderstorms are observed in the ocean regions. In summer, the air masses of the equatorial zone move towards the tropics. In the area of these winds, there are the humidity increase, rains, decrease of daily temperature range. In winter, the winds blow towards the equator — the humidity on the continents decreases, and precipitation almost stops.

The climate of temperate latitudes is characterized by significant cyclicity throughout the year. The continental climate differs by cold, snowy winters and warm summers, and the oceanic climate — by warmer winters and cooler summers than on the continents.

The climate of the subpolar and polar regions has the following specific nature: in summer, northward winds prevail, and in winter — the southward winds. Winters are very cold, and summers are relatively warm. Temperature fluctuations are most pronounced in this zone. The oceanic climate is characterized by small annual range of temperature, mild winters and cold summers. In the Polar Regions, snow cover is observed throughout

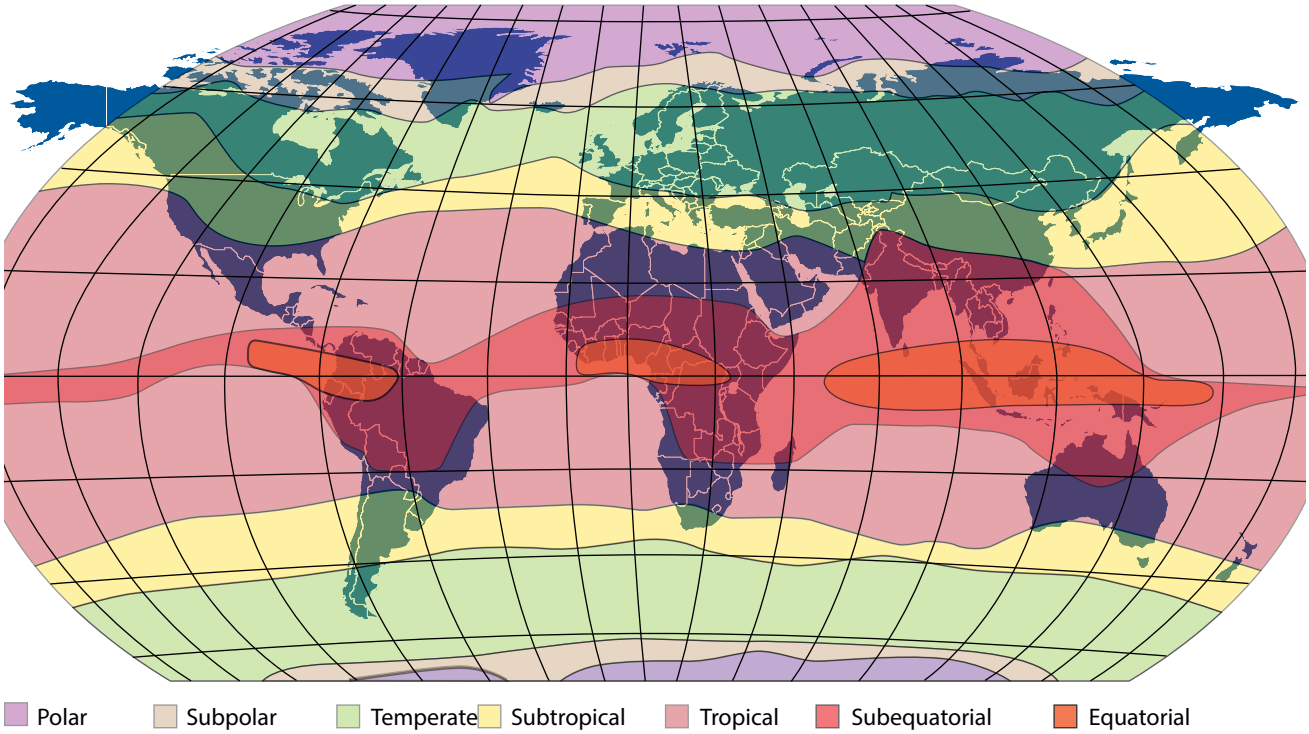


Fig. 10.2. Climatic zones of the Earth

the year. In the central regions of the Arctic and Antarctica, anticyclone weather prevails. The continental polar climate has very cold winters and cold summers.

There are several applied classifications of climate. In the construction classification, the territory of the former CIS countries, according to the average temperatures in January and July, is divided into four climatic regions: I — cold; II — moderate; III — warm; IV — hot (Table 10.1). The climate of Ukraine belongs to the II, III and IV climatic regions of this classification.

This classification is taken into account when solving the following issues: planning and housing development of settlements, orientation of buildings, calculation of wall thickness, size of window apertures, depth of water and heating piping, landscaping, etc.

10.5. Climatic zoning of Ukraine

According to climatic and landscape features, the following zones of Ukraine are distinguished: 1) Polissia; 2) forest-steppe; 3) steppe; 4) the Carpathians; 5) the Crimean mountains (Fig. 10.3).

Polissia is a zone located in the northern part of Ukraine. Its southern border runs along the following line: Lutsk, Shepetivka, Zhytomyr, Kyiv, Nizhyn, Konotop. In Polissia, summer is moderately warm, and winter is relatively mild. In the western part of Polissia, the average January temperature is –4.5 °C, and, on the left bank Polissia, it is –7.8 °C; in July, the average temperatures are 17–18 °C and 19–20 °C respectively. The average annual temperature is 7–5.5 °C, absolute minimum reaches –32–(–35 °C) (very rarely, usually –25 °C), and absolute maximum is 35–36 °C. There are often thaws in winter. The annual precipitation is 500–600 mm, 70 % of which accrue to April — October, 30 % — to the cold months. The total number of days with precipitation is 170–190, and days with a relative humidity of 30 % and less — 13–20 per year.

Forest-steppe. The southern border of the forest-steppe runs along the following line: Kotovsk, Kropyvnytskyi, Kremenchuk, Poltava, Kharkiv. The climate is moderately warm. The average temperature in January is –7…–8 °C, in July is 18–21 °C, and the absolute minimum is –31 °C. The frost-free period lasts 160–170 days. Precipitation is up to 700 mm per year (less precipitation in the east); seasonal snow cover is observed for 90–100 days (from November 15–20).

Table 10.1. Climatic zoning of the territory of CIS countries (construction classification of climate)

Climatic		Characteristics of temperature and humidity conditions of subregions					
Region	*Subregion*	*The average monthly temperature in January (°C)*	*The average monthly temperature in July (°C)*	*The average monthly relative humidity in July (%)*	*Precipitation (mm per year)*	*Prevailing wind direction*	*Average wind speed, m/s*
I	I A	–32 and lower	+4 to +19	omitted	192	N-NE	omitted
	I B	–28 to –32	0 to +13	more than 75	206	N-NE	5 and more
	I C	–14 to –28	+12 to +21	omitted	406	N-NE	omitted
	I D	–14 to –28	0 to +14	more than 75	456	E	5 and more
	I E	–28 to –32	+10 to +21	omitted	496	E	omitted
II	II A	–4 to –14	+8 to +12	more than 75	582	N-NE	5 and more
	II B	–3 to –5	+12 to +21	more than 75	605	W	5 and more
	II C	–4 to –14	+12 to +21	omitted	494	N	omitted
III	III A	–2 to –20	+21 to +25	omitted	295	NE	omitted
	III B	–5 to +2	+21 to +25	omitted	310	W	omitted
	III C	–5 to –14	+21 to +25	omitted	318	NE	omitted
IV	IV A	–10 to +2	+28 and higher	omitted	244	E	omitted
	IV B	+2 to +6	+22 to +28	50 and more	100	E	omitted
	IV C	0 to +2	+25 to +28	omitted	34–98	NE	omitted
	IV D	–15 to 0	+25 to +28	omitted	34–98	NE	omitted

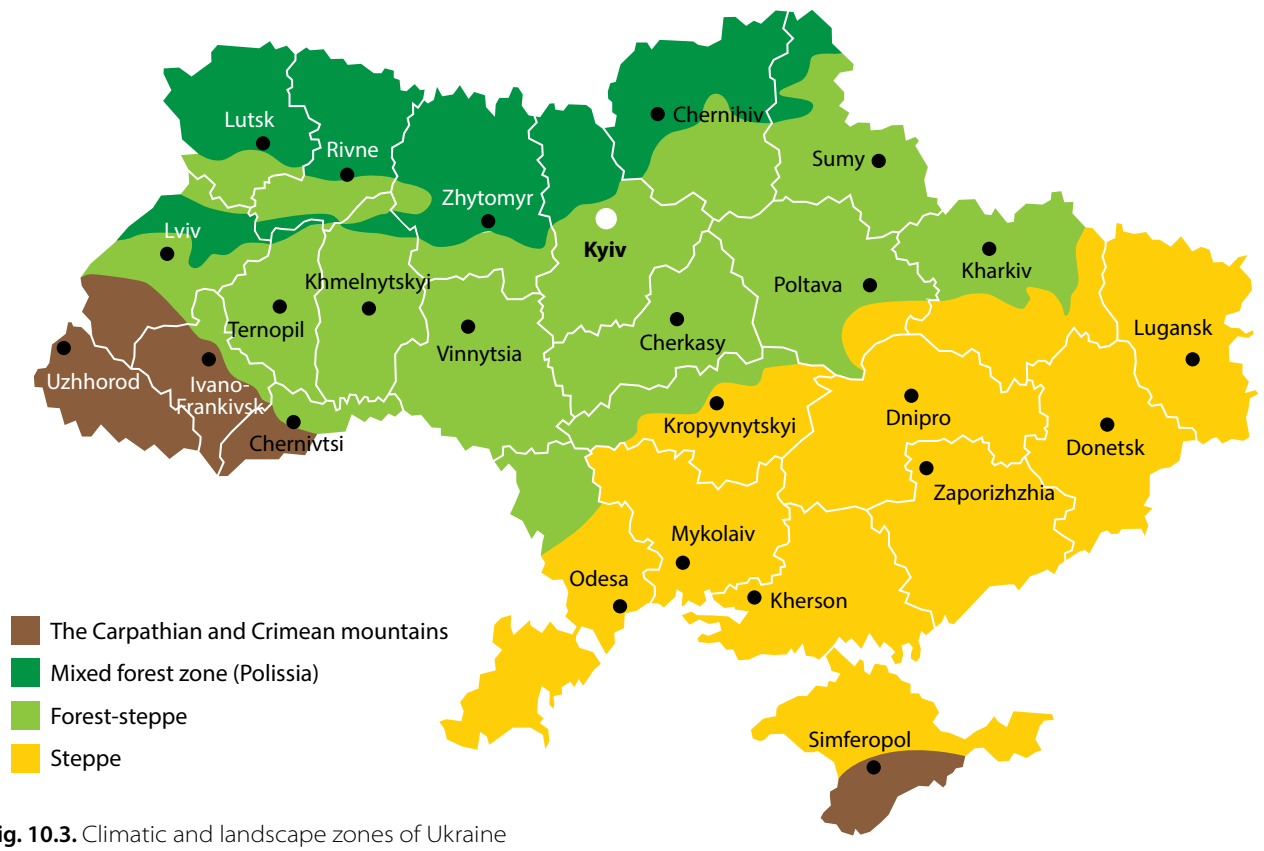


Fig. 10.3. Climatic and landscape zones of Ukraine

There are northern, central and southern *steppe*. The southern border of the steppe zone runs along the following line: Rozdolna, Odesa, Mykolaiv, Northern Crimea, Mariupol. The average temperature in January is –5…–2 °C, and, in July, it is 20–22 °C. Precipitation is relatively low — 250–300 mm per year; there are often dry hot winds with speed up to 10–12 m/s.

The Carpathians. Temperature conditions are roughly the same as in the forest-steppe, but summer and autumn are rainy. The amount of precipitation is 800–900 mm per year.

The Crimean Mountains (the South Coast of Crimea). The average temperature in January and in July is 4 °C and 24 °C respectively. This region is characterized by warm and sunny weather with a relatively small amount of precipitation — 400 mm per year. The climate is dry with a relative humidity of 60–64 % on average.

Developing forecasts and storm warnings, the Ukrainian Weather Bureau uses the zoning of the territory of Ukraine based on the principle of commonality of topographic features (landscape), climatic and other characteristics. According to this zoning, the territory of Ukraine is divided into such regions:

- northern (Zhytomyr, Kyiv, Chernihiv and Sumy regions);
- north-western (Volyn and Rivne regions);
- western (Lviv, Zakarpattia, Khmelnytsky, Ternopil, Ivano-Frankivsk and Chernivtsi regions);
- central (Vinnytsia, Cherkasy, Kropyvnytskyi, Poltava, Dnipro regions);
- eastern (Kharkiv, Luhansk, Donetsk regions);
- southern (Odesa, Mykolaiv, Kherson, Zaporizhzhia regions and the Autonomous Republic of Crimea).

This zoning of the country best meets the goals of practical bioclimatology, the objective use of meteorological forecasts for medical and meteorological forecasting, and for further prevention of meteopathology-associated reactions in patients.

10.6. Medical classification of climate: favorable and unfavorable (cold, mountain and hot)

In medical practice, the climate is grouped into favorable and unfavorable.

A *favorable climate* is considered to be warm with low air temperature amplitudes, relatively small annual, monthly and daily fluctuations of other meteorological factors. The forest climate of the temperate zone and the climate of the South Coast of Crimea are favorable, i.e. put the minimum requirements to adaptive physiological mechanisms.

Unfavorable climate is characterized by significant daily and seasonal amplitudes of meteorological factors; such climate puts the increased requirements to adaptive mechanisms. These are the cold climate of the North, the hot mountain climate of the steppe regions of Central Asia.

The main features of the climate in these areas are as follows.

The *cold climate of the North* (Fig. 10.4, Fig. 10.5) is characterized by low air temperatures, permafrost, and privation of light in winter (polar night) and ultraviolet deprivation, strong winds, uniformity of the landscape. This causes a number of relevant responses: stress of thermoregulatory functions, narrowing of capillary vessels and increase in circulating blood volume, decrease in pulse rate, and increase in basal and other types of metabolism, gastric hypersecretion. It can also cause the following disorders of the nervous system: intensification of inhibitory processes, weakening of conditioned reflex activity, negative psychological reactions due to the depressing effects of darkness, uniformity of the landscape, reduced performance capability, sleep disorders, irritability (during the polar night). In such conditions, exacerbations of chronic diseases are also possible: neuropsychic diseases, rheumatism, cardiovascular diseases (especially hypertensive diseases), diseases of the stomach, intestinal tract, kidneys, etc.

The *hot climate* of the southern steppes (Fig. 10.6, Fig. 10.7) and deserts (Fig. 10.8, Fig. 10.9) is characterized by hot summers, large daily range of temperature of often more than body temperature, dry air, short winters, excess of solar radiation.

This causes overheating and associated stress of thermoregulation, increased sweating (6–10 liters per day) and loss of mineral salts and vitamins, decreased basal metabolism, dilated capillaries, decreased arterial blood pressure, increased pulse rate and respiration, decreased erythrocytopoiesis, gastric hypersecretion, thirst, decreased appetite. In the hot hours of the day, work leads to exhaustion. This climate adversely affects many patients, for example, patients with cardiovascular, endocrine, neuropsychiatric diseases, tuberculosis, etc. Excess of ultraviolet radiation increases the incidence of skin cancer (especially in people with weakly pigmented skin), and excess of infrared radiation — cataract in-



Fig. 10.4. Cold climate of the North. A still from the movie *To the Arctic 3D, MacGillivray Freeman Films*



Fig. 10.5. Cold climate of the North. Source: *pic2me*



Fig. 10.6. Hot climate of the southern steppes. The Crimean steppe. Source: *zamky.com.ua*



Fig. 10.7. Hot climate of the southern steppes. The Chomutov steppe. Source: *pic2.me*



Fig. 10.8. Hot desert climate. The Sahara Desert. Source: *wordpress.com*



Fig. 10.9. Hot desert climate. The Kalahari Desert. Source: *nihaowang.com*

cidence. The dry steppe climate is favorable for patients with neuroses and contraindicated in the case of nephrolithiasis.

The *mountain climate* (Fig. 10.10, Fig. 10.11) begins at an altitude of over 2000 m. It has the following features: sharply reduced atmospheric pressure and oxygen partial pressure, dry and allergen-free air, low temperature, strong winds, intense solar radiation, high albedo of snow. In addition to the phenomena of oxygen starvation, it causes compensatory erythrocytopoiesis, increased vital capacity of the lungs, shift of acid-alkaline balance towards alkalosis, stress of thermoregulatory functions, light associated (visual) discomfort.

10.7. Acclimatization, its phases. Hygienic methods to improve the acclimatization of healthy people and patients

Repeated influence of climatic conditions and related microclimate patterns of habitation, food, clothing, day regimen on the human body leads to the formation of numerous compound reflexes and certain dynamic stereotype.

However, the development of social formations, advances in science and technology are inextricably linked with human migration, relocation to other climatic regions. The relocation of individuals and groups to new climatic conditions dictates the need for the alteration of a dynamic stereotype — acclimatization. New climatic conditions act as stress.

Acclimatization is a complex biosocial process of active adaptation to new climatic conditions. Repeated influences of new climatic factors lead to the emergence of a dynamic stereotype that best corresponds to the specific climatic conditions. Thus, acclimatization is a physiological adaptation, the capabilities of which largely depend on the conditions of work, life and nutrition, which mitigate and compensate for the effects of adverse conditions.

Physiological mechanisms of acclimatization are diverse. They depend on climatic influences. Thus, during acclimatization to high air temperatures, in addition to the reaction of the cardiovascular system, the secretion of sebum increases. As a result, sweat is evenly distributed on the skin surface and evaporates better. Acclimatization in hot climates is characterized by a decrease in pulse rate and respiration, some decrease in body temperature. There is a steady decrease in basal



Fig. 10.10. Mountain climate. Source: *expeditionsolidaria.org*



Fig. 10.11. Mountain climate. Source: *maharajatourstravels.com*

metabolism by 10–15 %, and blood pressure — by 15–25 mm Hg.

Prolonged and frequent exposure to cold leads to:

- increased metabolism;
- increased heat production;
- changes in both local and remote vascular response;
- increased circulating blood volume;
- body temperature recovers faster during cooling, etc.

There are **three phases of acclimatization:**

- Phase I (initial) — physiological reactions that have been described previously in the case of cold, hot and mountain climates;
- Phase II — dynamic stereotype reformation (favorable or unfavorable manifestations);
- Phase III — stable acclimatization.

If the alteration of the dynamic stereotype is favorable (socio-hygienic measures may be useful in this case), then the second phase gradually passes into the third phase. If the course of the second phase occurs with complications, the following adverse manifestations are observed: significant maladaptation meteoneurosis, meteorological arthralgia, cephalgia, myalgia, decreased vigor and performance, exacerbation of chronic diseases. However, the transition to the third phase can be achieved through the appropriate preventive medical and hygiene measures. Only if the course of the phase is extremely unfavorable, such a transition is not observed, and there are intensified pathological manifestations with no acclimatization. In this case, the person should return to the previous climatic conditions.

The third phase is characterized by the stability of metabolic processes, absence of nutrition disorders, unimpaired performance, "usual" level and incidence of the diseases, normal birth rate, healthy physical development of newborns.

Acclimatization occurs when the new climatic conditions do not make excessive demands that go beyond the compensatory capabilities of the body. Acclimatization to a hot climate is more difficult than to a cold one. The problem of acclimatization is of a great relevance because the development of the national economy requires the settlement of people in underpopulated and undeveloped places, and climatic zones are very diverse.

Acclimatization processes should be considered when moving to an area with a different climate, whether it is a health resort treatment, health-related trip, expedition, temporary or permanent residence or service at military bases.

If the health resorts are chosen correctly, acclimatization usually passes without complications.

Acclimatization is more difficult for migrants (or displaced residents), because, in addition to the climate change, they are forced to adapt to new living conditions. In such cases, there is often a reduced resistance to local diseases.

Personal hygiene, individual hardening (health promotion) and training are of great importance in a case of acclimatization. It is reasonable to perform a relocation of migrants during the transition periods of the year, when there are smaller differences in climatic conditions. However, the most important role is played by social and hygienic measures.

In the context of the North conditions, the following measures are reasonable to improve acclimatization: compact building development of settlements, structural arrangement of end walls of buildings to face the prevailing cold winds, covered passages between separate buildings, large usable space of the premises (a person spends more time indoors), winter gardens indoors. Considering solar starvation, preventive ultraviolet irradiation is carried out with the help of sunlamps (at photariums, production sites, home, swimming pools, gyms, child welfare institutions), which allows to effectively combat rickets and other manifestations of ultraviolet insufficiency. It is advisable to use only those light sources which spectrum is close to the spectrum of natural light.

In the North, food must have a high calorie count to compensate for the energy consumption that increased by 15–25 %. Additionally, food must be sensible (taking into account lifestyle, liability to coprostasis, insufficient amount of vegetables and fruits). The diet should contain at least 14 % of protein, including 60 % of animal protein, and at least 30 % of fat. The increased content of ascorbic and nicotinic acids, vitamin B and D complexes in the diet is of particular importance. Extreme climatic stimuli intensify the activity of sympathetic nervous system, and this causes increased consumption of ascorbic acid.

Clothes should reduce heat loss. Therefore, it should have low thermal conductivity and should be dry and windproof (two-layer clothing: top layer + capes of air- and moisture-proof fabric, coat). Shoes should be 2–3 sizes larger for opportunity to wear additional leggings, socks. Special glasses are used to protect the eyes from light reflected from the snow cover.

In a hot climate, the building development of settlements has less density with maximum planting of free space. Great attention should be paid to the improvements of public gardens (fountains), parks, to the construction of outdoor swimming pools and improvements of suburban areas (water reservoirs). In the hot climate zone, the following measures should be provided to reduce premises heating: sun protection measures, avoidance of western and south-western orientation of buildings, active indoor air ventilation (exhaust ducts, ventilation systems), open premises — balconies, verandas, etc. The most effective measure is air conditioning, which is used primarily in hospitals, enterprises, public buildings, child welfare institutions.

The balanced water-intake regimen and nutrition is of vital importance. Caloric value of the diet is reduced mainly due to animal fats, and content of mineral salts and water-soluble vitamins is increased, because they are lost with sweat. The dietary regimen is also changed: the main meals are in the morning and in the afternoon, not during the heat.

In the south, people need to protect their skin, in particular from solar hyper-irradiation (ultraviolet radiation). Therefore, appropriate clothing should be chosen for protection and heat loss.

Experience has shown that people can adapt to different climatic zones if they use the above measures. In this case, there is usually a complete acclimatization (no adverse health changes and high performance capability).

10.8. Climatic prophylaxis, climate-therapy, climatic health resorts

Climate-therapy is a factor in increasing the non-specific resistance of the body.

Based on the study of physiological changes in the body after climatic effects, the climate-therapy has a status as a factor in increasing non-specific resistance of the body.

The main elements of climate-therapy are:

1. Identical direction of physiological changes under the influence of the same method of climate-therapy of different diseases.
2. The same direction of physiological changes when using different methods of climate-therapy for the same disease.
3. The same climatic treatment method has a preventive effect in a case of different diseases.

The same reactions are manifested from any type of climatic treatment: training of thermoadaptation mechanisms, stimulation of metabolic processes, normalization of reactivity, restoration of functional state. Such treatment promote the increase in body's resistance to

diseases, decrease in the number of disease recurrences, the increase in body's functional reserves and adaptive capabilities. The general end nonspecific effect for different climatic influences affects the level of the organism as a whole, although first of all there may be a reaction from a certain physiological system depending on the stimulus: thermoadaptation in the case of aerotherapy, sympathoadrenal system and neurohumoral regulation — heliotherapy, circulatory, respiration, musculo-skeletal systems, thermoregulation — in the case of thalassotherapy with sea bathing.

The points of application of different climatic factors are always different, which reveals the specificity of their action differently reflected in the respective reactions of the organism. The endpoint of the appropriate effect for a particular state of the organism is to increase (renew) the tolerance of the organism, the level of functioning of all systems, which is general and nonspecific. Therefore, the nonspecific effect is achieved due to the specific influence of certain meteorological factors.

Experimental studies have shown that sunlight or ultraviolet radiation inhibits the development of atherosclerosis and hypertension, i.e. has a prophylactic nonspecific effect. This effect, in the case of atherosclerosis, is manifested by a decrease in serum cholesterol and lipids, in the case of hypertension — an increase in the latent period of the disease and a decrease in the degree of changes in the ECG.

Therefore, the effect of ultraviolet radiation on various diseases can be ambiguous, reflecting the features of specific (pathogenetic) mechanisms of development of one or another disease.

The nonspecific end effect of helio-, aero- and other prophylaxis (therapy) is increasing of the body's resistance. It is achieved through the restructuring of adaptation mechanisms, changing the threshold of their response. The trigger mechanism activates various physiological and biochemical processes, which ultimately cause a restructuring of adaptive reactions. Thus, on the one hand, the action of the same factor is specific for each disease, and, on the other hand, the action of different factors during one disease is specific.

Therefore, the factor affects specifically if it has a permanently fixed destination; in other words, the ways to achieve a general nonspecific effect — increasing the body's resistance — in climatotherapy are different and specific to each climatic method of treatment, i.e. nonspecific effect at the body level is manifested through specific effects (at the system, organ, cell levels).

Climatic health resorts. A more favorable climate compared to the climate of permanent residence is used for health purposes. It is believed that the area suitable for climate-therapy should have the following properties (Fig. 10.12):

1. Clean air, free from contaminations and allergens.
2. Favorable insolation (direct and diffuse).
3. Moderately humid air with slightly changeable temperature and humidity.
4. Appropriate conditions for heat transfer with no irritating strong winds.

The climate of coniferous and deciduous forests is especially noteworthy (Fig. 10.13). It has cool and clean air, high humidity and calm winds. This creates conditions for the organization of forest health resorts and recreation centers.

The climate of the temperate (mixed) forest zone is the most favorable for recreation and treatment of people with diseases of the respiratory, nervous and cardiovascular systems, metabolic disorders, etc. The climate of the zone can be used to expand the adaptive capacity of people who due to circumstances are forced to work in areas with extreme weather conditions. The most favorable for recreation is the warm period from May to October, and unfavorable — from November to April with peaks in December, February — March. The period of August — early September within the zone is a stable



Fig. 10.12. Requirements for climatic health resorts



Fig. 10.13. Coniferous forest at a climatic resort. Source: *ecolog.ua.com*

period without extreme changes in the main meteorological elements, which is especially favorable for the rest of debilitated patients.

It should be noted that the coniferous forest could cause the health deterioration in patients with cardiovascular diseases. Such effect is due to ozone formed during the oxidation of essential oils. The concentration of ozone increases with increasing air temperature. In the young coniferous forest, it is higher than in the old one. After staying for 2 hours in the forest with the ozone concentration of 0.004 mg/l (maximum allowable concentration 0.0001 mg/l), patients have dry mouth, retrosternal pain, impaired concentration, sleep disorders, cough. An important role in the impact on cardiac patients and the appearance of allergic reactions is played by pinene. It is the main active basis of volatile essential oils of coniferous forest.

The forest-steppe zone is characterized by moderate solar radiation, predominance of the flat surface with forest areas. In the conditions of forest areas, the chemical composition of the air changes significantly. It depends primarily on the tree species. The climate of the forest-steppe zone is the most favorable for recreation and treatment of people with diseases of the respiratory, digestive, nervous and cardiovascular systems, metabolic disorders, etc. The warm period from May to October is the most favorable for health purposes.

The steppe zone contains flat lands located at an elevation of 150–250 m above sea level or above the river valleys. A significant number of hours of the Sun's radiance and predominance of anticyclone weather conditions provide the opportunity for climate-therapy in the most optimal conditions throughout the year. According to the biological significance of solar radiation, the steppe zone is characterized by a small period of ultraviolet insufficiency and strong biological activity of solar radiation in the warm period of the year. Summer is sunny, warm and dry. It lasts from mid-May to mid-September. The steppe zone is distinguished by high frequency of sunny weather with a predominance of hot and dry conditions. Such features can cause a danger of overheating of the body, so the most favorable conditions for aerotherapy are in the morning hours. In autumn, the weather conditions are close to summer and is also favorable

for treatment. The period of widespread rains begins at the end of October. Variations of the weather conditions in autumn are more pronounced than in summer.

The climate of the steppe zone is favorable for the use of all types of climate-therapy. The warm period from May to October is the most favorable for recreation and treatment. During this period in the south of the zone, thalassotherapy can be widely used as the main method of climate-therapy. Meteorological conditions for air baths of the steppe zone in the warm period of the year are characterized as cool and comfortable in natural conditions. In the summer months, there is a high frequency of hot weather in the southeast of the zone. Such uncomfortable weather can cause meteotropic reactions, especially in patients with cardiovascular diseases.

The warm and mild Mediterranean climate of the Southern coast of Crimea (Fig. 10.14) and part of the Black Sea coast of the Caucasus has a beneficial effect on the human health — increase in the number of erythrocytes and hemoglobin, improvement of metabolism, and growth acceleration in children. Clear weather, clean air, the sounds of the sea have a positive effect on the nervous system and on the body as a whole. However, excessive solar radiation and disregard of the doctor's recommendations lead to hyperirradiation with the previously mentioned complications. If people with allergic diseases fail to abide by the gradual acclimatization, the course of their diseases may worsen.

The subtropical climate of the Black Sea coast from Tuapse to Batumi (Fig. 10.15) is characterized by high temperatures and humidity. Such conditions deteriorate the body's heat exchange. This area is favorable for recreation and treatment only in certain seasons.

A distinctive feature of the mountain climate (Fig. 10.16, Fig. 10.17) is the lower interdiurnal variability of the main meteorological factors. Mountain air is characterized by greater purity, saturation with negatively charged ions. The number of hours of sunlight and the biological activity of the ultraviolet part of the spectrum are increasing in the mountains. In the mountain climate, vigor, heart rate and respiration increase, lung activity intensifies and their vital capacity increases, the number of erythrocytes and hemoglobin increases (from a height of 100 m), and the body's thermoregulation improves. The vertical location of the belts creates unique conditions and great opportunities for treatment and recreation.

The doctor must take into account climatic conditions when solving hygienic issues in the period of



Fig. 10.14. Mediterranean climate of the Black Sea coast of Crimea. Source: *warsawinstitute.org*



Fig. 10.15. Subtropical climate of the Black Sea coast of the Caucasus. Source: *v-georgia.com*



Fig. 10.16. Mountain climate of the Carpathians. Bukovel in winter. Source: *pinterest.com*

building development of new settlements, rationing of housing and hospital services, and during the control of infectious and non-infectious diseases, study of natural pathogens, detection and elimination of endemic diseases, and especially when using natural climatic factors for health-improving and therapeutic purposes.

Appropriate choice of climatic conditions for a diseased or weakened organism facilitates its balance with the environment and contributes to the restoration of impaired nervous system function, better flow of trophic and plastic processes. Climate-therapy should be classified as the active, functional treatment that is close to pathogenetic. The essence of climate-therapy is defined as the effect of graduated intensity stress, which causes the activation of the nervous system and adrenal cortex. The positive effects of appropriate climatic conditions promote the establishment of balance at a new and even higher level of health.



Fig. 10.17. Mountain climate of the Carpathians. Bukovel in summer. Source: *pinterest.com*

11

CHAPTER

HYGIENIC SIGNIFICANCE OF NATURAL AND ARTIFICIAL ILLUMINATION, NOISE, ELECTROMAGNETIC RADIATION IN THE CONDITIONS OF POPULATED LOCALITIES

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Rational natural and artificial illumination is a necessary condition for the normal workability of the visual analyzer in a favorable mode for the whole body. Insufficient or irrational illumination leads to fatigue of vision, central nervous system, reduces mental and physical workability, promotes the development of myopia in children and adolescents.

11.1. Significance of illumination in human life

Illumination — natural or artificial — is a condition that ensures the functioning of the visual analyzer. The visual analyzer is considered the most sensitive of all human analyzers.

The idea of the integrity of the organism, clearly expressed in the works of I. P. Pavlov, is also confirmed in the reaction of the organism to the action of light. Acting through an adequate receptor — the visual organs, light causes excitation of the optic nerve endings, which extends to the sensory centers of the optic hemispheres and, depending on a number of conditions, excites or suppresses the cerebral cortex, rearranging physiological responses, changing overall tone, maintaining active and energetic state.

There are changes of metabolic processes in the body, increased gas exchange, nitrogen and mineral metabolism under the action of visible light. Light promotes the growth and weight increasing of animals (Godnev's experiments on kittens and chickens), as well as the rapid scarring of wounds (his experiments on puppies). Even different colors, in other words, rays with different wavelengths, effect differently on the central nervous system. It is known that red rays are stimulating, blue — soothing, and extreme blue — even depressing. Yellow, blue and green colors are the most pleasant.

Dr. Gorbatsevich, after conducting very interesting experiments, found a pronounced effect of rays with different wavelengths on the psyche of animals. He kept puppies of the same breed, one brood in cages of different colors. Experiments have shown that puppies that grew up in "white" cages had a character typical of this breed. Puppies that grew up in green cages became more playful, in orange cages — sluggish and angry. Puppies that grew up in purple and blue cages were marked by apathy.

S. V. Kravkov's monograph "Color Vision" provides interesting data that auditory sensitivity and muscle strength increase in green lighting and decrease in red lighting.

In Shcherbakov's experiments, only a change in the light regime caused the monkeys to disturb the curve of motor activity and body temperature, change the frequency of respiration and pulse, and the acidity of urine.

These facts indicate a great general biological influence of visible light.

According to S. I. Vavilov: "Light is a necessary condition for the work of the eye — the largest universal and powerful sense organ." The German physicist Helmholtz called human vision the most wonderful gift of nature.

Due to the organ of vision, people receive more than 80 % of information about the environment.

11.2. Influence of visible light on humans and the environment

1–2 photons are enough to feel light. People see at day and at night, although solar radiation creates the maximum illumination of the horizontal surface up to

100.000 lux, and lunar radiation — only up to 0.25 lux, stellar radiation — up to 0.001 lux.

Light:

1. Stimulates the vital activity of the organism.
2. Strengthens the metabolism.
3. Improves overall well-being.
4. Improves emotional mood.
5. Increases efficiency.
6. Thermal effect (up to 50 % energy).
7. Appears through the skin at 2.5 cm and:
   - enhances biochemical processes;
   - enhances immunological activity;
   - enhances pituitary secretion and metabolism;
   - increases excitability of the cerebral cortex;
   - signaling or conditioned-reflex significance.

In the long-wave part, light has the properties of infrared radiation, in the short-wave part — UV (erythematous, pigment-forming, bactericidal, general stimulating effect) (Fig. 11.1).

In addition, visible light has — depending on the spectrum — differences in psychophysiological action. Thus, violet and blue rays suppress neuropsychological activity, blue rays have a calming effect, green — indifferent, but stimulate the digestive process, bright yellow — irritate, red — excite.

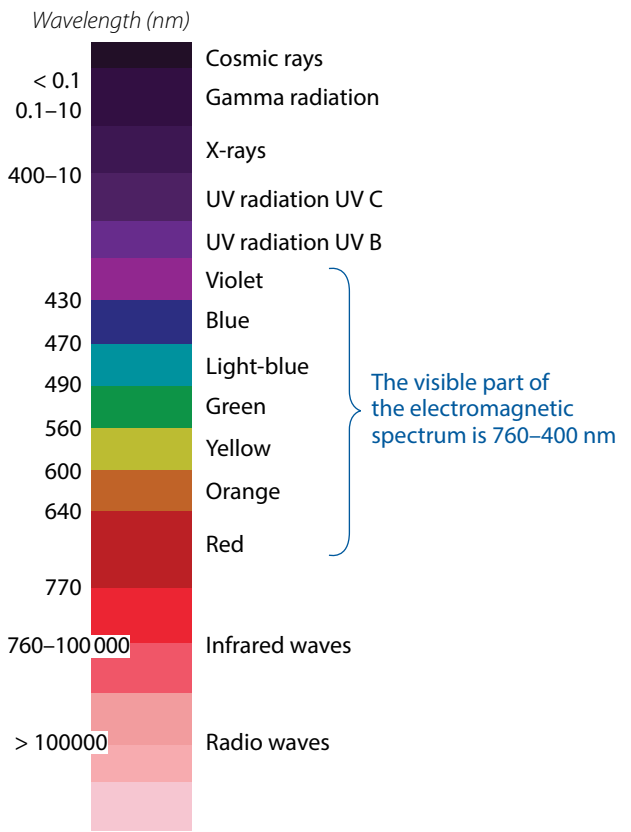


Fig. 11.1. Solar radiation (electromagnetic spectrum)

Visible radiation effects on not only the human body but also the environment. It provides:

- photosynthesis;
- phototaxis;
- bioluminescence.

As Professor I. Liechtenstein noted, light heals the environment. *"Wherever the Sun does not look, the doctor must look there more often".*

Insufficient lighting has a negative effect on the organ of vision, body functions in general:

- accelerates fatigue;
- reduces resistance;
- reduces productivity;
- promotes the development of myopia;
- the occurrence of injuries.

Possible changes in the human body when exposed to excess sunlight:

1. Blinding.
2. Erythema.
3. Overheating.
4. Sunstroke.
5. Exacerbation of chronic diseases.
6. Sensitization of the body.

Rational lighting in nowadays time of advances in science and technology increases the functional state of the visual analyzer, the whole body, the speed of orientation, reaction.

11.3. Basic provisions characterizing the physical basis of lighting

Visible or light radiation from the Sun has a wavelength of 400–760 nm (Fig. 11.1) and a photon energy of 1.66–2.75 eV.

The capacity of such radiation is called luminous flux. Radiations that are the same in power but different in wavelength have different light efficiencies. The human eye has the highest sensitivity at a wavelength of 555 nm (yellow-green part of the spectrum). The relative sensitivity of the eye to different parts of the spectrum is called relative visibility.

The sensitivity of the eye in the red or purple part of the spectrum decreases sharply, especially in adults and the elderly. In recent years, the decline is greatest in blue-purple area.

It is known that with age the yellowness of the retina increases.

The greatest sensitivity of the eye to all parts of the spectrum is in the age group of 22–28 years. It is non-standard in younger people. This fact has not yet found a scientific explanation.

Artificial lighting, as well as natural, is characterized by the following physical parameters:

- light intensity (I) is the power of light sources, which is determined in candelas (Kd). This is the power of light, which generates in a certain direction monochromatic radiation with a frequency of 540×1012 Hz, the energy power of light in this direction is 1/683 W/steradian;
- luminous flux (F) is the spatial density of light radiation, the unit of which is the lumen (lm) is the luminous flux emitted by a single source at a light intensity of 1 kd at a body angle of 1 steradian (spatial angle in the form of a cone with a vertex in the center of the cutting sphere the surface of this sphere is a surface whose area is equal to the square of the radius of the sphere);
- illuminance (E) is the surface light flux density. Determined by the formula:

$$E = \frac{F}{S}$$

where S is the area of the illuminated surface, m^2. Unit of illumination is lux (lux) — illumination of a surface of 1 m^2 with a luminous flux of 1 lm;

- brightness (B) is the intensity of light emitted or reflected per unit area in m^2 in a certain direction:

$$B = \frac{I}{S \times \cos \varphi} \text{ cd/m}^2,$$

where: φ is the angle of deviation of the beam from the normal to this surface. The unit of brightness is cd/m^2 — the brightness of the luminous surface (generating or reflecting) from an area of 1 m^2 at a light intensity of 1 cd.

The level of brightness of the luminous surface is determined by its brightness. Permissible brightness 2000–5000 cd/m^2. Brightness of more than 5000 cd/m^2 causes a dazzling effect, depending on the light intensity, the reflectivity of the surface, the reflection coefficient. And partly transmitted, partially absorbed, partially reflected.

- reflection coefficient (b) — the ratio of the reflected light flux ($F_{ref.}$) to the flux incident on the surface ($F_{inc.}$); determined by the formula: $b = F_{ref.}/F_{inc.}$ The value of b for fresh snow is — 0.9 (90%), for white paper — 0.7 (70%), for non-tanned skin — 0.35 (35%);
- light transmission coefficient (t) — the ratio of the luminous flux that passed through the medium ($F_{pass.}$) to the luminous flux incident on this medium ($F_{inc.}$): $t = F_{pass.}/F_{inc.}$ This coefficient allows to estimate quality and purity of window glass, glass of lighting fittings;
- luminosity (M) — the surface density of light flux in lm, emitted (or reflected) from an area of 1 m^2 (lm/m^2).

11.4. Functions of the visual analyzer

The functions of the visual analyzer characterize its functional state. They are the physiological basis for substantiating the hygienic requirements for lighting conditions.

The main functions of the visual analyzer:

- visual acuity;
- contrast sensitivity;
- speed of discrimination of image details (visual perception speed);
- clear vision stability;
- color recognition of the image;
- light adaptation;
- dark adaptation;
- accommodation;
- critical flicker frequency.

Most often, the first three functions are taken into account in the hygienic rationing.

Visual acuity is the ability of the eye to distinguish the smallest details of an object. It is determined by the angle at which two adjacent points are perceived as separate. Visual acuity (visual) is estimated in relative terms and is normally equal to 1. Visual = 1, if the angle = 1 min. From 100–150 lux the visa increases.

Contrast sensitivity is the ability of the eye to perceive the minimum difference between the brightness of an object and the background. If the work surface reflects 30–40% of light, the contrast sensitivity is highest at 1000–2500 lux.

The visual perception speed, or the speed of visual perception, is the shortest period of time during which the details of an object are distinguished. It grows with increasing illuminance to 100–150 lux. Then it slowly increases to 1000 lux. All visual functions are interconnected and determine the integral function — visibility.

The clear vision stability is determined by the ratio of the time of clear vision of the details of the object to the total time of its observation. This function is deter-

mined by the rate of destruction of visual purpura and the formation of protective visual black pigment in those areas of the retina where the image is the brightest. This feature characterizes the fatigue of the visual analyzer. Fatigue increases with poor lighting. It does not occur prematurely at 600–1200 lux.

Color recognition due to brightness and chromaticity. The eye is most sensitive to the yellow-green part of visible light; least sensitive to blue and purple. White and black — achromatic — are characterized only by brightness. At dusk, the sensitivity to color drops to zero.

Adaptation is the ability of the eye to reduce sensitivity during the transition from low light to high (light adaptation) and increase it during the transition from high light to low (dark adaptation). Light adaptation occurs within 2–3 minutes, dark — 20–60 minutes. Adaptation is affected by uneven lighting. The more even — the better.

Accommodation is the ability of the eye to regulate visual acuity by changing the curvature of the lens. In case of insufficient lighting, visual acuity decreases. There is myopia.

Critical flicker frequency is determined by the time during which trace images are stored in the visual analyzer. At the heart — the destruction and renewal of visual purpura. 25 frames per second ensure image continuity.

Therefore, all functions will be optimal if the lighting meets the basic hygienic requirements:

- optimal spectrum of rays;
- sufficient lighting;
- uniform lighting.

The brightness of the light source and reflective surfaces correspond to visual functions.

11.5. Hygienic requirements for natural light

Spectral composition. The standard spectrum of daylight is the spectrum of light from the cloudless sky in a room with a north-facing windows. In this light, the human eye distinguishes up to 6.000 shades of different colors.

Professional skills are important — artists, make-up artists are able to distinguish up to 30.000 shades.

Works in which you need to distinguish colors, can be performed only in daylight, so, for example, artists' workshops are oriented to the south.

Different colors have their own psychophysiological effect. White — snow, blue, purple — water, sky. They are cold. Green — grass, trees. This is a neutral color. Red, orange, yellow — the Sun, fire. These are warm colors.

White walls create a feeling of cold, cream, pink — warmth. Color affects the course of disease. Animal experiments have shown that blue color promotes rapid recovery.

The visual analyzer is less tired at yellow, green colors of furniture, walls, floors.

Lighting varies depending on external conditions: latitude, season, time of day, climatic conditions, clouds, purity of the atmosphere, the reflectivity of surfaces, the presence of objects that create shade. And also from the conditions in the room: orientation of windows, their quantity, the area, a configuration, thickness of frames, quality and purity of glass, depth of rooms, reflectivity of a ceiling, walls, furniture.

The illuminance of the surface is directly proportional to the intensity of light and inversely proportional to the square of the distance. $E = I / L^2$.

Levels of illumination with which the person meets: in a sunny day in the summer in the open air — 100 000 lux, in a shade — 25 000–50 000 lux, on a cloudy day in the summer in the open air — 12 000–20 000 lux, at a big cloudiness in the summer — 5000 lux, in winter — 2000–3000 lux, in the bright moon — 0.25 lux, in the starry sky — 0.001 lux.

The main requirement is **sufficiency**. It has a positive effect on the functions of the CNS and provides a stable long-term operation of the visual analyzer. Optimal illumination of 1200 lux. With a free choice of light level in terms of production, most workers choose 750–1200 lux. The optimal level of illumination increases with age.

Uniformity of illumination promotes maintenance of a high functional condition of the visual analyzer. As a rule, when using natural light, there may be problems with the rapid transition from a brightly lit area to a dark room or vice versa. Frequent readaptation causes fatigue of the visual organ, reduces productivity, leads to injury. For example: metro drivers on some lines of Kyiv need to use goggles and additional tunnel lighting.

Brightness should be optimal. It is necessary to prevent the creation of conditions that cause the blinding effect of surfaces, because it causes readaptation.

Brightness:

- the blue sky is 800–1600 cd/m^2;
- overcast sky — 4800 cd/m^2;
- white clouds illuminated by the Sun — 32000 cd/m^2.

Brightness up to 1000 cd/m^2 is optimal.

Brightness up to 2000 cd/m^2 — satisfactory.

Brightness up to 2000 cd/m^2 — tolerated without visual discomfort.

From 2000 to 5000 cd/m^2 — creates a dazzling effect.

Assessment of natural lighting of premises and buildings is carried out in accordance with DBN V.2.5–28–2006 "Natural and artificial lighting". Evaluated by two main methods: lighting (instrumental) and geometric (calculated).

The main index of natural light is daylight factor (DF).

There are actual DF (E_a) and calculated DF (E_c). E_a is measured with luxmeters. E_c has several methods of calculation: according to Danilyuk, Kitler, a simplified method. The minimum value of DF is taken for points located at a distance of 1 meter from the wall opposite the window at the level of the workplace.

The light coefficient (LC), angles of incidence, aperture, depth coefficient of the room are estimated by a geometric method. In addition, descriptive data should be evaluated. The insolation regime is also evaluated: maximum — 5–6 hours/day, floor insolation of 80 % and more than 550 kcal/m^2. Orientation: southwest (SW), southeast (SE).

Moderate insolation is 3–5 hours/day, 40–50 %, 500–550 kcal/m^2, SE-orientation of windows.

The minimum insolation regime is up to 3 hours/day, less than 30 %, less than 500 kcal/m^2, NE, NW, N-orientation.

It is established that the most favorable is the illumination by scattered sunlight. Human vision is best adapted to it in the process of phylogenetic development of man.

What are scattered rays? The sun's rays, passing through the atmosphere, bumping into air particles and other particles present in the atmosphere, are reflected, and only part of the direct sunlight reaches the Earth's surface. The reflected rays again collide with some particles and already in the form of scattered light fall on the Earth's surface. The human eye has adapted well to this diffused light.

When we do not see the Sun on a cloudy day, light still penetrates the Earth's surface due to scattered rays. Speaking of lighting, we understand lighting mainly in the premises — residential, public, industrial, etc., because outside the buildings during the day, as a rule, there is enough natural light.

In order to illuminate the room with daylight, different types of windows should be arranged. The room can be illuminated by vertically placed light slots located in the roof. The latter is possible, of course, only in one-storey houses; lighting would be best due to light slots located at the top of the roof; then the most light would get into the room. However, such lighting is not without its negative aspects. Horizontally or even obliquely placed light slots are quickly contaminated and then absorb many visible rays, letting little light into the room.

In some factories and other enterprises, single-storey shops have such overhead lighting, and experience shows that, despite even careful maintenance, the percentage of radiation absorption is very significant. Therefore most often light apertures are arranged in the walls.

It is natural that the greater the lumen of the windows, the more light will enter the room.

The big question is: is excess light possible? No, the human eye sees best outdoors, and in an open atmosphere the light is hundreds of times higher. In daylight with diffused light, outdoors, the human eye does not get tired for a long time. Therefore, it is natural that the more light enters the room, the better it is lit. Based on this, it would seem, you can build walls of glass so that a lot of light enters the room. This is hindered by other considerations. The thermal conductivity of windows is greater than the thermal conductivity of the walls, and therefore in those latitudes where it is necessary to store heat in the premises, it is impractical to arrange too large light slots. And in the southern latitudes, large light slots are undesirable, because the walls are a protection against excess heat coming from outside.

Therefore, developers sometimes try to make the light slots as small as possible. Hygienists, however, taking into account a number of considerations, develop optimal hygienic lighting standards, which will be discussed below.

The lighting of the premises is affected by the color of the walls. Receiving the same amount of light, the room may have different lighting depending on the color of the walls and ceiling. When sufficient light while whitewashing with chalk is taken as a unit, then to get the same light with light yellow walls, you need 4 times more light; with blue walls — 5 times more, with dark brown — 6 times.

This phenomenon depends on the percentage of absorption of light rays by the walls of different colors. The absorption of light by walls covered with wallpaper of different colors was studied. It turned out that white wallpaper absorbs only 8 % of light, yellow — 60 %, blue — 75 % and dark brown — from 87 to 96 %.

There is another important fact: the lighting is often affected by the color of the walls placed against the windows of the house. In cities where multi-storied buildings are built, very often the lower floors are only partial-

ly exposed to direct sunlight through window openings; they are largely illuminated by rays reflected from neighboring houses. If the latter are painted white or other light colors, they reflect the rays more and increase the brightness.

The number of rays entering the room largely depends on the nature of the glazing, as seen in Table 11.1.

As you can see, ordinary thin single glazing window retains 4% of light, and double glazing window retains up to 13% of light. Mirror glass (thick — 8 mm thickness) retains up to 10% of light, and glass like frosted can retain up to 66% (almost 2/3 of light), and milk even more — 75% of light.

Glass traps biologically active ultraviolet rays. However, ordinary glass does not block all ultraviolet rays. Window glass completely blocks ultraviolet rays with a wavelength of up to 320 nm.

Ultraviolet rays with a wavelength of more than 320 nm partially pass through the glass, but their intensity is significantly reduced. However, with the correct orientation of the windows, a sufficient number of rays can pass through them to sanitize the air in the room.

Belikova V. K. established the presence of bactericidal effect of ultraviolet rays penetrating through ordinary window panes on streptococci, but this required 2–3 hours of irradiation of the premises with direct sunlight. 2–3 hours of irradiation can be achieved only when the distance between the opposite buildings is not less than twice the height of the largest of them. On this basis, the norms of gaps between houses in cities have been established. This norm at meridional orientation of houses in average latitudes is equal to double gaps.

For the most favorable insolation, the orientation of houses in different latitudes should be different. It is recommended in settlements located to the south from 45° of north latitude (in the northern hemisphere), to orient buildings to the south, southeast or, at least, to the east-southeast. In areas located at latitudes between 45° and 52° of north latitude, windows should be oriented to the east-southeast and southwest. For areas on north from 52° of north latitude (these are temperate and cold zones), south-eastern and south-western orientations are recommended, eastern and western orientations are allowed. South in these conditions, at 52° north latitude, is not allowed, because the lower floors 3.5 months a year will not receive direct sunlight, even with a 5-fold gap (distance) between buildings.

Bedrooms in living premises: windows should face northeast, east and southeast. Study rooms, working rooms — windows should be oriented to the north, northeast and northwest.

Table 11.1. The degree of delay of sunlight depending on the quality of window glazing

Glass	Light retention (in % to falling)
Single glazing	4
Double glazing	9–13
Mirror	6–10
Matt	30–66
Milky	37–75

Dining rooms can have any orientation of windows. In this regard, it can be noted that the northern orientation is also undesirable for canteens. But a person does not stay in the dining room for a long time, and therefore the orientation is not crucial here. A person stays in the bedroom for a long time, and therefore the most favorable orientation is recommended here.

Kitchens, pantries for food storage can be oriented to the north, northeast and northwest. Such orientations from the point of view of a living room are not very favorable, and for the mentioned premises are quite admissible. Storage rooms can also be oriented by 8 rhumbs, as well as bathrooms and toilets. When considering the construction of residential and other buildings, it is necessary to take into account the orientation of the rooms for different purposes.

Ultraviolet rays have such a beneficial effect on the body and the healing of indoor air that an idea arose to make window glasses that would transmit these rays; they were called "**uviol**". Some children's institutions were glazed with such glasses; mainly schools where pupils' health was monitored. But these glasses have not yet received wide practical application, because ordinary window glass with sufficient insolation of sunlight allows a sufficient amount of useful ultraviolet rays into the room.

In order to regulate the amount of light rays or the amount of daylight for the premises, hygiene has established norms for the area of light slots. It is recommended that the area of the glazed surface of the windows (and not the area of the windows) is equal to at least 1/8 of the floor area for living quarters. In hygiene, this concept is expressed in the form of the so-called **light factor**, which is the ratio of the area of the glazed surface of the windows to the floor area.

For residential premises, the desired light factor is at least 1/8. At a light factor of 1/10, the lighting will be worse. In a room where more light is needed, the light factor should be higher, for example, for schools 1/4–1/5. In corridors and stairwells, lighting will be sufficient at a light factor of 1/12 and even less. For classrooms and laboratories, the rules are the same as for classrooms.

However, this should be strictly adhered to in relation to children's institutions, because the child's eye is most vulnerable to lack of light. Contrary to the common misconception that children's myopia is linked to heredity, Erismann has shown that it develops primarily from poor classroom lighting.

The light factor can be used to estimate both the illumination of the existing premises and the designed ones (according to the drawings).

Indoors, there are **first light and second light**. We call *the first light* daylight, which penetrates through the windows directly into the room. But the room can be arranged so that its windows face the corridor. Such rooms are illuminated by rays that passed through the windows of the corridor. This is *the second light*. Of course, in this case, the light factor cannot be an index of lighting adequacy. When evaluating lighting by light factor, it is very important to take into account other factors, such as the color of the walls of neighboring houses, the presence of shading objects — houses, trees, mountains, etc. At the same light factor, the presence of these objects will create the first illumination. It is also important to keep the windows clean.

It was mentioned above that when calculating the light factor, not the entire area of the windows is taken into account, but the total area of the glazed surface of the windows. In accurate calculations, the area of the glazed surface of the windows is measured, and if high accuracy is not required, then from the measured area of the entire window 10 % of the area of the window frames are discarded, because they prevent the penetration of light into the room.

With sufficient light, the illumination will be different in different parts of the room. Near the outer wall, closer to the windows, it will be larger, near the inner wall, farther from the windows — smaller. In order to estimate the illuminance in the workplace, in addition to determining the light factor, Fonster proposed to measure the angle of incidence of light rays on the workplace.

The angle of incidence (α), according to Forster, is the angle formed at the workplace by two lines: one, which goes from the workplace horizontally to the window, and the second, which also goes from the workplace to the upper edge of the window. Or the angle of incidence is the angle at which direct sunlight falls on the work surface. Schematically, this angle (α) is presented in Figure 11.2.

As can be seen from the figure, a rectangle triangle is formed: the height of the window is the cathetus opposite to the angle of incidence; horizontal line is the adjacent cathetus; the line leading to the upper edge of the window is the hypotenuse.

Workplace lighting is considered normal if the angle of incidence of the light beam is not less than 27 °. At the value of this (acute) angle of 27°, the adjacent cathetus is twice as large as the opposite. Therefore, in order for the angle of incidence to be within the norm, the workplace should not be further from the window beyond its double height. If you move the workplace closer to the window, the natural light on it will be better, and the angle of incidence will be more than 27 °. Moving the workplace into the room, then twice the height of the window, will give an angle of incidence below the norm, i.e. less than 27°, and the lighting will be insufficient.

Good visibility in the workplace at a normal angle of incidence will be when an open area of the sky is visible through the window from the workplace. In settlements, this is often hindered by opposite houses, trees, mountains, etc. Therefore, it is not possible to demand that the sky be visible through the whole window, and this is not necessary. The light will be sufficient when the sky is visible through at least part of the window, which depends on the so-called angle of the opening.

The angle of aperture (γ) is also formed by two lines coming from the workplace, with one, the top, line — the same as in the angle of incidence — it goes to the upper edge of the window, and the bottom line is directed to the upper edge of the object that shades the window — to the ridge of the roof of the house, the top of a tree, the top of a mountain, etc. In other words, the angle of

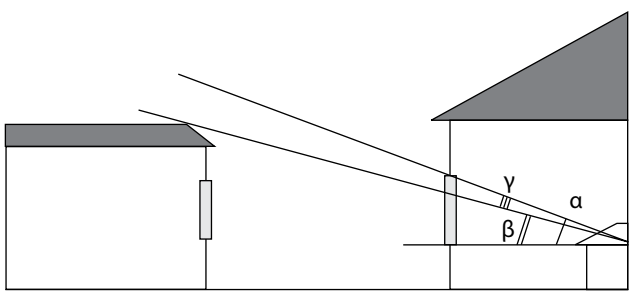


Fig. 11.2. Scheme for determining the angle of incidence and the angle of aperture. α is the angle of incidence; β is the angle of shading; γ is the angle of aperture

aperture is the angle at the workplace at which the sky is visible; shown in Figure 11.2.

The angle of aperture must be at least 5° at a normal angle of incidence. The method of determining these indices of illumination (angles of incidence and aperture) is taught in practical classes.

Recently, for the hygienic assessment of illumination in workplaces and premises with natural light, another method has been proposed. It consists in determining the degree of illumination outside the house and indoors with the help of devices. The device shows illumination in units of illumination (luxes). It is established that the lighting in the room (depending on its purpose) or in the workplace (depending on the size of the viewed details) should be a certain part of the lighting in the open air.

This index is called the daylight factor, abbreviated — DF. It is formulated as follows: the day light factor is the percentage of horizontal illumination at a given point inside the room to the simultaneous horizontal illumination by diffused light under the open sky (but not under direct sunlight).

Mathematically DF can be expressed as follows:

$$DF = E_{in} / E_{out} \times 100\%,$$

where E_{in} — horizontal illumination in the room, lux;
E_{out} — external illumination, lux.

There are norms for lighting according to DF. According to these norms, industrial, residential and public premises are divided into 8 categories of visual work.

I. For rooms where very precise and fine work is carried out (work of the highest precision), which requires a distinction of parts smaller than 0.15 mm, the minimum DF is allowed 2% for side lighting or 6% — for top or combined lighting. This may also include drawing rooms, painting halls, art galleries, panoramas.

II. For production facilities where precise and fine work is carried out (work of very high accuracy) with a separation of details from 0.15 to 0.3 mm, DF should be not less than 1.5% for side lighting and not less than 4.2% — for top or combined lighting.

III. In rooms where high-precision work is carried out with a resolution of details from 0.3 to 0.5 mm, DF should be not less than 1.2% for side lighting and not less than 3% — for top or combined lighting. This category may also include reading rooms in libraries, exhibition and sports halls.

IV. In premises where works of average accuracy with details in the sizes more than 0.5 to 1.0 mm are carried out, DF has to be not less than 0.9% for side lighting and not less than 2.4% — for top or combined lighting. This also includes auditoriums, classrooms, laboratories in educational and scientific institutions, meeting rooms.

V. In rooms where low-precision work is carried out with parts ranging in size from 1.0 to 5.0 mm, the DF shall be at least 0.6% for side lighting and at least 1.8% — for top or combined lighting. This category also includes bookstores of libraries, foyers, living rooms, receptions, living rooms.

VI. In rooms where rough work is carried out (very low accuracy), where the size of the parts is more than 5.0 mm, the minimum DF should be 0.6% for side and 1.8% — for top lighting. They also include lobbies, stairs, passages, corridors, bathrooms. All of the above applies to natural light and natural light standards.

VII. Premises where work with luminous materials and products in hot shops is carried out.

VIII. Premises in which general monitoring of the production process is carried out.

The level of natural light in the room is influenced by numerous factors (Fig. 11.3).

11.6. Artificial lighting (lighting concepts and units)

Man has invented and widely uses artificial lighting to prolong the time of active activity that benefits him. Academician S. I. Vavilov, characterizing the importance of artificial lighting, pointed out that light actually prolongs the conscious existence of man, and in this first of all its great importance.

Before proceeding to the presentation of hygienic requirements and standards for artificial lighting, it is necessary to dwell on the concepts of light and units, which will have to be repeatedly addressed. Hygiene does not use all the units used in lighting, but only those that are necessary for the hygienic assessment of lighting. These include units of light source strength, surface illuminance and brightness.

An international candle (candela) is taken as a unit of light intensity. In fact, in physics, the unit of light is not a candle, but another, larger unit, violle, named after the author who proposed it.

Violle is the force of light that is formed from a square centimeter of the surface of molten platinum at the time of solidification, and candle is 20 times smaller, i.e. equal to 1/20 of violle. Now the power of light bulbs is ex-

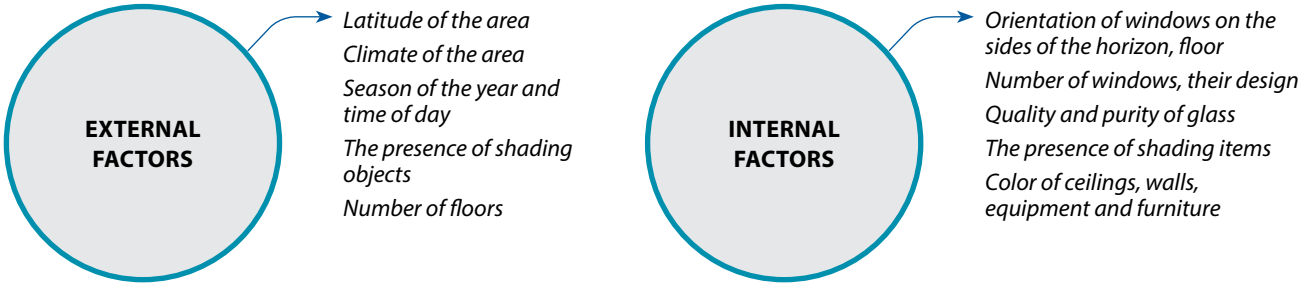


Fig. 11.3. The influence of external and internal factors on the level of natural light in the room

pressed in watts. 1 watt creates a light intensity that is approximately equal to 1 candle, so with some degree of error we can say that a 50-watt light bulb has a light output of about 50 candles.

But knowing only the power of the light source does not allow to assess the lighting of the room. In fact, if a light bulb of 100 candles is placed close to the illuminated surface, it will create a single illumination, if placed further, it will create less illumination. Therefore, the unit of illumination was proposed — **lux**.

Lux is the illumination of an area of 1 m^2, created by a luminous flux of 1 lumen with its uniform distribution on the illuminated surface.

Instruments used to measure light are called luxmeters.

The principle of their work is based on the fact that under the influence of light energy in a selenium photocell there is an electric current, which is registered by a sensitive galvanometer. The strength of the electric current is directly proportional to the illuminance.

Not only light sources have brightness, but also any surfaces that reflect light, and the intensity of their brightness will depend on the reflection coefficient of the rays. The **reflection coefficient** is the ratio of the reflected luminous flux to the incident luminous flux. This ratio can vary significantly. For example, for white walls it is from 0.75 to 0.84, and for black surfaces — from 0.02 to 0.03.

We mentioned above that the illumination of the surface will be worse the farther from it is the light source. From the course of physics it is known that the illuminance is directly proportional to the strength of the light source and inversely proportional to the square of the distance between it and the illuminated surface:

$$E = J / R^2,$$

where J is the intensity of light; R is the distance from the source to the surface in m; E is illumination in lux.

There is also a relationship between illuminance and light intensity: illuminance is directly proportional to light intensity and inversely proportional to the surface on which it is distributed:

$$E = F / S,$$

where E is the illuminance in lux; F is luminous flux intensity, lm; S is an area of the illuminated surface, m^2.

Knowledge of these patterns allows you to calculate the number of lamps to illuminate the room, as well as the height of their suspension. The sanitary doctor, knowing these regularities, at detection of insufficient or irrational lighting in the inspected premise can recommend to change height of a suspension bracket of fixtures or their distribution in the premise. In this way, you can increase the light without even resorting to increasing the power of light sources.

The level of artificial lighting in the premises depends on many factors.

The influence of various factors on the level of artificial lighting in the room:

1. Type of light source.
2. Number of lamps.
3. Lamp power.
4. Height of suspension and placement of lamps.
5. The nature of the fittings and the degree of its purity.
6. The ability of surfaces to reflect light (color).
7. Artificial lighting system (local, general, combined, mixed).

Artificial lighting in the premises is achieved through various sources.

11.7. Sources of artificial lighting (their advantages and disadvantages)

Depending on the type of energy used, there are the following sources of artificial lighting: non-electric and electric.

1. **Non-electric sources:**
   - sources with solid fuel — candles;
   - sources of liquid fuel — wick lamps (used as spare sourceor in non-electrified regions);
   - sources of gas fuel — Auer burner.
2. **Electrical sources:**
   - incandescent lamps;
   - gas discharge lamps;
   - luminescent (fluorescent) lamps;
   - mercury vapor lamps (MVL);
   - xenon lamps;
   - LED lamps.

Kerosene lamp and candle are very unhygienic light sources. They give a spectrum that is significantly different from the spectrum of daylight. There are a lot of red and orange rays in the kerosene lamp and candles and very few violets and blues. This makes it difficult to see. The lighting fixture should be lit and nothing more is required of it, and the kerosene lamp and candle greatly spoil the room air.

12 standard stearin candles, which glow with a force equal to about 12 international candles, give 336 g of carbon dioxide per hour. It gives 132 g of carbon dioxide per hour, and an adult emits 44 g of carbon dioxide per hour. Thus, a kerosene lamp emits 3 times, and candles of the same power as the lamp — 8 times more than a person for the same period of time. This clearly shows that kerosene lamps and candles are a source of indoor air pollution.

When the lamp burns, the gas burns, hydrogen and carbon are oxidized. When carbon is oxidized, carbon dioxide is formed, and when hydrogen is oxidized, water is formed. Thus, in addition to carbon dioxide, stearin candles emit water. A person emits only 33 g of water per hour, and 12 stearin candles emit 132 g of water per hour. This is also 4 times more than a person; hence the amount of moisture in the room when using these lamps increases. These products are formed under the condition of complete combustion, i.e. complete oxidation of carbon and hydrogen, which consist of gas and stearin.

If there is incomplete combustion, the products of incomplete combustion are formed, in particular carbon monoxide — CO. Kerosene lamps always form a small amount of carbon monoxide, and prolonged operation with a kerosene lamp often leads to headaches, "heavy" feeling of the head, reduced efficiency.

In addition, kerosene contains impurities, most often sulfur (sulfuric acid is used in gas distillation). During oxidation, sulfur is converted into oxides (SO_2, SO_3), which are also poisonous gases.

Along with this, the kerosene lamp generates heat. Heat may sometimes be needed, but this is not required from the light source — this is the task of heaters. At a close distance of such a lamp from the head there is overheating of the latter, which, of course, also has a bad effect on the person.

In order to reduce the negative impact of kerosene lamps, it is necessary to ensure a sufficient supply of oxygen. Incidentally, lamps with a flat wick do not provide sufficient air flow to its central parts, and lamps with a round wick have a more complete combustion. Therefore, lamps with a round wick are more hygienic.

Of course, kerosene has certain hygienic requirements: it should not contain impurities, including sulfuric acid.

There's nothing to say about candles. When you have to use them, you have to put up with all the negative phenomena. Candles, of course, are used in extreme cases. Electric lighting is much higher than all the mentioned light sources, but electric lighting is also different.

Until recently, **incandescent light bulbs** were widely used around the world. In it, an electric current passes through a thin thread, causing it to heat up and glow.

In the autumn of 1873, posters informed the people of St. Petersburg that experiments on electric lighting according to Lodygin's method would be carried out at the Technological Institute. Then, for the first time, a remarkable invention of a talented Russian scientist, locksmith by profession, self-taught, was shown.

Six years later, in 1897, the incandescent lamp, perfected by the American Edison and brought to such a degree of technical completion that it became possible to mass-produce and use a new light source, began its triumphant march around the world. Edison's improvement was that he proposed passing an electric current through a carbon filament placed in a glass flask. In these flasks, the carbon filament gave a glow of constant force.

Some may ask: excuse me, but the father of electric lighting is considered Yablochkov? Quite rightly, in 1876 Yablochkov in Paris was the first to take a patent, as it was then called, the first privilege, for his candle. Yablochkov suggested improving the arc lamp. Prior to it, the coals

were placed against each other in an arc lamp, and as they burned, they had to be moved to each other to close the arc. Yablochkov also proposed to place the coals in parallel, with a layer of clay between them; when the coals burned, they did not have to be moved, because as they burned, the rods shortened. This is the merit of Yablochkov. Yablochkov's invention has nothing to do with the incandescent light bulb.

In 1890, Lodygin proposed to put a metal (tungsten) thread in a light bulb instead of a carbon filament.

An incandescent light bulb, of course, has many advantages over gas lamps and candle lighting. First of all, it does not give any combustion products. In addition, its spectrum is much closer to the spectrum of natural light, i.e. shifted to the purple part. Keep in mind, however, that incandescent light bulbs emit relatively less violet and blue rays and more red and orange rays than daylight. This explains why mixed light, daylight and incandescent lamps, are not very pleasing to the eye. In mixed light (daylight and from an incandescent bulb) it is impossible to draw pictures, to consider them, as well as at illumination only by an incandescent bulb.

The incandescent light bulb began to be used especially widely when it was proposed to make a metal thread instead of carbon filament: tungsten, tantalum. Metal thread has a higher brightness and better range than coal. Shortly after the proposal to use a lamp with a metal filament, Edison's charcoal lamp was replaced.

The illuminance obtained from an incandescent lamp is also normalized: it must be sufficient and uniform, as we have seen when considering the functions of the eye. Both the work surface and the entire room should be adequately lit. It is essential that the light on the work surface is diffused or open. You can achieve a fairly high illumination of the work surface due to direct rays from an unprotected incandescent lamp. However, as already mentioned, an electric incandescent lamp gives great brightness and can blind the eyes.

In addition, the light from an unprotected incandescent lamp creates sharp shadows from objects, hands, head, especially when the room is illuminated by a single lamp. To prevent this, it is necessary to arrange several lamps in the room, distributing them evenly throughout the room. To eliminate the glare from the filament of the lamp, it is necessary to use vane devices, which either scatter the rays from the incandescent lamp or reflect it to the ceiling and walls, where it falls on the work surface in the form of scattered rays. These scattering or reflecting devices are called **lighting fixtures**. In everyday life they are often called lampshades.

Lighting fixtures absorb a significant amount of light energy, which is economically, of course, unprofitable. However, in the interests of human health and efficiency, slightly increased lighting costs should be neglected and lighting fixtures should be installed wherever appropriate. Purposes of lighting fixtures:

1. Luminous flux distribution.
2. Protection the eyes from the glare of the light source.
3. Protection of the light source from pollution, mechanical damage, moisture, explosive gases.
4. Serving for power supply and lamp mounting.
5. Aesthetic significance.

Luminescent lamps meet these requirements much more than electric incandescent lamps. The word "luminescence" comes from the Latin word lumen (Luminis) — light. Luminescence is now understood as a cold glow in lighting technology.

In nature, we often encounter a cold glow, for example, a rotting tree gives a cold glow; some insects glow due to the chemical processes that take place in them; mechanical impact on some objects causes a cold glow, such as the splitting of sugar in the dark.

Luminescent lamps are tubes from 0.5 to 2.5 m long. Such a lamp is filled with mercury vapor at low pressure and an electric current is supplied to it: on the one hand — the anode, on the other — the cathode. When an electric current passes through mercury vapor, it emits energy quanta, which are dominated by waves of short length — ultraviolet rays. In other words, mercury vapor emits ultraviolet radiation when electric current is passed.

Fluorescent lamps are covered with special salts — phosphors. Ultraviolet rays are absorbed by phosphor atoms, as a result of which the latter also begin to emit quanta, but of less energy, i.e. rays with a longer wavelength — visible: purple, blue, red, and others. The emission of quanta of lower energy than the energy of ultraviolet radiation is due to the fact that part of the electricity in these lamps is also spent on heating.

By selecting the composition of phosphors, you can get visible light of any desired spectrum. Some salts give a lot of purple, blue, green rays, others give green and yellow salts, others — red, orange and so on. One salt that would give the full range of visible sunlight has not yet been found. Therefore, the salts are mixed in such proportions that the desired ratio of rays of all colors is formed in the emission spectra of the fluorescent lamp. It is possible to choose such structure that the spectrum of radiation of a lamp was very close to daylight.

Phosphors are salts of tungsten, boric acid, silicic acid, calcium halophosphate, activated by antimony

and manganese. Recently, it is the main phosphor used in the manufacture of fluorescent lamps. Due to the proximity of the spectrum of fluorescent lamps to daylight, they are called fluorescent lamps. These lamps are 4 times more economical than incandescent lamps, i.e. they require 4 times less electricity consumption. Fluorescent lamps for different voltages are made: 110, 127, 220 volts. The service life of such lamps is by no means less than incandescent lamps — up to 2000 hours. An incandescent lamp works well for up to 1000 hours, and then it glows poorly.

In luminescent lighting, you can use mixed light — daylight and artificial. Because they are similar in spectrum, luminescent lamps simply enhance daylight. This is very important because it is often needed. In many companies during the day, depending on the degree of illumination from the sky, you can increase the lighting due to fluorescent lamps.

These lamps make it possible to carry out work related to color discrimination under artificial lighting, which is impossible to do with incandescent lamps. You cannot, for example, draw or view pictures with incandescent lamps, and with luminescent lamps — you can.

Thus, fluorescent lighting has a number of advantages over incandescent lamps.

However, fluorescent lamps have a number of disadvantages:

- selection of phosphors is not always successful;
- lamps have a stroboscopic effect, which means periodic oscillations of light flux, which leads to more or less light. It can't even be called a flicker, but rather a periodic rapid oscillation.

However, they have already learned to eliminate this effect. It turns out that if you create illumination with fluorescent lamps of at least 75 lux, then this phenomenon is not observed. This effect is not noticeable to the eye.

- the disadvantage is the difficulty of connecting fluorescent lamps to the mains. To do this, each lamp must have special devices — starters and chokes (special inductive resistance).

However, these lamps have so many positive qualities that they will certainly displace incandescent lamps.

Luminescent lamps have a large luminous surface, much larger than incandescent lamps. Therefore, at the same light intensity, their brightness is less, and this is also a positive hygienic indicator.

It must be said that although the influence of these sources on vision has been studied and is being studied today, this study cannot yet be considered complete. Further study of the effect of fluorescent lighting on the functions of the eye will undoubtedly lead to progress in understanding the technical improvement of this light.

In childhood, the human eye is particularly labile, unstable, easily exposed to adverse effects. Therefore, the best, luminescent lighting should be used in children's institutions and schools.

The trend towards energy saving, which has captured the attention of the whole world, has not bypassed Ukraine either. This may partly explain the growing popularity of energy-saving lamps in our country.

Energy-saving lamps consist of an electronic unit, a base and a luminescent lamp — so they are often called simply fluorescent lamps.

British scientists have found that energy-saving lamps can be harmful to health. According to the British Association of Dermatologists, the new generation of light bulbs can primarily affect people with hypersensitivity of the skin, because fluorescent bulbs emit more intense light than conventional ones. According to scientists, the use of energy-saving lamps can exacerbate skin diseases that already exist in humans, and lead to skin cancer, as well as cause migraines and dizziness in people with epilepsy.

Disposal of environmentally harmful energy-saving lamps is also a problem, so it is actually forbidden to throw them away. There should be collection points and disposal systems for mercury-containing lamps, but there are none in Ukraine. Therefore, hazardous lamps together with household waste are brought to a landfill, where mercury enters the soil, or to a landfill, where such lamps are burned or, at best, taken away and handed over for industrial processing.

The legislation of Ukraine obliges to hand over energy-saving lamps for recycling only to business entities. They must create special storage facilities for such lamps, properly assemble them, and then dispose of them to specialized companies, as well as pay a fee for environmental pollution. Therefore, only large industrial enterprises comply with the law.

In recent years, the use of LED lamps is becoming more common.

LED lamps are practically ordinary-looking lamps with many LEDs in it, as well as a semiconductor crystal on a substrate and an optical system.

LED is a semiconductor device that converts voltage into light. The spectral range of the emitted light depends on the chemical composition of the semiconductor.

The use of Light Emitting Diode (LED) technology in the lighting of rooms for various purposes — a relatively new phenomenon. This technology is used in two ways:

- lighting of premises;
- light effects.

LED lamps have the following advantages:

1. Low power consumption compared to conventional lighting. Such a lamp requires 14 watts to illuminate the room, that is equivalent to an incandescent lamp of 100 watts.
2. No ultraviolet radiation. The ultraviolet component of normal lighting can damage eye tissue.
3. High efficiency (very little heat is produced in the light).
4. Service life of 20–50 thousand hours. If you use the lamps every day for 5 hours, the service life will be more than 10 years.
5. Environmentally friendly compared to energy-saving lamps, which contain mercury.
6. Light weight.
7. Significant strength (shock, vibration, temperature) and moisture resistance.
8. Instant warm-up, less than 1 sec.
9. Wide choice of shades and colors.

Disadvantages of LED lamps:

1. The main and most important disadvantage of these lamps is their price. It is much more expensive than an incandescent lamp and energy efficient.
2. Some complain that LED lamps have an unpleasant glow spectrum. Therefore, their use in lamps for reading books or other painstaking work is unacceptable.

Among the main parameters that characterize the quality, hue and brightness of the lighting element — the color temperature of LED lamps. When choosing, be sure to pay attention to the color temperature, as this indicator affects the feeling of comfort in the room.

The color temperature range ranges from 1800 to 10.000 K. The most favorable color temperature is in the range of 2700–6600 K for residential, office and public buildings. Conditionally allocate some ranges:

- 2700–3200 K — warm white glow color;
- 3500–4500 K — neutral or daylight;
- 4700–6000 K — white;
- 6000 K — cold white glow.

For example, an incandescent lamp is characterized by the color temperature of the first group. The working atmosphere is created by lamps with neutral white light.

The recommended color temperature in the workplace is from 4200 to 5500 K, ie white or neutral glow color is advisable. Under such conditions, there is a maximum efficiency of staff.

An incorrectly selected light source can cause discomfort to the visual analyzer, so it is important to consider the color temperature of the lighting element.

Generalized information on the advantages and disadvantages of different types of electric lamps are given in Table 11.2.

11.8. Classification of lamps

A light source built into the fixture (lampshade) is called a lamp. Lighting fixtures (lighting characteristics) can be divided into three major groups: diffuse, reflective and mixed. Scattering lamps are balls or other forms of milk glass caps in which lamps are placed. The rays from the lamps, passing through the glass of such fixture, are evenly distributed and fall on the work surface, already being scattered.

Reflected lamps are made open from top, the lower part of them is impenetrable. As a result, the rays are reflected to the walls and ceiling, and from there to the work surface. Mixed lamps are luminaires made of reflective type, but made of frosted or milk glass. In this case, part of the rays are scattered, passing through the glass fixtures, and part is reflected to the ceiling and walls, and from there — to the work surface.

There are also lamps of direct, or directed, light, and also mainly direct light. In these lamps, the bulk of the luminous flux is directed downward to the work surface, and part is scattered through the milk glass. Their disadvantage is the brightness created by direct light, if the work surface or parts on it have a high reflectivity. In addition, when illuminated by direct light lamps in the room, sharp shadows are formed.

Classification of lamps:

1. *By appointment:*
   - general lighting;
   - local lighting;
   - emergency;
   - signal;
   - special purpose (in hospitals — shadeless lamps).
2. *According to the distribution of light flux in space:*
   - direct light (at least 80 % of the total flux is emitted into the lower hemisphere);
   - mostly direct light (60–80 %);
   - evenly scattered light (40–60 % of the flux in each hemisphere);

Table 11.2. Advantages and disadvantages of different types of electric lamps

Disadvantages	Advantages	
Incandescent lamps (IL)		
Spectrum shift to yellow-red Distortion of color sensation Low efficiency The blinding effect of direct rays	Small Quiet operation Cheap	
Luminiscent lamps (LL)		
Stroboscopic effect Large dimensions Noise during throttle operation Difficulty of disposal UV radiation Price	High efficiency Light output is 3–4 times higher than in IL No feeling of blindness Uniform illumination of surfaces No thermal effect The radiation spectrum is approaching daylight	
Light Emitting Diode lamps (LED)		
Price	Energy savings (up to 90 %) High light output Directional light, no scattering Long service life (20–50 thousand hours) Variety of sizes and shapes Significant strength (shock, vibration, temperature and moisture resistance) Environmentally friendly (no UV radiation, mercury vapor) Wide choice of shades of light colors	

- mainly reflected light (in the upper hemisphere 60–80 % of the luminous flux);
- reflected light (more than 80 %).

3. *According to the shape of the light intensity curve:*
   - concentrated light distribution;
   - deep light distribution;
   - sine light distribution;
   - semi-wide light distribution;
   - wide light distribution;
   - uniform light distribution.
4. *By method of installation:*
   - suspended;
   - attached (plafonds), which are mounted on the ceiling;
   - wall lamp (sconce);
   - floor lamp;
   - table/desk lamp;
   - recessed lighting;
   - hand lamp;
   - head lamp.

From the point of view of protection of an eye from frequent readaptation, certain requirements to uniformity of illumination of a working surface and other room are put forward. It is desirable that the difference in illumination on the work surface and outside it was as small as possible. General lighting should be 1/4–1/2 of local lighting in the workplace.

11.9. Types of artificial lighting

1. By purpose:
   - working;
   - emergency;
   - security;
   - queues standby.
2. By way of light supply:
   - general (for the whole room);
   - local (local);
   - combined (general + local).

In the case of combined lighting, the illuminance of the work surface created by general lighting fixtures should be 10% of normal.

Lighting due to a combination of natural and artificial light source is called **mixed (compatible) lighting.**

11.10. Hygienic requirements for artificial lighting

Human life and activity in the conditions of modern scientific and technical revolution is impossible without the use of artificial lighting. It is necessary to provide the required level of illumination during the day at home, at work, for professional activities while underground, underwater, in space and in many other situations.

Artificial lighting must meet the following basic hygienic requirements:

1. To provide the required level of general and local lighting in technological, hygienic standards under domestic, industrial and other conditions.
2. Get as close as possible to the spectrum of natural visible light.
3. Not to create excessive brightness.
4. Within the viewing boundaries, to ensure the required uniformity of illumination.
5. Not to be a source of fire hazard, additional noise and additional thermal radiation.
6. To be compact, aesthetic, accessible for care and maintenance of cleanliness.

11.11. Norms of general artificial lighting

Hygienic standards for illumination and some other parameters and conditions for illumination of premises of various function and workplaces are based on studying of functions of the visual analyzer. The main indices of these functions are considered to be visual acuity, contrast sensitivity, adaptation to light and darkness, color recognition, clear vision stability, visual capacity and so on.

Table 11.3 shows the normalized indices of lighting of premises and buildings.

Visual acuity is of paramount importance in physiological and hygienic terms. If the brightness of the surface does not exceed 2000–250 cd/m^2, then the higher the level of illumination, the better the conditions are created for visual perception. But it is noted that a significant increase in visual acuity is observed only at a light level of 150–200 lux, and an improvement in other visual functions — at a light level of 250–500 lux. Further increase in illuminance has almost no effect based on the function of the visual analyzer.

In addition, during the hygienic standardization of lighting, depending on the purpose and conditions of use, different rooms are divided into 4 groups:

1. Premises in which the distinction of objects of visual activity is carried out at a fixed direction of the line of sight of workers on the work surface (main production facilities, offices, manipulation, operating rooms, laboratories, reading rooms, classrooms, school classrooms, etc.).
2. Premises in which the distinction of objects is carried out with a fixed line of sight and a general overview of the surrounding space (trade halls of the store, art galleries, halls of catering establishments, production facilities, which require only general supervision of technological equipment, playrooms, etc.).
3. Premises that require a general overview of the surrounding space by short-term (episodic) distinction of individual objects (concert, theater, club, cinema halls and foyers, assembly halls, recreation, waiting rooms, lobbies, dressing rooms of public buildings, etc.).
4. In rooms where there is a general orientation in the interior space (corridors, passages, bathrooms, closed parking lots, etc.).

Taking into account these provisions, as well as specific working conditions (size of objects, contrast, degree of accuracy of work, etc.), the standards for natural and artificial lighting are set (Table 11.4).

The background of the visual surface, i.e. the surface on which the object under consideration is located, is of great importance for the hygienic assessment of the conditions of visual work and the normalization of illumination. The background is considered light, medium or dark with reflection coefficients, respectively, more than 0.4; from 0.2 to 0.4 and up to 0.2. The contrast of

Table 11.3. Normalized indices of lighting of premises and constructions (excerpt from DBN V.2.5–28–2006)

Premises	Artificial lighting	Natural lighting	Compatible lighting
	illumination, lux	*DF, %*	*DF, %*
9. Laboratories: organic and inorganic chemistry, thermal, physical, spectrographic, stylometric, photometric, microscopic, X-ray diffraction analysis, mechanical and radiomeasuring, electronic devices, preparatory	500/300	3.5–1.2	2.1–0.7
10. Analytical laboratories	600/400	4.0–1.5	2.4–0.9
12. Classrooms, lecture rooms, study rooms, laboratories of secondary schools, boarding schools, secondary special and vocational and technical institutions	500/400	4.02) –1.52)	2.1–1.3
13. Lecture rooms, classrooms, laboratories in technical schools and higher educational institutions	400	3.5–1.2	2.1–0.7
36. Insulators, rooms for sick children	200	2.0–0.5	—
37. Chambers, bedrooms	100	2.0–0.5	—
68. Health points: a) waiting rooms; b) reception desk, rooms of duty personnel; c) doctors' offices, dressings; d) procedural offices	500/200	0.7–4.0	0.4–2.4
72. Corridors and passages:	50/75	—	0.14

Table 11.4. Illuminance indices depending on the characteristics of visual activity (excerpt from DBN V.2.5–28–2006)

The category of work	Characteristics of visual work	The smallest size of the object of distinction, mm	Illumination, lux (general artificial lighting)*	DF, %** (natural light)
I	The highest accuracy	Less than 0.15	1200–300	2.0–6.0
II	Very high accuracy	From 0.15 to 0.3	750–200	1.5–4.2
III	High accuracy	From 0.3 to 0.5	500–200	1.2–3.0
IV	Medium accuracy	More than 0.5 to 1.0	300–200	0.9–2.4
V	Low accuracy	More than 1.0 to 5.0	300–200	0.6–1.8
VI	Rough (very low accuracy)	More than 5.0	300–200	0.6–1.8
VII	Work with luminous materials and products in hot shops	More than 5.0	200	0.6–1.8
VIII	General observation of the production process	—	20–200	0.1–1.8

* depending on the contrast of the object with the background.
** due to geographical conditions and type of lighting (top, side, combined).

the object relative to the background (the ratio of the absolute value of the difference between the brightness of the object and the background to the brightness of the background) is high if its value is greater than 0.5, medium if its value ranges from 0.2 to 0.5, and small if its value is less than 0.2.

When evaluating and normalizing artificial lighting, it should be borne in mind that due to the proximity of the spectral composition of the radiation of fluorescent lamps to natural light — to ensure better physiological perception of fluorescent lighting, its illuminance should be approximately 2–2.5 times higher, than that created by incandescent lamps.

Our country has adopted a two-stage standardization of industrial lighting — general hygiene standards and industry. The general norms of industrial lighting provide the basic provisions for the development of industry standards, in which the requirements for lighting are specified for specific work operations and production equipment.

The current norms set the level of illumination determined by the conditions of visual work, the lighting system used, the minimum size of the recognition object, and for artificial lighting — its contrast with the background, the nature of the background, the light source.

According to DBN V.2.5–28–2006, all types of work are divided into digits, based on the linear dimensions of the smallest recognition object with which the worker works. The distance from the eye to the object of recognition must be at least 0.5 m.

Thus, a careful approach to the assessment of indoor lighting is a major factor in creating optimal conditions (light comfort) to ensure certain activities.

Light comfort is a lighting condition in which the brightness of the lamps or the contrast between the field of view and the environment (field) have such relationships that do not cause an unpleasant subjective feeling in the eyes of the observer and do not lead to visual fatigue over time.

11.12. Hygienic value of noise in the conditions of inhabited cities

Researches in recent years have shown that among the many natural and man-made environmental factors that affect public health, urban noise is the most common and aggressive.

Sources of street and residential noise are all types of public transport, industrial facilities, loud radio and television equipment (Fig. 11.4).

Noise is a chaotic combination of sounds of different frequency and intensity, which interfere with the perception of useful signals, disturb the silence, negatively affect the human body, reduce its efficiency.

The main internal sources of technogenic noise in buildings for various purposes are technological and engineering equipment.

The main sources of external man-made noise are the flows of road, rail, water, air transport, industrial enterprises and their individual installations, utilities and transport enterprises, transformer and gas distribution substations, central heating stations, pumping and compressor stations, construction sites, garages, parking lots, etc.

Sources of external nutrient noise are stadiums, marketplaces, rally grounds, dance floors, outdoor cultural and recreational areas, sports grounds, discos, zoos, livestock farms and more.

Different noise sources form different noise levels (Fig. 11.4):

- rustle of wind and leaves create noise at the level of 20–30 dBA;
- raindrops — 40 dBA;

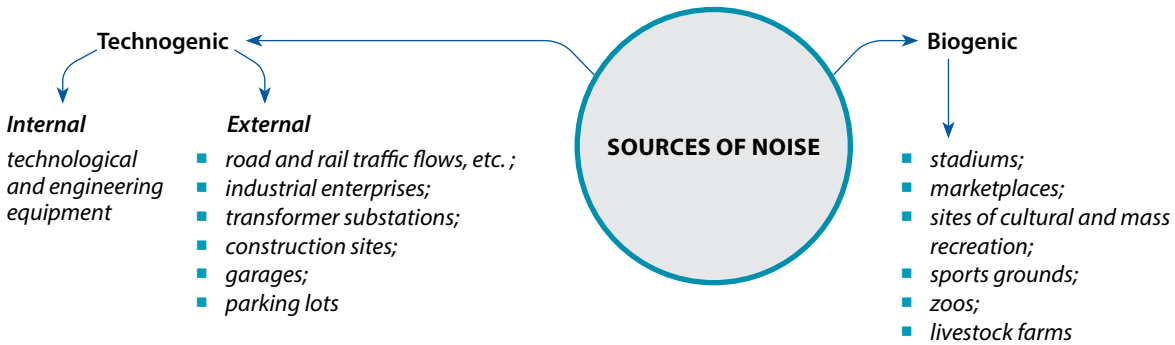


Fig. 11.4. The main sources of urban noise

- calm conversation — 60 dBA;
- vacuum cleaner, highway at rush hour, hair dryer — 80–90 dBA;
- perforator — 105 dBA; rock concert — 105 dBA;
- chainsaw, jackhammer — 110–120 dBA;
- jet — 140 dBA and exceeds the pain threshold.

The noise level in many modern cities is 80–90 dBA, staying within these limits for 15–18 hours a day. The noise regime in each city is related to planning (width of streets, number of storeys of buildings, type of construction of the neighborhood), the presence of greenery and zoning, the intensity of traffic and the composition of traffic.

WHO experts emphasize the problem of noise, which is especially relevant for urban life. Silence for a person in an urban environment is a luxury. We will consider the negative impact of different noise levels on human health.

The effect of noise on the human body is that sound vibrations are transformed into nerve impulses that enter the subcortical formations and the auditory field of the cerebral cortex. The effect of noise on the human body depends on its intensity.

Noise, the intensity of which does not exceed 30 dBA, is almost harmless. This is a natural background noise, necessary for human life, because it stimulates the processes of excitation in the cerebral cortex.

Noise with an intensity of 30–65 dBA can cause neuropsychiatric reactions and disorders. Noise can cause increased irritability, irritability, neurosis, sleep disturbances, headaches, and memory impairment. Noise is associated with accelerated aging in 30 % of people, reduced life expectancy by 8–12 years.

WHO experts have found that children who grow up in conditions of constant noise, such as traffic, lag significantly behind their peers in terms of reading, language skills and memory.

65–90 dBA — autonomic reactions and disorders (asthenovegetative syndrome, asthenoneurotic syndrome, vascular and autonomic dysfunctions).

The constant presence of loud sounds increases the level of stress hormones (adrenaline, noradrenaline, and with prolonged exposure — even cortisol) in the human body. According to WHO, noise is the cause of strokes, hypertension, arrhythmias and heart attacks, which are associated with chronic stress and insomnia, which invisibly affect human health.

90–120 dBA — hearing impairment. Hearing loss is possible, especially with chronic exposure. As a rule, it is a question of occupational hazards. Of particular concern is the use of headphones with portable electronic devices for listening to music in public places (subway, public transport, on the street, etc.). When using headphones, the sound bypasses the auricle and immediately enters directly into the ear canal, which in turn inevitably leads to hearing loss, especially in young people. With chronic use of headphones, there is a high risk of replacing headphones with a hearing aid at the age of 40.

According to the WHO study of middle- and high-income countries, almost 50 % of adolescents and young adults between the ages of 12 and 35 are exposed to unsafe volume from personal audio devices, and about 40 % are exposed to potentially traumatic volume at entertainment events. A dangerous sound level can, for example, occur when exposed to sound above 85 decibels (dB) for eight hours or 100 dB for 15 minutes.

Today, 360 million people worldwide suffer from hearing loss for a variety of reasons, such as noise, genetic disorders, complications in childbirth, certain infectious diseases, chronic infection of the auditory analyzer, the use of specific drugs and aging. It is estimated that half of all cases of hearing loss can be prevented.

> 120 dBA — hearing loss.

To combat the harmful effects of noise on public health, a set of preventive measures is used:

1. Noise standardization (SBC of Ukraine "Protection of territories, buildings and structures from noise" DBN V.1.1–31: 2013).
2. Creation of sanitary protection zones.
3. Change of constructions and control over the technical condition of vehicles.
4. Rational planning of highways and residential areas.

An important measure in the fight against noise is planning: proper planning of settlements, construction of ring roads, reducing the number of intersections in the village.

Development of hygienic standards for noise levels depending on the purpose of noise. Document regulating permissible noise levels — SBC of Ukraine "Protection of territories, buildings and structures from noise" DBN V.1.1–31: 2013.

Preventive measures include the creation of sanitary protection zones, control over the technical condition of technical means.

11.13. Electromagnetic radiation in the conditions of modern settlements

The biosphere has been under the influence of electromagnetic fields (EMF), background radiation caused by

natural factors. There are electric and magnetic fields around the Earth, the intensity of which does not remain constant. There are annual, daily fluctuations of these fields under the action of thunderstorms, precipitation, winds, as well as under the action of solar activity (magnetic storms).

In the process of scientific and technological development, mankind has added to the background radiation a number of factors that have amplified this radiation several times (anthropogenic EMF). Equipment and devices related to the generation of electromagnetic radiation in a wide range of frequencies have become widely used in everyday life and industry. The growth of the EMF level has sharply increased since the early 30s of the 20th century. In some areas, their level is hundreds of times higher than the level of fields of natural origin.

Sources of electromagnetic energy are powerful radio and television stations, repeaters, radio communications for various purposes, including satellite, industrial installations of high-frequency heating of metals, high-voltage power lines, electric vehicles, measuring instruments, personal computers (PCs), mobile phones (Fig. 11.5).

Airports and military facilities have powerful radars that emit streams of electromagnetic energy into the environment. The power and number of EMF sources are constantly growing.

The problem of the impact on the human body of electromagnetic fields as a factor of habitat is becoming increasingly important, because every year the number of sources and the power of their radiation increase.

In 1995, WHO officially introduced the term "global electromagnetic pollution". The level of this pollution increases 10–15 times every ten years.

Living organisms in the process of evolution have adapted to a certain natural level of intensity of the electromagnetic field, and significant deviations from it to a greater or lesser extent are a stress factor. Today, the level of the Earth's electromagnetic background is 200.000 times higher than the natural one.

Prolonged and intense exposure to EMF leads primarily to functional changes in the heart vascular and central nervous systems. Due to the transition of electromagnetic energy into heat under the action of EMF, there is an increase in body temperature and selective heating of organs and tissues of the body. Such heating is espe-



Fig. 11.5. Sources of electromagnetic energy

Electromagnetic fields

These are alternating electric and magnetic fields that propagate in space in the form of waves at the speed of light

The value of the strength of magnetic fields around household appliances)

Electrohousehold device	At a distance of 3 cm (microtesla)
Hair dryer	6–2000
Electric shaver	15–1500
Vacuum cleaner	200–800
Microwave oven	73–200
Portable radio	16–56
Electric oven	1–50
Washing machine	0.8–50
Iron	8–30
Dishwasher	3.5–20
Computer	0.5–30
Refrigerator	0.5–1.7

Threshold value for the population — 100 microtesla

cially dangerous for organs with weak thermoregulation (brain, eyes, kidneys, stomach, etc.).

The most sensitive to EMF are neurodynamic processes that directly or indirectly affect the chronobiological processes of the body, translating it into a pathological or stressful mode of functioning. In 1928, O. L. Chizhevsky called solar activity "a factor that contributes to the emergence and spread of psychosis." Depression is on the rise among people working in the EMF industrial frequency band or living near high-voltage power lines.

It is established that under the influence of weak EMF in the human body the amplitude and phase of rhythms of biological indices change. Desynchronosis is known to be a common sign of poor health in the early stages.

Exceeding the electromagnetic load against the normative by 50 % leads to an increase in morbidity of the population by 17 %, and with an increase of 150 % — by 37 % (most often it is respiratory diseases, allergic diseases, diseases of the nervous system). Electromagnetic radiation affects human reproductive function (there is a violation of the maturation of sperm and eggs, which leads to infertility). Among the population living in the conditions of electromagnetic radiation, the incidence of chronic pathology is 1.5–2 times higher compared to the population living in "clean" territory. Thus, the field strength of 1000 V/m causes headache, severe fatigue; greater values cause the development of neuroses, insomnia. In 2004, researchers at the University of Malaga (Spain) found that high-intensity microwaves increased the chances of developing depression by a factor of 40 and suppressed melatonin synthesis, especially in people with chronic diseases and weakened immune systems.

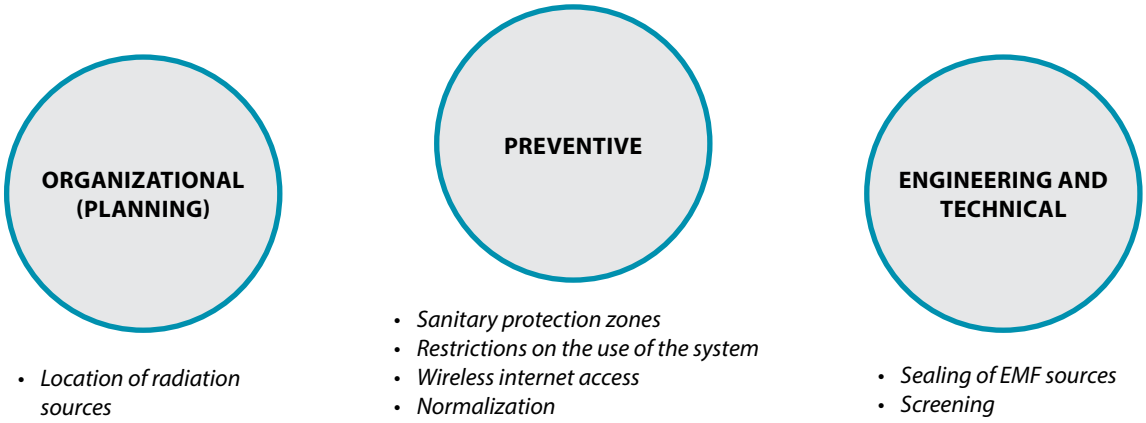
The effect of electromagnetic radiation on humans has not been studied enough. It is known that with increasing wavelength, the negative effect of EMF decreases.

A set of measures is used to protect against electromagnetic radiation, among which are organizational, engineering and preventive measures (Fig. 11.6).

Organizational measures include the optimal choice of site for radio facilities (radio stations, telecentres, television repeaters, radar stations).

Engineering measures are aimed at sealing sources of electromagnetic radiation. All EMF sources are shielded as much as possible by metal caps, partitions.

Preventive measures include the creation of sanitary protection zones. The limits of SPZ are determined by calculation, taking into account the technical characteristics of the EMF source.



Maximum permissible levels of electromagnetic fields (excerpt from the "State sanitary norms and rules of protection of the population from the effects of electromagnetic fields")

No of diapason	Matrix distribution of diapasons	Matrix distribution of ranges	Wavelength	MAL
5	Kilometer waves (low frequencies, LF)	30 : 300 kHz	10 : 1 m	25 V/m
6	Hectameter waves (medium frequencies, MF)	0.3 : 3 kHz	1 : 0.1 m	15 V/m
8	Meter waves (very high frequencies, VHF)	30 : 300 kHz	10 : 1 m	3 V/m

Fig. 11.6. Measures to protect against the negative effects of EMF

WHO experts recommend refraining from using Wi-Fi wireless access systems in children's schools, as electromagnetic radiation creates an additional burden on the child's body. In the United States, Britain and Germany, Wi-Fi is increasingly being abandoned in schools, hospitals and universities. WHO considers the use of this system and mobile phones to be unproven risk factors.

Based on the generalization of the results of experimental research, MAL (depending on the frequency or wavelength) of electromagnetic energy was developed, which was included in the "State sanitary norms and rules of protection of the population from the effects of electromagnetic fields", 1996.

Light factor that accompanies a person throughout life, provides 80 % of information about the outside world, has a biological effect, plays a primary role in regulating the most important vital functions of the body, and therefore hygienic control over hygienic standards of lighting is a guarantee of prevention pathological conditions.

Improper lighting, irritating noise and EMF pose a significant threat to the health of the population of modern cities. Proper organization of lighting, distance from noise sources and EMF in the workplace, in residential areas, recreation facilities — the key to health, high productivity, comfortable emotional and psychological state of man.

12 CHAPTER MICROCLIMATE AND ITS HEALTH EFFECT. INDOOR MICROCLIMATE IMPROVEMENT WAYS AND RESOURCES

O. P. Vavrinevych, A. M. Hrynzovsky, A. M. Antonenko

Microclimate parameters (temperature, humidity, air movement speed and radiation temperature, heat intensity, surface temperature) are of particular importance among the physical factors that affect human health. These air factors are associated with the emergence of so-called "colds" in the population, which occupy a leading place in the overall structure of morbidity of all ages and professions.

Uncomfortable microclimate affects the cardiovascular system, digestive system; it can lead to pathological changes in the nervous system and peripheral nervous system diseases. Uncomfortable microclimate significantly affects a person's ability to work. Therefore, knowledge of the factors that determine the thermal state of the body is essential for the future doctor.

12.1. Microclimate, definition

Premises for various purposes (residential, public, industrial) are characterized by an artificial microclimate. The microclimate has a huge influence on human body, it determines our well-being, mood, and affects our health.

Firstly we will start from definition.

The microclimate is the thermal state of the air environment, which affects the processes of thermoregulation, it determines the human heat sensation and depends on air temperature, relative humidity, air movement speed and radiation temperature (intensity of heat radiation, surface temperature).

According to the State Building Code, the **microclimate** is the conditions of the indoor environment that affect the heat exchange of a person with the environment through convection, conduction, heat radiation and evaporation of moisture; these conditions are determined by a combination of temperature, relative humidity and air movement speed, temperature of the surfaces surrounding the person, and the intensity of heat (infrared) radiation.

The main factors that form the microclimate: air temperature, relative humidity, air movement speed and radiation temperature. Each component of the microclimate should correspond to hygienic standards and its parameters, should not vary significantly to disrupt the normal heat sensation and unfavorably affect human health.

Air temperature, relative humidity, air movement speed and radiation temperature are united by the fact that they all affect heat exchange and thermoregulation. And, first of all, we will focus on questions related to heat exchange processes.

12.2. Brief information about human heat exchange with the environment (chemical and physical thermoregulation)

The human body constantly produces heat. It is a by-product which is formed during transformation of chemical energy into mechanical energy.

According to Academician O. O. Bogomolets, "Heat is the main essence of the human body."

The body must free itself from the heat generated in it. The heat from the body is lost by its return to the environment.

One of the most important conditions for physiological human homeostasis is the maintenance of isothermy — the relative balance between heat production and

heat emission to the environment. This condition is thermal homeostasis. It can be described by the formula:

$$Q_1 = Q_2,$$

where Q_1 — the amount of heat generated in the human body; Q_2, — the amount of heat that a person emits to the environment.

Heat is constantly produced in the body to maintain vital processes, to function, and then it is emitted to the environment.

To provide the normal biological, biochemical, biophysical and physiological processes, the organism needs constant temperature support. Its rise by 1–2 degrees leads to "*harmful changes in the whole body*" *(O. O. Bogomolets)*.

However, in the human body, there are periodic fluctuations in body temperature within 1 °C (Fig. 12.1). There are circadian or daily fluctuations (the minimum body temperature is observed at night at 3–4 o'clock and maximum — in the evening at 17–18 o'clock); seasonal (depending on the hormonal status of the body, associated with traveling from one time zone to another; due to muscular strain).

Body temperature means the temperature of its core. The temperature of different areas of the skin can differ significantly not only from the core temperature, but also between each other. The core temperature is measured as the temperature (representative temperature) under the armpit (36.6 °C), in the oral cavity (36.7–37.0 °C), in infants — in the rectum (37.3–37.6 °C).

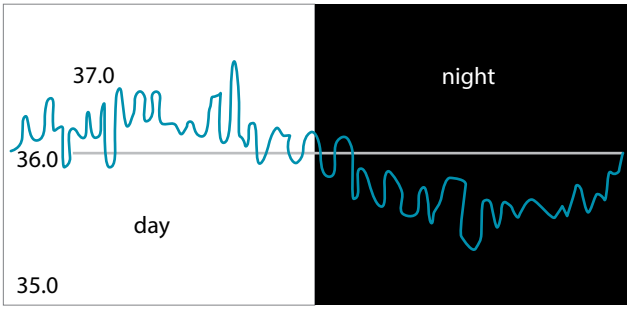


Fig. 12.1. Daily fluctuations in human body temperature

The surface temperature of the human body under comfortable conditions differs from the core temperature of the human body. Table 12.1 shows the body surface temperature (°C) in terms of thermal comfort, according to various authors (I. I. Rusets, A. D. Slonim, R. M. Knyazhevich, L. Kolier).

Complex chemical reactions, most of which are accompanied by the emission of heat, take place in the body all the time. These include hydrolytic decomposition reactions, oxidation processes etc. This process of heat production in the body is called chemical thermoregulation. The amount of heat produced in the body depends on its characteristics (age, sex, nutrition peculiarities, etc.) and the characteristics of work.

Table 12.1. Body surface temperatures (°C) under conditions of thermal comfort, according to various authors (I. I. Rusets, A. D. Slonim, R. M. Knyazhevich, L. Kolier)

Body area	I. I. Rusets	A. D. Slonim	R. M. Knyazhevich	L. Kolier
Forehead	32.2–34.0	33.5	32.5	34.6
Chest	34.0–34.8	33.4	34.8	34.6
Abdomen	34.5–35.2	31.1	35.9	34.6
Back	—	33.3	33.5	34.6
Shoulder	34.0–34.5	32.4–33.3	32.9	33.0
Forearm	33.4–33.8	32.9	—	30.8
Hand	33.5–33.7	31.0	31.0	28.6
Thigh	32.5–33.7	32.5	31.8	33.0
Shin	—	32.2	31.7	30.8
Foot	31.0–31.5	29.9	30.9	28.6

Heat production in the human body occurs constantly, but the intensity varies. Heat is produced in all organs and tissues, but in different proportions. This ratio varies depending on the functional state of the organism. So, at rest 20 % of heat is formed in a liver, 56 % — in other organs and 20 % — in skeletal muscles. During exercise, the muscles produce 90 % of the heat; in addition, all heat production increases in 4–5 times. Heat production is divided into the **contractile** (muscle tone, muscle tremor and voluntary muscle movements) and **non-contractile** one.

Under normal conditions, an increase of body temperature is not observed, because the body has a reliable system of heat emission to the environment **(physical thermoregulation)**.

Phylogenetically, physical thermoregulation emerged later. There are two ways of heat emission (Fig. 12.2): the main amount is emitted from the body through the skin (about 80–85 %), and the rest (15–20 %) — extradermally (to heat water, food consumed by humans, for heating of the air entering the respiratory tract, for defecation and urination).

There are 3 main mechanisms of heat emission through the skin:

- radiation;
- conducting (convection and conduction);
- heat loss due to evaporation of moisture (sweat) from the surface of the skin and mucous membranes (respiratory tract, visual organs). This mechanism is termed as evaporation.

Under normal (comfortable) environmental conditions, heat transfer by radiation makes 40–45 %, conduction — 25–30 %, evaporation — 10–15 %. The given values of heat loss through the skin by different mechanisms of physical thermoregulation are generalized values, depending on specific combinations of air physical properties and temperature of surrounding objects (so-called "radiation temperature"); they can vary significantly.

All these ways of heat emission occur simultaneously. However, in order to better understand these dependences on the parameters of the microclimate, we will consider them separately.

Heat emission by radiation is the emission of heat energy by the body into the environment by infrared radiation. The human body, like any other body with a temperature above absolute zero, gives off heat to surrounding surfaces. Heat emission by radiation is directed towards the surfaces with lower temperature.

The Stefan — Boltzmann law determines the amount of heat emission through radiation. Heat loss by radiation according to this law depends on the difference

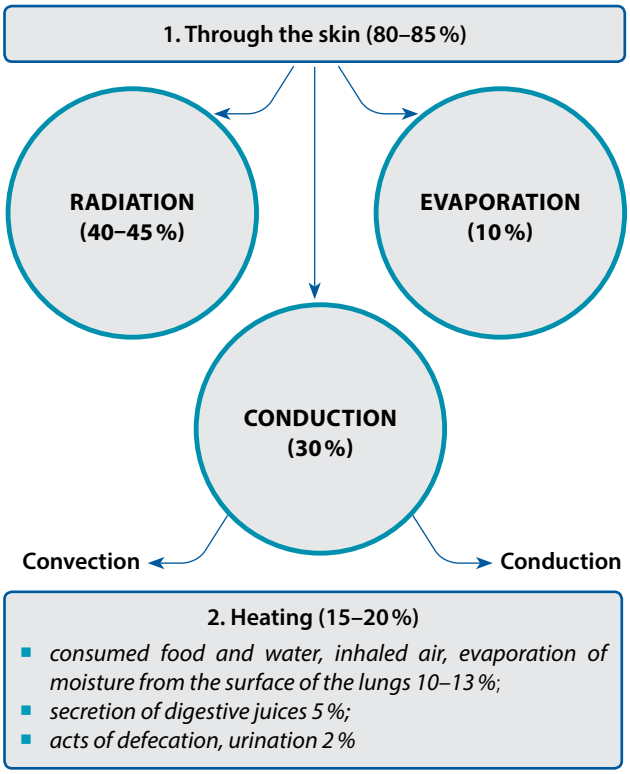


Fig. 12.2. Ways of heat emission under the conditions of a comfortable microclimate

between the temperature of human skin and radiation temperature; it is described by the equation:

$$E = K (T_1^4 - T_2^4),$$

where E is the heat loss by radiation; K is a constant value (5.77×10^{-12} J/s); T_1 — the absolute temperature of human skin; T_2 — the absolute temperature of surrounding objects.

The Stefan — Boltzmann law states that the higher is the temperature of the heat source (human skin) compared to the temperature of the surrounding surfaces, the more heat will be emitted by radiation, and the greater its value among the heat transfer mechanisms will be. The equation shows that if $T_1 > T_2$ — *the radiation balance is negative*.

On the contrary, with increasing temperature of the surrounding surfaces and objects, the amount of heat lost by radiation decreases. The equation shows that if $T_1 < T_2$ — *the radiation balance is positive*, i.e. a person will receive from the objects around more heat radiation than he or she emits to environment. This situation is

observed in the workshops and it leads to overheating. Heat loss by radiation depends on solar radiation, soil temperature and the building walls.

If the temperature of the surrounding objects is equal to the temperature of human skin, the heat emission by radiation completely stops.

Heat emission by radiation from the skin surface under normal conditions makes approximately 0.05 cal/cm^2, solar radiation is 1–15 cal/cm^2, the radiation of heated surfaces in manufacturing premises can be 15 cal/cm^2.

Radiation exceeding 2 cal/cm^2 causes a burning sensation and requires protection measures.

Do air temperature, humidity and air movement speed affect heat emission by radiation? No, they don't.

For example: *in the cold period (winter) if you have entered a room that had not been heated for a long time. To warm up, turn on the heater, and the air heats up relatively quickly to a temperature of 18–20 °C. However, you still do not feel warm. This is due to the fact that the walls, floor and ceiling in the room remain cold, and due to the large difference between their temperature and body temperature, large amount of heat is lost by radiation.*

Since at normal temperatures (18–20 °C) in residential and public buildings a person loses a half his heat through radiation, it is obvious that in order to create thermal comfort for a person it would be advisable to have a device to regulate the temperature of surrounding surfaces (ceilings, walls, floors). Then you could increase their temperature in the cold season. This idea has found its application in practice: for example, there is achieved by radiant heating a floor with built-in heating system.

Heat emission by conducting can be carried out by convection and conduction. Convection is the direct transfer of heat from the surface of the human body to the less heated layers of air that surround it. The intensity of heat transfer in this way is proportional to the surface area of the body and the difference between body temperature and ambient air:

$$Q = S \times (T_1 + T_2),$$

where Q — heat loss by convection, cal/m^2; T_1 — human body temperature; T_2 — air temperature; S — surface area of the human body.

Conduction is the transfer of heat from the surface of the body to less heated objects or surfaces by direct contact with them. Heat loss in this way is insignificant. Further, we will use only the first "convection" to denote heat loss by conduction.

Does heat emission by conduction depend on the air movement speed and its humidity? Yes, it does.

The movement of air promotes heat emission by conduction. Due to the air movement, outflow from the surface of the heated body and inflow of colder air are provided. You should remember that there is no straight line between the air movement speed and its cooling capacity, because it takes some time to heat the air.

For example, if at an air velocity 0 m/s heat loss is Q calories, then:

- at 1 m/s — it will be 2 Q calories;
- at 2 m/s — it will be 3 Q calories;
- at 4 m/s — it will be 4 Q calories;
- at 8 m/s — it will be 5 Q calories.

The practice of using the air movement speed to improve heat emission shows that air movement speeds above 3–4 m/s are impractical.

Humidity, when combined with low temperatures, also increases heat emission by conduction. This is due to increased heat absorption by the air, and due to increased heat conductivity of clothing.

Thus we can easily explain why low winter temperatures are relatively easily tolerated in the Urals and Siberia, where humidity is relatively low, and the small frosts are much worse tolerated in the Baltics or St. Petersburg, where humidity is higher.

Heat loss by evaporation is the body emission of heat energy into the environment by evaporation of water from the surface of the skin, pulmonary alveoli and respiratory tract. Heat emission by evaporation of sweat is due to the fact that to convert 1 ml of water into steam consumes about 0.6 kcal of heat. Evaporating from the surface of the body 2–3 liters of sweat, heat emission will be 1200–1800 kcal.

The amount of sweat that evaporates from the surface of the skin at medium temperatures and when performing light work, ranges from 400 ml to 1 liter. With increasing physical activity, sweating will equal a few liters. Sweating while working in a hot place or sweating in deserts reaches 10 liters.

Heat emission by evaporation depends on humidity and air movement.

The intensity of sweat evaporation is inversely proportional to the saturation of air with water vapor. It follows that under conditions of high humidity, heat emission by sweat evaporation will be difficult. And, vice versa, low humidity is a favorable condition for heat emission by evaporation. However, humidity below 30% is undesirable. Such conditions disrupt the function of the ciliated epithelium and the upper respiratory tract mucous membranes barrier function.

The movement of air has a positive effect on heat emission by evaporation, as it replaces air saturated with water vapor with drier air.

The air temperature is usually lower than the human body temperature, and it does not produce any significant effects on the heat emission by evaporation.

The surrounding surface temperature does not affect heat emission by evaporation of sweat if it is lower than body temperature.

Conceiving the laws of heat transfer mechanisms, the following question should be regarded: *Is the consumption of a large amount of hot tea by the peoples of Central Asia during the hot summer effective?*

When we drink 1 liter of tea, the temperature of which is approximately 60 °C, the human body receives heat, the amount of which is the difference between the tea temperature (60 °C) and body temperature (36.6 °C), i.e. 24 kcal. Tea drinking will be accompanied by sweating. And the evaporation of 1 liter of sweat, as you know, consumes 600 kcal of heat.

Table 12.3 shows heat emission by different ways dependence on the parameters of the microclimate.

Thereby, a complex of air physical factors affects the state of heat balance of the body: its temperature, humidity and air movement speed, radiation temperature. Consider the hygienic significant of each of them separately.

12.3. The influence of temperature, humidity, air movement speed and radiation temperature on the body heat emission by different ways

Air temperature affects the processes of heat production and heat emission in the body. Heat production mostly depends on air temperature and it remains almost the same within 15–25 °C.

Air temperature has effect on the human body both directly and indirectly.

The depth and frequency of respiration, the speed of blood circulation, the intensity of the response and the peculiarities of metabolism, i.e. those intracellular biochemical processes that determine the body's heat production, depend on temperature fluctuations. The processes of interaction of the organism with the environment are carried out using by thermoreceptors — sensitive nerve endings of the skin that respond to changes in temperature. As mentioned earlier, physiological processes take place in the human body and ensure the constancy of body temperature.

A decrease in air temperature contributes to an increase in body heat emission due to conduction, and a decrease in the temperature of the surrounding objects leads to an additional increase in heat emission due to radiation. An increase in temperature causes a decrease in heat exchange by conduction and radiation and increased evaporation (Fig. 12.3).

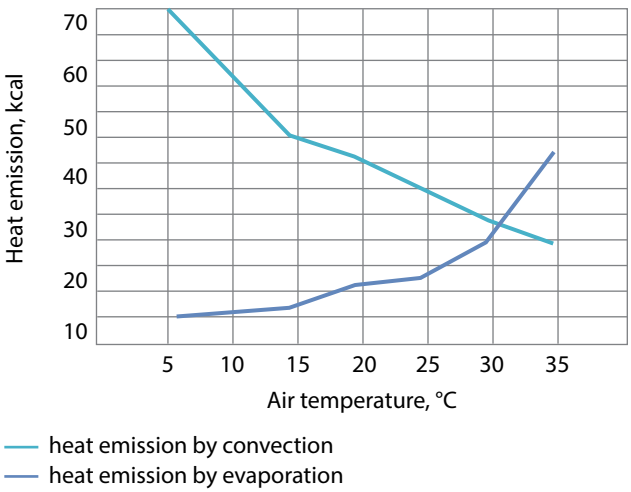


Fig. 12.3. Ways of heat emission by the body at different air temperatures

Table 12.3. Dependence of different heat emission ways on microclimate parameters

Heat emission ways	Influence of microclimate parameters			
	air temperature	*relative humidity*	*air movement speed*	*radiation temperature*
Radiation	—	—	—	+
Convection	+	+	+	—
Conduction	+	+	+	—
Evaporation	+	+	+	—

A decrease in air temperature causes an increase in heat emission by the body due to convection and conduction, and a decrease in the temperature of objects surrounding the person leads to a decrease in heat emission by evaporation.

The average limits of the human body temperature fluctuations, at which its viability is maintained, are relatively small. These limits of temperature range from 25 to 45 °C. Air temperature affects the body's heat loss by conduction: at low air temperature heat emission increases in this way, at high air temperature the heat emission decreases or the body itself receives heat from the environment.

Different air temperatures affect the intensity of sweating, moisture loss and water-salt metabolism. Table 12.4 shows information on heat sensations, average skin temperature and loss of moisture at rest.

For normal functioning of the human body it is necessary to provide thermal comfort, i.e. conditions that lead to minimal functional stress of thermoregulatory processes.

Comfortable thermal environment conditions are considered to be those when a person doing easy work, at an air temperature of 18–22 °C, the maximum allowable value — at the upper limit of 25 °C and the lower limit — 14 °C.

Humidity is the water vapor content in the air. This index is one of the most significant characteristics of the microclimate of the premises and, with the temperature, it provides for the human thermal comfort.

The source of water vapor indoors is a person: moisture enters the room with the exhaled air, and moisture evaporates from the surface of the skin. Water vapor is one of the most volatile components of air. Its parameters vary widely.

Humidity is characterized by several indices, such as: absolute humidity, relative humidity, physiological relative humidity, maximum humidity, humidity deficit, physiological humidity deficit, dew point.

ABSOLUTE HUMIDITY is the moisture quantity in grams, which is contained in 1 m^3 of the air.

RELATIVE HUMIDITY is the ratio in percentage between absolute and maximum humidity or percentage of water vapor saturation of the air at the present moment.

The degree of water evaporation from the surface of the human body depends on physiological relative humidity.

PHYSIOLOGICAL RELATIVE HUMIDITY is defined as a percentage between absolute air humidity at the present air temperature and maximum air humidity at 37 °C.

MAXIMUM HUMIDITY is maximum possible water vapour saturation of the air at the temperature. With increasing temperature, the maximum humidity increases.

HUMIDITY DEFICIT is defined as the difference between the maximum and absolute humidity.

PHYSIOLOGICAL HUMIDITY DEFICIT is defined as the difference between the maximum air humidity at 36.5–37.0 °C body temperature and absolute air humidity at present temperature.

DEW POINT is defined as a temperature when the absolute air humidity is maximum. At this temperature, the water turns into a drop-liquid state, i.e. dew appears.

In hygienic terms, the most important indices are the relative humidity and humidity deficiency, which give an idea of the degree of air saturation with moisture and the possibility of heat emission by evaporation.

The main hygienic significance of humidity for a person is that it affects the heat exchange by evaporation and conduction. Saturation of air with water vapor in the cold season can contribute to hypothermia, as the heat capacity of water is much higher than the heat capacity of

Table 12.4. Heat sensation, average skin temperature and loss of moisture by the human body at rest

Heat sensation	Average skin temperature, °C	Moisture loss, g/h
Very hot	> 36.0	500–2000 (a significant portion of sweat is dripping)
Hot	36.0 ± 0.6	250–500 (a significant portion of sweat is dripping)
Warm	34.9 ± 0.7	60–250 (no sweat is dripping)
Comfort	33.2 ± 1.0	50 ± 10 (sweat is not formed)
Cool	31.1 ± 1.0	40 (sweat is not formed)
Cold	29.1 ± 1.0 (27.9 ± 1.5)	Moisture loss is not typical
Very Cold	< 28.1 (26.4 and low)	

air (1 and 0.237). On the contrary, in hot weather at high temperatures, high humidity will make it difficult to emit heat by evaporation, which will lead to overheating of the body.

At the same time, excessive dryness of the air in combination with high temperature and strong winds is harmful because it causes thirst, drying and cracking of mucous membranes. This is especially dangerous for young children, as these conditions can lead to dangerous consequences associated with dehydration.

The optimal value of relative humidity ranges between 40 and 60 %, the allowable lower value — 30 % (at elevated temperature) and the upper value — 70 %.

Important factor is indoor **air movement** that influences a person's heat sensation. The air movement in the room is predisposed for the temperature gradient. Air masses move from heat to cold temperature.

An increase in the air movement to 0.25 m/sec causes an increase in heat loss by 30 % compared to heat emission at a speed of 0.1 m/sec. In a hot room, the movement of air increases the body heat loss and improves its well-being, but it has an adverse effect at low temperatures in the cold season. In the presence of air movement, sweat evaporates faster from the body surface, which leads to more intense heat emission. It is known that in areas with low air movement speed in hot workshops, workers feel worse. Increasing of the air movement speed leads to improved well-being, but to a certain extent, after which the person senses the draft. In combination with physical stress, the movement of air up to 3–3.5 m/sec is perceived positively. The minimum speed of air movement that a person may feel is 0.03 m/s.

The optimal air movement speed in the room varies between 0.1 and 0.2 m/sec.

Radiation temperature — the intensity of heat radiation and surface temperature. Different objects have different degrees of absorption of infrared radiation, and therefore they are heated differently when they are irradiated. *The air practically does not absorb infrared rays. Bright light surfaces reflect up to 94–95 % of infrared rays, and absorb only 5–6 %. Black matt surfaces absorb up to 96 % of these rays and therefore heat up more intensely.*

Radiation temperature affects heat transfer only by radiation.

The greatest importance here belongs to the radiation temperature as an occupational factor, namely — the influence of high radiation temperatures. Hot workshops workers are constantly or periodically exposed to infrared radiation. Irradiation intensity varies from a few tenths to 15 cal/cm^2/min. For comparison, the intensity of solar radiation in a summer cloudless day reaches only 1.3–1.5 cal/cm^2/min.

In contrast to the effect on the body of high air temperature, high radiation temperature (infrared radiation) is characterized primarily by local action. Subjectively, it is expressed in the heat sensation in the irradiated areas, and the heat sensation depends on the intensity of irradiation: the greater the intensity of irradiation, the more pronounced the heat sensation, up to burning effect.

Infrared radiation also has a general effect on the human body, which is largely similar to the effect of high temperatures; in particular, when irradiated with infrared rays, one observes an increased body temperature, increased sweating, increased heart rate and increased gas exchange. A specific feature of infrared radiation is its ability to cause chemical changes in cells' protein, and when the vision organs are affected — to cause lens opacity (cataract).

Infrared radiation affects the functional state of the central nervous system; the transmission of nervous impulse is complicated under the influence of infrared radiation. This effect increases with increasing wavelength of infrared radiation.

These mechanisms of favorable conditions for heat exchange will be created at a combination of some conditions, the other factors will bring unfavorable conditions.

12.4. Types of microclimate. Physiological reactions, pathological disorders and diseases associated with the impact of uncomfortable microclimate on the body and health

Any environment surrounding a person is characterized by a certain microclimate. In this regard, we can talk about the microclimate of a particular settlement, the microclimate of a forest or park, the microclimate of a particular street, the microclimate of a living room, shop, hospital ward, and operating room. And the space under clothes is characterized by its own microclimate (Table 12.5).

The microclimate of each of these objects is characterized by certain properties. Thus, the microclimate of forests is characterized by coolness in the hot season, in

Table 12.5. Classification of microclimate (according to location)

ACCORDING TO LOCATION:
1. MICROCLIMATE OF SETTLEMENT (microdistrict, resort, forest, park)
2. MICROCLIMATE OF PREMICES (a living room, a hospital ward, an operating room)
3. MICROCLIMATE OF THE SPACE UNDER CLOTHES

the cold period — by pleasant cosiness. The urban microclimate (squares, streets, etc.) is characterized by stuffiness in the hot summer period of the year, increased heat condition in winter, weak solar radiation, increasing cloudiness and precipitation in summer, fog in autumn and winter.

The microclimate of the premises depends on the type of premises and their purpose, the number of persons in them, the nature of human working, the number and type of equipment in it.

Human adaptation to the microclimate occurs in two ways:

1. Passive way — by using physiological mechanisms of thermoregulation.
2. Active way — by appropriate clothing, housing, arrangement in residential and industrial premises heating, ventilation, air conditioning.

F. F. Erismann also said that the man in the environment surrounds himself with two "belts of fortifications" — clothing and housing.

The microclimate can be comfortable and uncomfortable for human (Fig. 12.4).

Comfortable microclimate is a microclimate in which the human body can maintain heat balance with the environment without stressing the processes of thermoregulation. Comfortable microclimate is important in human life: only it provides a satisfactory thermal well-being, normal functioning and high mental and physical performance. Under such conditions, the human body is resistant to the impact of negative environmental factors.

Uncomfortable microclimate, depending on the predominance of heat or cold effects on the body can be hot and cold. In conditions of uncomfortable microclimate we observe strained stressed thermoregulatory processes, impaired heat sensation, deterioration of conditioned reflex activity and function of analyzers, reduced work capacity and quality, reduced body resistance to harmful factors (infectious, chemical, etc.). Uncomfortable microclimate can cause acute and chronic diseases.

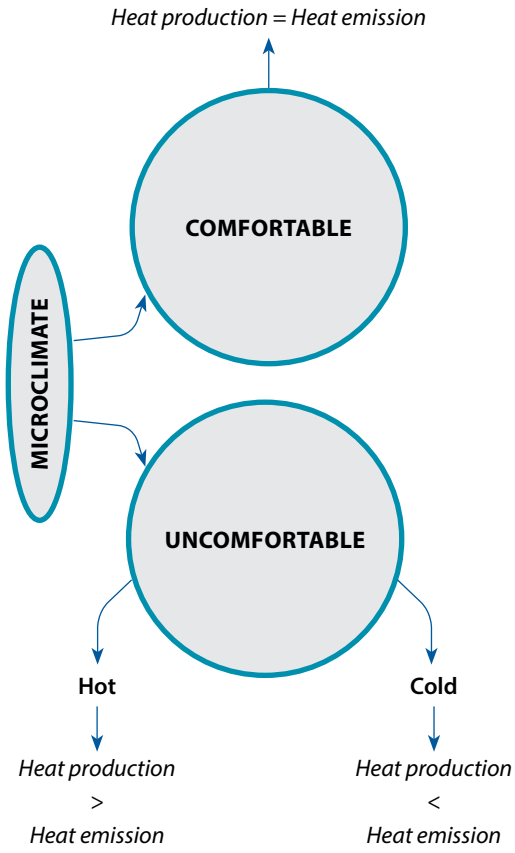


Fig. 12.4. Classification of microclimate (according to human sensation)

Hot and cold microclimates can be seen in an open atmosphere, especially in agricultural, building and other types of work, when working on vehicles, and other occupational facilities.

Both hot and cold microclimates, depending on intensity and duration of influence, can cause in a human body:

1. Physiological changes.
2. Pathological changes.

Consider the changes that occur in the human body as a result of the hot microclimate influence.

At moderate overheating in an organism there are physiological shifts which provide maintenance of heat balance with external environment.

The first sign of overheating is the *dilatation of skin capillaries* and, as a consequence, an increase in its temperature. In comfortable conditions, the temperature of the forehead skin is approximately 33 °C, and the tem-

Table 12.6. Physiological responses of the organism in different types of microclimate

Reactions of the organism	Types of microclimate		
	Comfortable	Uncomfortable	
		hot	*cold*
Forehead skin temperature, °C	32–33	+(2–3)	–(2–3)
The temperature of the back of the hand, °C	29–30	30–32	20–22
The difference in temperature between the skin of the forehead and the skin of the back of the hand, °C	3–4	2–3	–(7–8)
Moisture loss through the skin, g/h	60–80	200–500	< 50
Heart, beats/min	65–70	+(20–30)	–(5–10)
Respiratory rate, per min	16–18	+(5–6)	–(2–3)
The level of gas exchange, %	100	–(5–10)	+(10–15)
Body temperature, °C	36.6	36.6	36.6
Subjective heat sensation	"comfortable" "normal"	"warm" "hot"	"cool" "cold"

perature of the back of the hand and foot is 5–6 °C lower. When overheated, this difference decreases and is about 2–3 °C (Table 12.6).

The skin temperature is changed by special thermoreceptors. These receptors function basing on the change of the electrical resistance of the skin depending on its temperature.

The second sign of overheating is *sweating*. Sweating begins in open areas of the skin and later spreads to the upper half of the body. It is considered permissible for a person to lose 2–3 % of weight by evaporating moisture. Dehydration by 6 % leads to impaired mental activity, decreased visual acuity; 15–20 % dehydration is fatal.

The third sign of overheating is an *acceleration of the pulse and an increase in respiratory rat*e. In high temperature conditions, both at work and rest there is a significant acceleration of the heart rate. At rest the heart rate doesn't usually exceed 100 beats per minute, at work — it ranges between 140 to 180.

The next, fourth, sign of overheating is a disordered *higher nervous function*, which is characterized by prolonged latent period of reflexes, reduced strength of reflexes, and reduced functional capacity of the analyzers, reduced mental and physical workability.

Disordered analyzer function in the hot microclimate may lead to industrial injuries.

The fifth sign of overheating is a change in *basal metabolism (BM)*. At an air temperature of 15–25 °C the basal metabolism is permanent, due to which this temperature range is called the *zone of invariance* (Fig. 12.5). The permanent heat state of the body is provided mainly by physical thermoregulation under such temperature conditions.

If the air temperature rises in the range of 25–35 °C, the basal metabolism decreases. This temperature range is *zone of decreased metabolism*. With a further increase in temperature in the range of 35–45 °C, there is an increase in metabolism caused by the breakdown of proteins due to high temperatures. This temperature range is the upper zone of increased metabolism.

The sixth sign of overheating is a *rise in body temperature*. The body temperature in the heating microclimate remains permanent for a long time. And it begins to increase only when proteins start to breakdown, which is accompanied by an increase in basal metabolism. A significant increase in temperature indicates a disorder of the human thermoregulatory system. Therefore, a slight increase in body temperature (by a few tenths of a degree) requires the most careful attention from doctors.

Finally, the seventh sign of overheating is the *subjective feelings of a person*, which are characterized by the terms "warm", "hot", "stuffy".

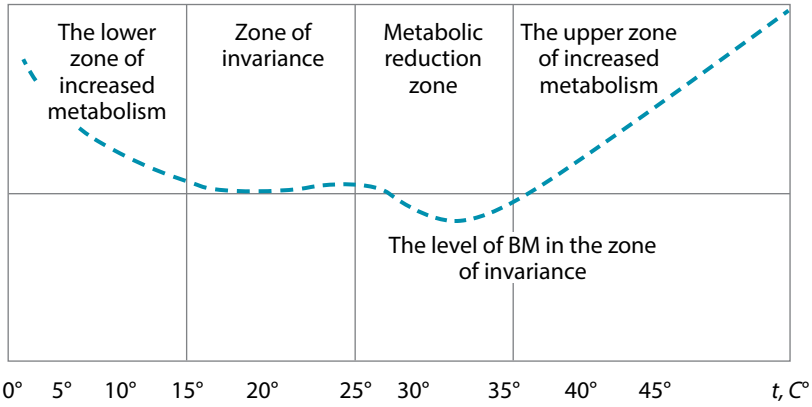


Fig. 12.5. Basal metabolism at different air temperatures

Table 12.7. Classification of overheating of the human body by the nature of the thermoregulation adaptive mechanisms (Azhaev A. N., 1985)

Index	Degree of overheating		
	I	*II*	*III*
Adaptation of the organism to environmental conditions	Stable adaptation	Partial adaptation	Adaptation failure
Compensation of heat emission load	Full compensation of the total heat load	Compensation of external heat load	No compensation for external heat load
Heat content of the "core"	Preserved	Increased	Significantly increased
Heat content of the "shell"	Enlarged	Significantly increased	Significantly increased
Effective sweating	Significant	Reduction	Significantly reduced

A. N. Azhaev classified overheating of the body by the nature of the thermoregulation adaptive mechanisms (Table 12.7).

According to this classification, there are three degrees of overheating, due to such indices as the degree of the organism adaptation to environmental conditions, compensation of heat load, heat content of the "core", "shell" and effective sweating.

As it mentioned before, pathological changes may occur in the human body under the hot microclimate condition.

According to the WHO classification, heat injuries include:

1. Heat (sun) stroke.
2. Heat fainting. Loss of consciousness
3. Heat convulsions.
4. Heat exhaustion due to dehydration.
5. Heat exhaustion due to loss of salts by the body.
6. Unspecified heat exhaustion.
7. Transient heat exhaustion.
8. Heat swelling of the shins and feet.
9. Other manifestations of heat effects.

Pathological changes in the body under the heating microclimate could be observed outdoors and in working conditions, when hard physical work is done at a temperature of 40 °C, high humidity (80–90 %), no air movement and intense heat radiation.

Acute hyperthermia, heat stroke and convulsive disease may occur in acute hot microclimate impact.

Acute hyperthermia is characterized by a sharp rise in body temperature — up to 40–41 °C, with the pulse increasing by 2–2.5 times, profuse sweating, muscle weakness, sensations of heat, palpitations, thirst, headache. Dizziness, sluggish gait, and nausea are observed in the initial period of thermoregulation disorders.

In a ***heat stroke***, a person falls suddenly, skin is dry and red, which is associated with insufficient sweating, body temperature is 43 °C or higher, loss of consciousness, collapse.

Convulsive (spastic) disease develops on the background of the common symptoms of hyperthermia and characterized by the appearance of sudden tonic convulsions, mainly in the extremities. Intense sweating precedes the convulsive disease, farther leading to body dehydration and chloride ions loss.

Chronic effect of a hot microclimate causes ***chronic hyperthermia.*** Chronic hyperthermia manifests in different physiological systems lesions. Digestive, cardiovascular, urinary systems are affected. Heart muscle overload due to vasodilatation. This causes tachycardia, myocardial hypertrophy and dystrophy; health deterioration among patients with heart and vessel problems.

Redistribution of blood with anemia of internal organs and water-salt imbalance significantly affect the functional state of the digestive system and kidneys.

Intake of significant amounts of water into the stomach in combination with the direct effect of high temperature on its secretory apparatus lead to appetite loss, gastric secretion disturbance and stomach juice acidity decreasing. Therefore, gastritis, colitis may develop.

In high temperature conditions, the main amount of fluid is excreted from the body by extrarenal way, mainly with sweat. This often leads to the development of kidney failure, resulting in the appearance of protein, cylinders, and erythrocytes in the urine.

Cold microclimate, like hot one, causes both physiological and pathological changes in the human body.

Physiological changes arise at moderate exposure to cold because of organism cold adaptation. *Change in skin temperature* is one of the earliest symptoms of the cold exposure. The temperature of exposed body areas (forehead, forearms and especially the hands), compared to the non-exposed areas temperature, declines. The difference can reach 10–15 °C.

The next symptom of the cold exposure is the *"goose bumps",* which occur because of contraction of muscle fibers around the hair follicles, and muscle tremor — a reflex contraction of muscle fibers, which leads to increased heat production in the body.

An important sign of cold exposure is the *CNS dysfunction*, which is represented with the weakening and even disappearing reflexes as well as the reduction of various sensitivity types.

One of the signs of cold exposure is an *increase of basal metabolism.*

The cold microclimate can lead to a *decrease in workability*, when it becomes especially difficult to perform precise types of work.

A sign of cooling can be represented with the person's subjective feelings and behavior. The subjective feelings can be described by a person with the terms "cold" or "very cold", and the behavioral changes deal with an attempt to adopt a posture that reduces the body surface.

Pathological changes, due to the cold exposure, can manifest itself as the acute and chronic hypothermia.

Acute effects of cold exposure can manifest in the body in two ways: either in the form of local hypothermia, or in the form of general hypothermia.

1. Local cold exposure can manifest with the frostbites, promotes local inflammatory processes.

Frostbite is a result of exposure to cold air accompanied with high humidity and strong winds. Frostbites may be promoted by doing of static work.

Frostbite can occur not only at low temperatures, but also at subnormal air temperatures in conditions of high humidity. Similar phenomena are common on fishing boats.

Local inflammatory diseases caused by exposure to the cold microclimate take a high percentage in the overall morbidity structure. The cold morbidity increases in winter and decreases in summer.

Local hypothermia caused by a draught, sitting on cold ground, drinking cold water and wetting the feet, can cause the pathological process directly in the chilled area of the body. Myositis, neuralgia and sore throat may develop.

Local cold exposure can cause a *reflected reaction*, which can manifest itself, for example, as a runny nose when one's feet are overcool. The reflected reaction is associated with reflex changes in blood supply and metabolic processes.

Laryngitis, bronchitis, sore throat, pneumonia, cystitis, pyelitis and other diseases can occur due to this mechanism of cold exposure.

2. General cold exposure of body can lead to decreased immune reactivity, which causes diseases of upper respiratory ways and kidney diseases.

Many scientists believe that cold can stimulates allergic reactions, such as bronchial asthma or paroxysmal hemoglobinuria, because cold, affecting the skin, promotes production of histamine-like substances known as allergens.

Chronic influence of cold microclimate causes chronic hypothermia. It is manifested by decreased workability and, decreased body resistance to unfavorable factors (chemicals, biologicals, etc.).

12.5. Methods of microclimate complex assessment and their hygienic characteristics

Hygienic complex assessment of microclimate effect onto the human heat exchange is performed by two groups of methods:

1. ***Subjective methods:***
   - questionnaires;
   - method of effective temperatures;
   - method of equivalent-effective temperatures;
   - method of resulting temperatures.
2. ***Objective methods:***
   - factor method;
   - method of catathermometry;
   - method of phrigometry;
   - calculation, or method of heat balance assessment;
   - method of clinical-physiological reactions assessment.

Questionnaire method shows subjective characteristic of human heat state. The method is based on questioning of a homogeneous group of people who are staying in the same microclimatic conditions. Seven characteristics are used to describe temperature perception: very cold, cold, cool, comfortable, warm, hot and very hot. Additional characteristics, which are used in the subjective assessment of the microclimate, are: stuffy, humid, and windy.

Method of effective temperatures uses nomograms. The *effective temperature* is an index of the heat feeling that a person experiences at different combinations of temperature and humidity. To compare the thermal effect, it is based on still air of a certain temperature saturated with moisture. The degree of effective temperature is expressed in the temperature of stationary air, saturated to 100 % of relative humidity, which causes this effect.

There are two notions: *a comfort zone* — not less than 50 % of people feel comfortably, and a *comfort line* — almost 95 % of people feel comfort.

Method of equivalent-effective temperatures. As in the previous method, nomograms are used to determine the equivalent-effective temperatures. The e*quivalent-effective temperature* is an index that takes into account the effect of three parameters on the human thermoregulation — temperature, humidity and air movement speed.

Method of resulting temperatures. Method of resulting temperatures takes into consideration the complex effect on the organism of temperature, humidity, air velocity and radiation temperature. The radiation temperature is determined using the globe thermometer.

The resulting temperature is a temperature that causes heat sensation similar to that one felt in a room where the stationary air is completely saturated with moisture, and the average temperature of the inner surfaces of the walls is equal to the air temperature.

The standard parameters of effective temperatures are: comfort areas for the human body 17.2–21.2 °C, the line of comfort 18.1–18.9 °C; comfortable heat sensation of workers during light working activity occurs at the resulting temperature of 16–18 °C, and during hard work — 10–13 °C.

Factor method *is another objective method*. This method is based on determination of air temperature, humidity, air movement speed and radiation temperature using special devises; comparing results of microclimate parameters with standards, and making conclusions.

Method of catathermometry. The catathermometer determines air cooling capability (compared to the human body), but, as it turned out, the catathermometer does not reproduce the conditions of heat loss from the surface of human skin and does not regard the effects of heat radiation, which significantly affect heat exchange. Since the reaction of the human body is not taken into account when determining air cooling capability with a catathermometer, the readings of the catathermometer are considered conditional and are used only as indicative ones.

The catathermometer shows heat loss (mcal/sec) from 1 cm^2 of the device. The general condition of a person depends on the heat loss, and therefore it feels good when you lose the heat amount equivalent to that produced by the body per time unit. A clothed person usually loses 1.2–1.4 mcal per 1 sec from 1 m^2 of body surface.

When air cooling capability equals 5.5–7.4 mcal/sec per cm^2, the person will feel the best in the premises of seated professions. If air cooling of catathermometer is more than 7.0, the person feels cold; if it is less than 5.5, the person will have suffocation.

Method of phrigometry takes into account the influence of all microclimate factors: temperature, humidity, air movement speed and radiation temperature. For this purpose the Shahbazyan – Erman device is used, which registers the cooling capacity of the air.

Calculation, or method of heat balance assessment, provides assessment of heat exchange by comparing the magnitude of heat production during work and the heat emission, which is determined by calculating the heat emitted by a person through radiation, conduction and evaporation.

Method of clinical-physiological reactions assessment is used for assessment of the organism functional state. It is based on such indices:

1. The temperature of the skin in different parts of the body (back of the hand, sternum, back of the foot, forehead), covered with clothes. The temperature in different areas of the skin ranges from 31 to 34 °C, which corresponds to normal human well-being. The skin temperature is measured with an electronic thermometer.
2. *The temperature difference in different areas of the skin — in thermal comfort conditions of a healthy person, the temperature of the forehead skin is 32.5–33.5 °C, hands — 29–30 °C, the difference between them — 3–4 °C. Since the distal parts of the body lose temperature faster, the difference increases with decreasing air temperature, and decreases with increasing temperature. Human heat sensation changes according to the dynamics of air temperature.*
3. *Heartbeat rate (pulse) per minute.*
4. *Blood pressure in mm Hg.*
5. *Respiratory rate per minute.*
6. *The presence and intensity of sweat on the forehead skin by iodine-starch test (Mishchuk's method) or measurement of skin conductivity.*

These issues will be considered thoroughly in practical classes.

12.6. Regulation and control of microclimate parameters in premises used for various purposes

In order to maintain health and high work capacity, it is necessary to create the most favorable air conditions for humans, both at home and work.

There are the concepts of "optimal" and "allowable microclimatic conditions".

Optimal microclimatic conditions — a combination of microclimate parameters, which with long-term and systematic exposure ensure preservation of the normal heat state of the body without activating the mechanisms of thermoregulation. They provide a feeling of thermal comfort and create the conditions for a high level work capacity.

Allowable microclimatic conditions — a combination of microclimate parameters, which with prolonged and systematic exposure can cause changes in the heat state of the body, which quickly pass, normalize, and are accompanied by stress mechanisms of thermoregulation within physiological adaptation. They don't lead to injuries or health problems, but uncomfortable heat sensation, well-being impairment and reduced workability could occurr.

Hygienic regulation of microclimate parameters should provide for their complexity, differentiation and guarantee. Standard parameters of the microclimate must provide for preserved health and workability, even for a person with reduced tolerance to environmental fluctuations.

Main principles of microclimate parameters regulation:

1. It is necessary to take into account the daily and seasonal rhythm of fluctuations of the physiological functions of the organism.
2. Differential approach to different population groups.
3. The levels of energy consumption (activity), the severity and intensity of labor, the nature of technological processes and their impact on the processes of thermoregulation and heat-protective properties of clothing of the respective population group must be regarded.

The additional criteria should be used:

1. Dynamic pattern of changes in heat emission by radiation and convection.
2. Indices that characterize the state of the central and autonomic nervous system.
3. Study of the lability of the thermoregulatory system.
4. The level of energy consumption and heat deficit.

The following documents regulating microclimate indices are valid in Ukraine today:

1. Building Codes and Standards SNiP 2.04.05–91 "Heating, ventilation and air conditioning".
2. State Building Code DBN V.2.2–15–2005 "Buildings and structures. Residential buildings. Substantive provisions".
3. State Sanitary Code DSN 3.3.6.042–99 "Sanitary standards of microclimate of industrial premises".

Tables 12.9, 12.10, 12.11 show the optimal standards of temperature, relative humidity and air movement speed in residential, public, administrative, hospital and industrial premises.

Based on the fact that the heat comfort area ranges between 20–23 °C, it is necessary to ensure that the difference in air temperature does not exceed 2–3 °C vertically, 2 °C horizontally, and the difference between the temperatures of the inner wall surfaces and air doesn't exceed 5 °C. The air velocity should not exceed 0.2–0.3 m/sec, relative humidity — 30–60 %.

Table 12.9. Optimal standards of temperature, relative humidity and air movement speed in residential, public and administrative premises (excerpt from SNiP 2.04.05–91 "Heating, ventilation and air conditioning")

Season of the year	Air temperature, °C	Relative humidity, %	Air movement speed, m/sec
Warm period	20–22 23–25	60–30 60–30	Up to 0.2 Up to 0.3
Cold period. Mid-seasons	20–22	45–30	Up to 0.2

Table 12.10. Estimated values of microclimate parameters in the main premises of a hospital

Season of the year	Air temperature, °C	Relative humidity, %	Air movement speed, m/sec
Physician's office	20	40–60	0.1–0.2
Operating room	23	55–60	Up 0.15
Wards for patients with hypothyroidism	24	40–60	0.1–0.2
Wards for patients with thyrotoxicosis	15	40–60	0.1–0.2
Postpartum wards, combustion wards, wards for children, boxes, semiboxes	22	40–60	0.1–0.2
Wards for newborns	25	40–60	0.1–0.2
Ward sections of infections department	20	40–60	0.1–0.2

Table 12.11. Optimal values of temperature, relative humidity and air movement speed in the working area of production facilities (excerpt from the Sanitary standards of the microclimate of production facilities DSN 3.3.6.042–99)

Season of the year	Category of work	Air temperature, °C	Relative humidity, %	Air movement speed, m/sec
Warm period	Light Ia	22–24	60–40	0.1
	Light Ib	21–23	60–40	0.1
	Medium complexity IIa	19–21	60–40	0.2
	Medium complexity IIb	17–19	60–40	0.2
	Heavy III	16–18	60–40	0.3
Cold period	Light Ia	23–25	60–40	0.1
	Light Ib	22–24	60–40	0.2
	Medium complexity IIa	21–23	60–40	0.3
	Medium complexity IIb	20–22	60–40	0.3
	Heavy III	18–20	60–40	0.4

12.7. General measures used to normalize the premises' microclimate and ways to prevent diseases caused by the uncomfortable microclimate. Ways of improving human working capacity

The following measures are used to create favorable microclimate conditions in residential, public and administrative premises:

1. Hygienic standardization.
2. Architectural and planning measures.
3. Technological and sanitary measures.
4. Medical-preventive measures.
5. Individual measures.

In the previous chapter, the issues of the microclimate parameter hygienic standardization were considered.

Architectural and planning measures provide the correct choice of materials and structures in the construction of buildings for various purposes. Namely: building materials must possess sufficient thickness, low thermal conductivity, high air permeability and porosity.

For example, increasing the thickness of walls that are insolated for long period to 0.7 m or more leads to their slow heating, while the room remains cool.

The optimal orientation of the windows is significant. Orientation of the windows impact on the time of insolation, and, accordingly, on the temperature in the room.

Rooms, in which it is necessary to prevent the heating effect of direct sunlight, such as operating rooms, should face the north side.

Reduction of premises overheating can be carried out by painting external walls in white color, arrangement of peaks over windows and protection of walls and windows by green plantings.

Technological and sanitary measures are provided through different heating systems (central, local, steam, central radiant or panel), ventilation (natural, artificial, mixed) and air conditioning (central, local). In working area, effective measures to prevent overheating are measures to localize heat emission, shielding and thermal insulation of radiation and convection heat sources.

Medical-preventive measures are based on sanitary-educational activities held by physicians among the population as well as preventive medical examinations to prevent overheating and hypothermia. These are also optimal work and rest ratio and immunity training in order to increase the adaptive capacity of the human body.

Individual measures provide for a rational choice of clothing and footwear, a rational regimen and the type of food and drinking regimen depending on the microclimatic conditions (Fig. 12.6, Fig. 12.7).

For example, all those who work at high temperatures and significant heat radiation are provided with carbonat-

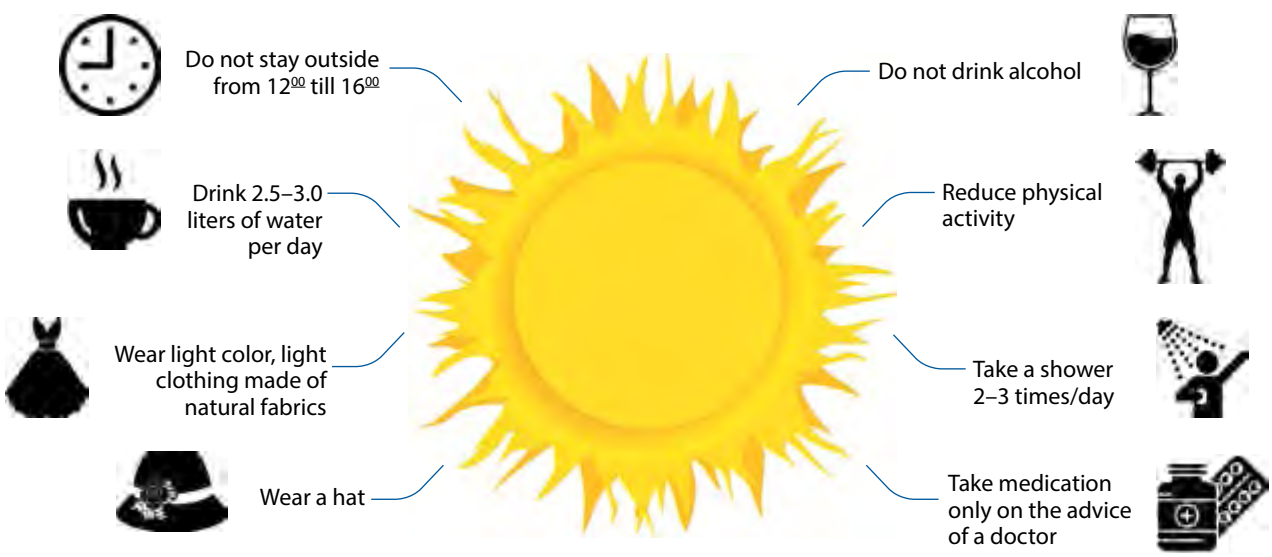


Fig. 12.6. Individual measures to prevent overheating

ed water, which provides normalization of water-salt metabolism. At low temperatures, it is necessary to consume warm food and increase the amount of fat in the diet.

When working under unfavorable microclimate conditions, it is mandatory for personnel to use personal protective equipment (uniform, footwear, head, eye, face, hand protection).

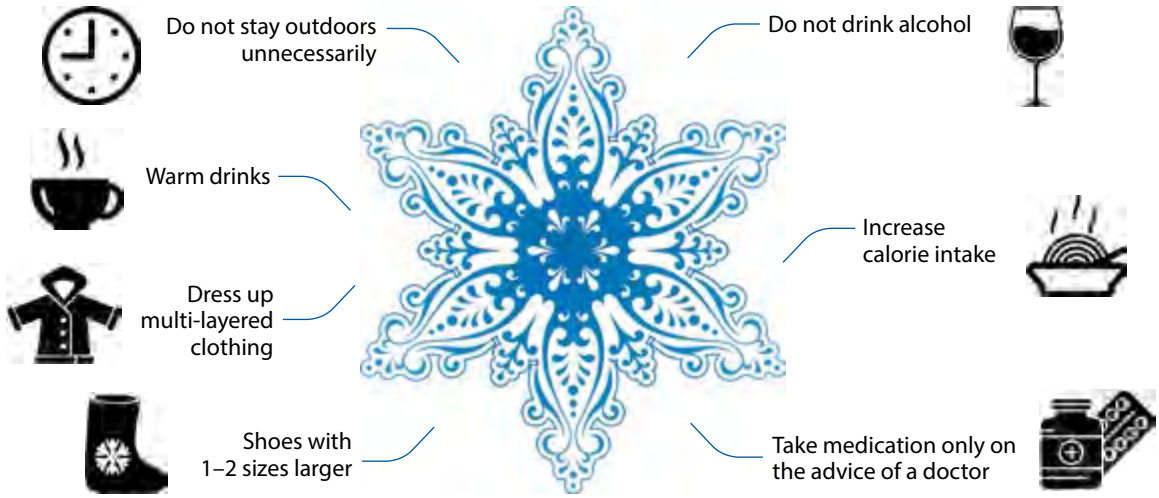


Fig. 12.7. Individual measures to prevent hypothermia

Knowledge of the microclimate parameters is of great importance for the physician. The doctor must be able to determine and assess the impact of the microclimate on the well-being and the course of disease. Equally important is the introduction of measures to prevent pathological conditions caused by uncomfortable microclimate. A doctor of any specialty must be able to carry out a set of measures to create favorable conditions for human habitation, in educational, medical, health care facilities, and industrial premises in order to strengthen and maintain the health.

13

CHAPTER

HYGIENIC SIGNIFICANCE OF ATMOSPHERIC AIR, ITS DENATURATION, WAYS AND MEANS OF PRESERVING THE NATURAL COMPOSITION

O. P. Vavrinevych

The air environment (atmosphere) is the environment surrounding people. The atmosphere is the gas (air) layer of the Earth, which extends to an altitude of 1000–1300 km.

The atmosphere is conditionally divided into the following layers: troposphere and tropopause (height about 16 km in the tropics and 8.5–10 km at the poles of the Earth), stratosphere, stratopause, mesosphere and mesopause (up to 80–100 km), ionosphere, thermosphere (up to 800 km); the upper layer of the thermosphere is called the magnetosphere (Fig. 13.1).

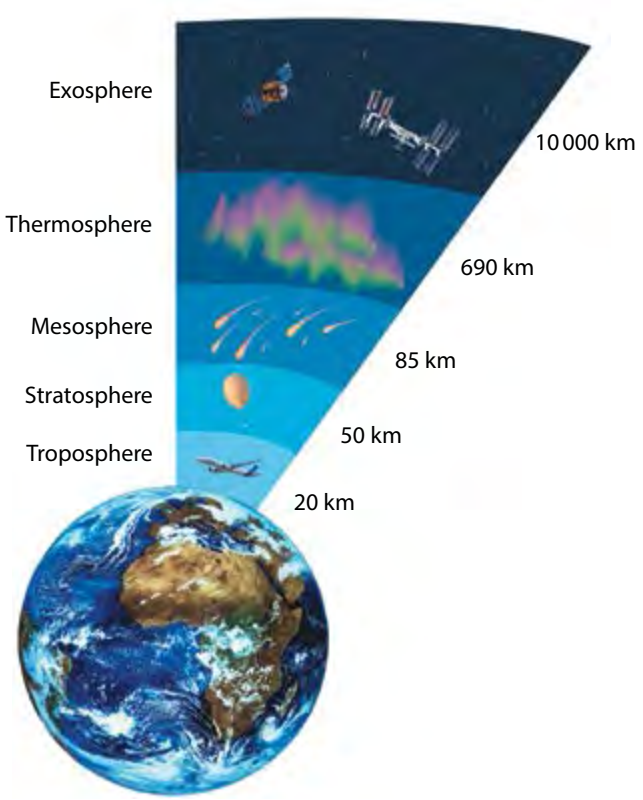


Fig. 13.1. Atmospheric layers

The greatest interest from a hygienic point of view represents the lower part of the atmosphere: the troposphere and tropopause (translated from the Greek "tropean" — to turn or change). Vast majority of the atmosphere volume (almost 80 %) is concentrated in this part. It is where the main processes of converting solar energy into kinetic energy (extensive movement of giant air masses, evaporation of water from seas, rivers and oceans, formation of surface runoff of rivers, groundwater basins, etc.) as well the life processes of flora and fauna take place. Therefore, the lower part of the atmosphere (troposphere and tropopause), together with the lithosphere and hydrosphere, is called the biosphere.

In the troposphere, temperature changes occur both in latitude and longitude, and with increasing altitude: for every 1 km of altitude, the temperature gradient decreases by an average of 6 °C. Such changes in temperature lead to rising of the pollutants (dust, gases, etc.) with air in the upper layers, i.e. the airspace of the atmosphere, especially its lower layers, serve as a reservoir for gaseous metabolic products, and products of household and industrial activities.

Other layers of the atmosphere are also characterized by considerable hygienic significance. Unlike the troposphere, the stratosphere is an extremely low-motioning layer, and chemicals can remain in it for a long time, over the years.

Knowledge of the hygienic significance of the air environment is important for a doctor of any specialty, especially that one about the troposphere, with which people contact directly.

The issue of the importance of the atmosphere studies dates back to ancient times:

Thus, Anaximenes — the ancient Greek philosopher — said:

"*Air is the first matter.*"

"Air is the foundation of everything that exists."

"Air is the source of life and mental phenomena."

Aristotle, the ancient Greek philosopher, believed that "*Air is one of the four elements that make up all matter in nature.*"

Hippocrates asserted "*Air is the pasture of life.*"

Atmospheric air is one of the most important elements of the environment that surround human.

13.1. Chemical composition of atmospheric air and air exhaled by human

For a long time, people imagined air as a homogeneous substance. Only in the second half of the 17th century. French chemist Antoine Lavoisier found that air is a complex mixture of gases.

Atmospheric air is a physical gases mixture, which due to changes in atmospheric density at different altitudes change only their partial pressure. The ratio of different atmospheric gases is the same up to an altitude of 80–100 km.

Constant gas composition of the atmosphere is maintained due to the biological cycle of biospheric ecological systems' substances, as well as due to the continuous movement of air masses in the horizontal and vertical directions. Air is necessary for maintaining human life.

The chemical composition of atmospheric air and the air exhaled by human are represented in Table 13.1.

Nitrogen is important in the substances circulation in nature. Air nitrogen is assimilated by some species of bacteria and blue-green algae, which synthesize nitrogenous organic compounds from it. Under the influence of atmospheric electric discharges, a small amount of nitrogen oxides is also formed, which are washed out of the atmosphere by precipitation and enrich the soil with salts of nitric acids. Nitric acid salts are converted to nitrates by the soil bacteria. Nitrates and salts of ammonia are compounds that are assimilated by plants and participate in protein synthesis. Some nitrogenous substances can be completely decomposed.

Nitrogen is a colorless gas, which is odorless and tasteless, inactive. It does not support respiration and combustion. Because of this, it is called the "lifeless" one. However, nitrogen is an important component of amino acids that form proteins, and it also takes essential part in the natural cycle of substances. Legumes using specific microorganisms absorb nitrogen directly from the air and fix it in the soil as nitric acid and ammonium salts. From here, bound nitrogen enters the body of herbivores and, thus, represents animal proteins, and later human proteins. Nitrogen enters the atmosphere mainly during plant decomposition and volcanic eruptions. It is inert. At high pressure, nitrogen is a drug.

Its physiological role is determined by participation in creating the level of atmospheric pressure required for vital processes. An increase in nitrogen content in the air can lead to hypoxia and asphyxia due to decrease in the partial pressure of oxygen.

As blood pressure increases, the solubility of nitrogen in the blood and tissues increases, and this causes various morbid symptoms in people. The quick change of the pressure to the normal one leads to nitrogen forming small bubbles in the blood that clog blood vessels, causing caisson disease.

Oxygen is the main component of air. Life is impossible without it. It is a colorless gas that dissolves well in water, and all life on Earth appeared owing to its presence. Oxygen is contained in almost all organic substances. Its presence in the air is required for respiration, combustion and putrefaction. The source of oxygen in nature is photosynthesis.

Oxygen is 65 % of the gaseous composition of the organism. At rest, a person absorbs 25 liters of oxygen per

Table 13.1. Chemical composition of atmospheric air and exhaled air, %

Air	Nitrogen (N_2)	Oxygen (O_2)	Carbon dioxide (CO_2)	Inert gases (He, Kr, H_2, O_3 etc.)
Atmospheric	78.09	20.7–20.9	0.03–0.04	Up to 1.0
Exhaled	78.26	15.4–16.0	3.4–4.7	Up to 1.0

hour and exhales 22.6 liters of carbon dioxide. All tissues and cells of the body continually absorb oxygen. All oxidative processes occur due to the presence of oxygen in the human body.

Reduction of oxygen content, according to some data — up to 15 %, and according to others — up to 13 %, can lead to disruption of physiological functions of the human body, namely — gas exchange and transfer of oxygen from the respiratory organs to the tissues. Lack of oxygen can lead to increasing of respiratory and heart rate. At 7–8 % asphyxia, low body temperature, anuria, loss of consciousness and death may occur.

Ozone (O_3) is contained in the atmosphere in small quantities. It is formed during a thunderstorm due to electric discharges, as well as due to the photochemical effect of UV radiation on oxygen. It is a simple substance that is a modification of oxygen. Ozone possesses strong oxidizing effect. Due to the interaction with organic substances, ozone decomposes very easily, and an oxygen atom is released. Ozone actively oxidizes all air pollutants, and therefore serves as an indicator of air purity. It is characterized by disinfectant effect, so it is used for purification of air and water.

Inert gases (helium, neon, krypton, xenon) are present in the atmosphere in small quantities and are associated with uninterrupted processes of natural radioactive decay.

Carbon dioxide (CO_2) is a colorless gas, sour in taste, with a peculiar odor, soluble in water. The source of carbon dioxide is mainly the respiration of humans, animals, plant particles, the decomposition of organic substances and the evaporation of gas from the soil.

Increasing the carbon dioxide content in the inhaled air has a negative effect on the body. In the presence of high concentrations of CO_2 in the air, human respiration accelerates and deepens, and its increase causes a feeling of pressure in the head and headache, tinnitus, mental excitation. The 20 % carbon dioxide in the air causes paralysis of the brain centers after a few seconds.

The amount of carbon dioxide in the atmosphere has increased by **about 10 %** over the last 100 years. It has led to an increase in the average global temperature of the Earth's surface by 0.3–0.4 °C.

13.2. Hygienic significance of atmospheric air

The hygienic significance of the atmospheric air is huge, namely:

1. Physiological.

A human can live without air for not longer than 5–6 minutes. Approximately 10–12 m^3 of air per day passes through the lungs. Human makes 16–18 breathing movements per minute, inhaling 0.5 liters of air each time. If a human performs heavy physical work, he needs about 30 m^3 of air.

2. Epidemiological.

Air is a factor of transmission of infectious diseases pathogens of viral and bacterial etiology by airdrop way (pathogens of viral etiology — SARS, adenoviral infection; bacterial nature — Pneumococci, Meningococci, Staphylococci, Mycobacterium tuberculosis, etc.).

3. Climate forming.

A separate book chapter is devoted to this issue.

4. Self-purification.

The basis of self-purification of the atmosphere are physical and physical-chemical processes (adhesion, adsorption, oxidative-reductive chemical reactions), which cause sedimentation, leaching of atmospheric impurities.

5. A reservoir for accumulation of chemicals.

Technical progress, development of various industries, transport, chemicalization of agriculture, city building have led to the accumulation in the air of specific chemical impurities (lead, manganese, fluorine, arsenic, etc.), which adversely affect population health.

This creates a danger because approximately 10–12 m^3 of air per day passes through the lungs when the person is at rest. Poisons that affect the lungs are 80–100 times more dangerous than those that pass through the gastrointestinal tract.

6. The factor that determines the air quality of indoor premises.

Every year tons of harmful gases and dust are released into the atmosphere, including more than 150 million tons of hydrocarbons and 20 million tons of nitrogen oxide. In total, more than 500 million tons of various chemicals are released into the atmosphere every year. Currently, it is very difficult to list all sources of air pollution, so they are divided into separate groups, although air pollution can be complex and occur simultaneously from several sources.

13.3. Sources of air pollution

Main sources of air pollution are:

1. Natural sources:
   - biogenic (decomposition of organic substances; substances released by plants, animals and microorganisms);

- abiogenic (gases and dust resulting from volcanoes eruptions, geysers and hot springs, forest and steppe fires, space dust).

2. Anthropogenic sources:
   - transport vehicles (carbon monoxide, hydrocarbons, nitric oxide, sulfur dioxide, polychlorinated biphenyls);
   - ferrous metallurgy (gases, iron ore dust, sulfur oxides, phenol, carbon monoxide, ammonia, arsenic, manganese, benzene, etc.);
   - nonferrous metallurgy (emissions of sulfur dioxide, dust, tin, antimony, oxide Cu, Pb and Zn);
   - chemical industry (sulfur dioxide, sulfuric acid vapor);
   - construction industry (cement dust);
   - thermal power plants (products of fuel combustion — coal, oil, peat, natural gas).

The problem of air pollution has attained greater significance with the development of overpopulated industrial cities. Using of cars and other machines has led to the fact that the environment has become constantly and intensively polluted. Motor transport ranks first among air pollutants.

Automobile sources of air pollution represent about 70 % of all pollutants.

The main air pollutants (WHO) are:

1. Solid particles (ash, dust, zinc oxide, silicates, lead chloride).
2. Sulfur compounds (sulfur dioxide, hydrogen sulfide, mercaptans).
3. Organic compounds (aldehydes, hydrocarbons, resins).
4. Nitrogen compounds (nitrogen oxide, nitrogen dioxide, ammonia).
5. Oxygen compounds (ozone, carbon monoxide, carbon dioxide).
6. Halogen compounds (hydrogen fluoride, hydrogen chloride).
7. Radioactive compounds (gases, aerosols).

Vehicle emissions lead to carbon monoxide, hydrocarbons, nitrogen oxides, soot, and sulfur compounds released into the atmosphere.

The analysis of Kyiv air pollution level (according to the B. I. Sreznevsky Central Geophysical Observatory) showed 20 identified pollutants. The main ones are suspended solids, sulfur dioxide, carbon monoxide and nitrogen dioxide. Hydrogen sulfide, phenol, hydrogen fluoride, hydrogen chloride, ammonia, formaldehyde, 8 heavy metals, etc. were identified. The assessment of the air pollution state was carried out by comparison with the corresponding maximum allowable concentrations (MAC) of substances in the air of populated cities.

High concentrations of pollutants in the atmosphere were recorded at stationary observation posts. In particular, the average monthly concentrations of the following five pollutants in the city exceeded the MAC: nitrogen dioxide and phenol — in 3.3 times, formaldehyde — 3 times, nitric oxide — 1.5 times, carbon monoxide — 1.2 times.

During the study, meteorological conditions observed in Kyiv contributed to the accumulation and retention of harmful impurities in the surface layer of the air. The increase in air pollution during these periods was due to the anticyclone characteristics of the weather, heat, and mild wind in the surface layer of air.

According to the Air Pollution Index (API), the city pollution level in August was very high. The level of pollution varied throughout the city: at four posts it was characterized as very high, at eight — as high, at one — as elevated, at another one — as low (according to the B. I. Sreznevsky Central Geophysical Observatory).

The highest average monthly concentrations of pollutants were observed in places of accumulation of vehicles: on Bessarabian Square, Dovzhenko Street and Peremohy Avenue, on Demiivska Square and Obolonsky Avenue.

Air pollution in Kyiv increased in August 2016: average monthly concentrations of phenol, carbon monoxide, nitric oxide, formaldehyde, and hydrogen fluoride increased. Compared to July 2016, the level of air pollution by phenol, nitrogen oxide, carbon monoxide, hydrogen fluoride increased.

Increasing of the air pollution level in Kyiv in August 2016 was due to meteorological and weather conditions (anticyclone, high air temperature, light wind), which contributed to the accumulation and retention of harmful impurities in the atmosphere. The main air pollutants were vehicle emissions and emissions from asphalting on many roads in the city.

Air pollution with anthropogenic chemical impurities is currently associated with the following problems:

1. Smog.
2. Greenhouse effect.
3. Ozone holes.
4. Acid rain.

13.4. Influence of air pollution on public health

Air pollution represents the chemical danger No1 to humans by the degree of chemical hazard. This is primarily because air pollutants are the most widespread, being released into different environments.

For example, precipitation represents up to 10 % of water pollution in the Dnipro basin, significantly polluting the soil and so on.

In addition, a human consumes much more air (in volume) per day water and food (through all life). Natural mechanisms provide significant protective barriers only for harmful substances that enter the body through the gastrointestinal tract, without providing the same protection of the lungs.

Assessing the rate of damage from chemical air pollution is very important. It is necessary to take into account that such pollution can:

1. Reduce the adaptive capacity of the organism and, as a consequence, — resistance to negative factors of other etiology.
2. Increase the morbidity, especially with diseases of the respiratory system.

Hygienists have determined a correlation between industrial emissions into the air and the increased morbidity of bronchitis, asthma, emphysema, cancer, chronic pneumonia, allergies, and the appearance of reflex reactions caused by chemicals.

3. Lead to acute and chronic poisoning by chemical compounds.
4. Lead to malformations in children.
5. Influence the mortality rate.

According to research carried out at the Institute of Public Health under the leadership of A. M. Serdyuk, the state of immunity of the children, who lived in areas with varying air pollution rate, was studied (Fig. 13.2).

Almost a third of the population of Ukraine is exposed to air pollutants. This fact could explain the increase in infectious diseases of diphtheria, tuberculosis, etc., and also the absence of proper vaccination effect.

The occurrence of chronic bronchitis, bronchial asthma and tumors of the respiratory system is growing.

Finally, it was found that among 19 cities with different levels of air pollution, the lowest life duration at birth (both men and women) was observed in cities with developed metallurgical and chemical industries. Situation is better in cities without such industry, with less air pollution.

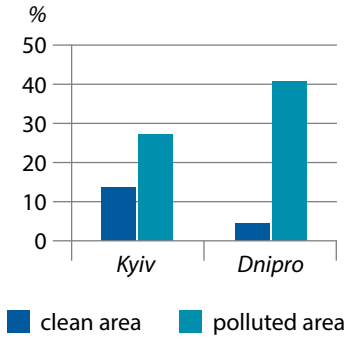


Fig. 13.2. Frequency of immunodeficiencies in children living in areas with varying rate of air pollution

According to WHO, the main pollutants in large cities are solid particles (SP 10, SP 2.5), ozone, nitrogen dioxide and sulfur.

The main components of SP are sulfates, nitrates, ammonia, sodium chloride, carbon, mineral dust and water. The most health-damaging particles are 10 microns or less in diameter (≤ SP 10), which can penetrate deep into the lungs and precipitate in them. Chronic influence to particulate matter increases the risk of cardiovascular and respiratory diseases, as well as lung cancer.

O_3 is a component of photochemical smog.

The main sources of anthropogenic NO_2 are combustion processes (heating, electricity generation, engine operation, etc.).

SO_2 is formed during the combustion of fossil fuels (coal and oil) and smelting of mineral ores containing sulfur; when heating homes, generating electricity in cars.

Also the effects of ozone (O_3), nitrogen dioxide (NO_2) and sulfur dioxide (SO_2) are dangerous for human health. The highest levels of their concentrations are noticed in urban areas of low- and middle-income countries. Ozone is a major risk factor for asthma morbidity and mortality, while nitrogen dioxide and sulfur dioxide may also be involved in the mechanisms of asthma, bronchial symptoms, pneumonia, and decreased lung function.

According to the World Health Organization, in 2012, air pollution caused one in eight deaths on the planet. The structure of deaths caused by polluted air (WHO) is shown in Figure 13.3.

13.5. Atmospheric air protective measures

A complex of measures is used to keep the population health in Ukraine:

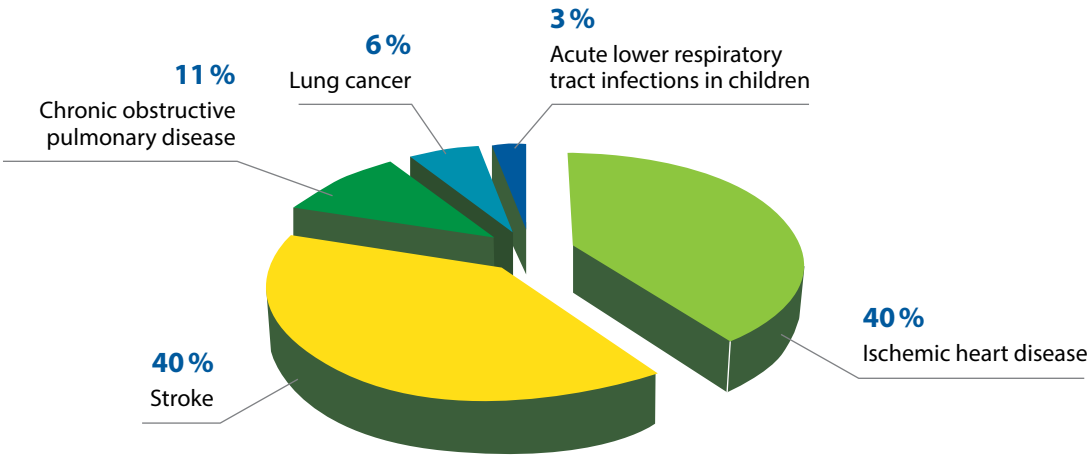


Fig. 13.3. Deaths caused by air pollution

1. **Legislative measures** — a complex of measures that determine the legal basis of air protection
   - Law "On Environmental Protection" (1991);
   - Law "On Atmospheric Air Protection" (1992);
   - Law "On Ensuring Sanitary and Epidemiological Welfare of the Population" (1994);
   - DBN 360–92 "Planning and construction of urban and rural settlements";
   - GOST "Rules of air quality of settlements";
   - "State sanitary rules for protection of atmospheric air of populated areas";
   - "State sanitary rules of planning and development of settlements".
2. **Technological:**
   - closed technological processes;
   - replacement of technological processes;
   - purification of gases in production.
3. **Sanitary and technical:**
   - dust collectors;
   - electrostatic precipitators;
   - gas washers.
4. **Planning:**
   - zoning of urban areas;
   - landscaping of cities;
   - organization of sanitary protection zones.

Among the new technologies, it is necessary to mention the creation of air filters which are the size of a building — building filters. In 2015, the Manuel Gea Gonzalez hospital in Mexico City was built with a facade that absorbs smog. The facade is covered with titanium dioxide, which is able to decompose pollutants into less harmful components when interacting with UV rays. The developers say that they can absorb the maximum waste gases of thousands of cars a day. The same buildings are planned to be built in London.

It is also planned to build a building in Milan, covered with cement, which is able to purify the air.

7-meter-high open-air purifier "Smog Free Tower" was built ***in Beijing,*** *in 2016, with the support of the Chinese Ministry of Ecology. This filter absorbs pollutants and blows clean air. This tower can clean the air in an area the size of a football field, consuming a minimum of electricity.*

13.6. Sources of indoor air pollution

The specifics of living in the city leads to the fact that 80–95 % of people spend their time indoors (houses, subways, offices). One of the indices of the urban life quality is indoor air. According to the US Environmental Protection Agency, indoor air is 100 times more polluted than that outside. Such phenomena are observed because there are additional sources of air pollution in the room.

Sources of indoor air pollution are:

1. Atmospheric air.
2. Human (exhaled air; pathogenic microorganisms with coughing and sneezing; smoking, decomposition of organic substances on the skin and clothing).
3. Indoor dust (decomposition of organic matter; microorganisms, which precipitated on dust).
4. Accidental (mercury from broken thermometers, uniform with residues of toxic substances, etc.).
5. Industry (harmful chemicals, radioactive substances, pathogenic microorganisms, water vapor, aeroions).

1. Polymer and other synthetic substances (building materials, furniture, clothes, detergents, insecticides, etc.).
2. Gas of cookers and heating appliances, cooking and so on.
3. Household chemicals, aerosols, cosmetics.

13.7. Influence of different CO_2 concentrations on the human organism

Indirect index of indoor air pollution is the concentration of CO_2. The maximum allowable concentration (MAC) of CO_2 in the premises is 0.07–0.1 %.

Influence of different CO_2 concentrations on the human organism are shown in Table 13.2.

Table 13.2. Influence of different CO_2 concentrations on the human organism

CO_2 concentration in air, %	Effect
0.1–0.5	Threshold of effect in the most sensitive people. Temporary changes of the brain biopotentials (electroencephalography — EEG)
0.5–1.0	The first signs of rapidly disappearing acidosis. Barely noticeable increase in minute volume of breath. Slight increase in peripheral blood flow in the limbs. Temporary changes of EEG (γ-rhythm)
1.0–2.0	Acidosis. Moderate signs of intoxication (from the central nervous system activity). Reduction of work capacity during long-term action
3.0–4.0	Sharp excitation of the respiratory center cells. Increase in pulmonary ventilation. Clinically — suffocation, fever, rebound pain. A sharp decline in work capacity
6.0–8.0	Paralysis of the respiratory center cells. Clinically instantaneous loss of consciousness, death
10.0	Quick death
15.0–20.0	Instant death

13.8. Hygienic significance of room ventilation. Types, classification of ventilation of municipal and domestic, industrial premises

Various room ventilation systems are used for maintaining purity of air and keeping the necessary parameters temperature and humidity.

Ventilation is removing air from the room and replacing it with fresh or processed air.

Industrial ventilation is an organized air exchange, which helps maintain the necessary hygienic and technological parameters of the air in the industrial premises.

Classification of ventilation systems of premises

1. *By the transfer of air:*
   - natural — air exchange is due to temperature difference and under the influence of wind;
   - artificial (mechanical) — air exchange is conducted using such ventilation systems: inflow, outflow, inflow-outflow.
2. *By organization:*
   - by appointment:
     - inflow;
     - outflow;
     - inflow-outflow.
   - by the service area:
     - local;
     - general;
     - emergency;
     - mixed.
   - by design:
     - channel;
     - non-channel.

Each of the ventilation systems has its advantages and disadvantages.

Natural ventilation makes it possible to carry out a large air exchange with low energy consumption. However, it has the following disadvantages: significant fluctuations in air exchange and the inability to process air. For natural air exchange in the room, we use windows, transoms, infiltration and exfiltration through building structures.

Artificial ventilation allows distributing inflow air, processing of inflow air (heating, cooling, drying, and cleaning) is possible as well as cleaning of the outflow air. With artificial ventilation, air exchange is the same at any time of the year. One of the disadvantages of artificial ventilation is high-energy consumption.

13.9. Ventilation efficiency indices. Required and actual ventilation volume and rate, methods of their determination

The following indices are used to assess the effectiveness of ventilation:

Required ventilation volume is the volume of the fresh air, which is to be drawn inside so that CO_2 concentration does not exceed the allowable value.

Actual ventilation volume — the amount of fresh air that actually enters the room.

Required ventilation rate is the number, demonstrating how many times the indoor air has to be completely renewed by the ventilation so that CO_2 concentration does not exceed the maximum allowable concentration (MAC).

Actual ventilation rate is a number that indicates how many times the room air is actually changed by fresh air.

Comparing the rates of ventilation, you can assess the quality of ventilation in the room (Fig. 13.4).

Assessment of indoor air quality is carried out according to the following indices:

1. Direct — the content of certain chemicals.
2. Indirect — oxidation, CO_2 concentration.

Express and chemical methods are used to determine these indices.

The following methods are used for air sampling:

1. Aspiration.
2. Sedimentation.
3. Simultaneously in a tank.

Various absorbing devices are used for air sampling: filters, solid and liquid absorbing media.

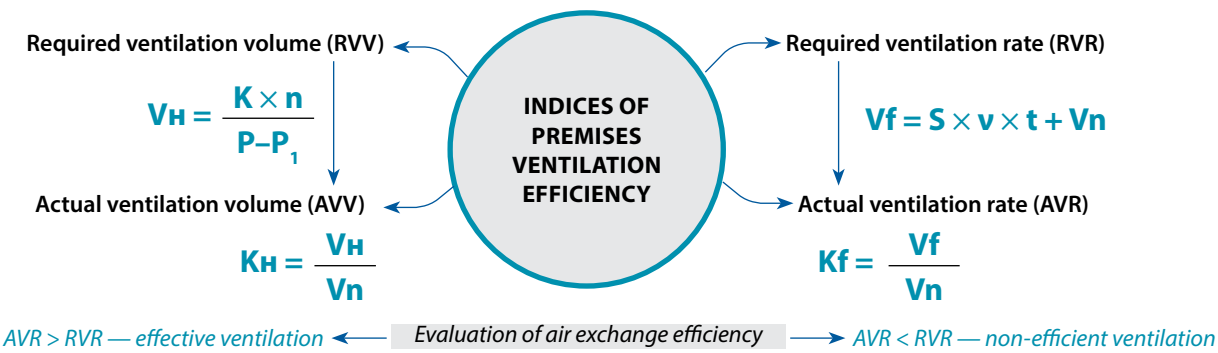


Fig. 13.4. Evaluation of the indoor ventilation efficiency

It is necessary for healthy human body function that the environment contains sufficient oxygen, being free of mechanical, chemical and bacterial contaminants. Nowadays, there is a strong correlation between human health and the intensity of air pollution.

The above-mentioned determines the need for knowledge of methods of control of purity and hygienic assessment of atmospheric air and indoor air in premises of various purposes by doctors of curative specialty.

14

CHAPTER

SOIL HYGIENE AND PURIFICATION OF SETTLEMENTS. PROBLEMS OF URBANIZATION

O. P. Vavrinevych, T. I. Zinchenko, A. O. Shevchenko, A. M. Antonenko

14.1. Urbanization as an objective reality of advances in science and technology. Features of living conditions and sanitary-hygienic provision of the population in modern cities and villages

Urbanization is the process of industrial, scientific and cultural accumulation in cities; predisposed for the human migration from rural to urban areas as well as increased concentration of urban population due to the growth of the cities and its population.

Urbanization is the process of increasing the cities significance in the development of society, which is followed by the growth and development of urban settlements and the growth of the urban population share.

According to experts, economic losses from urbanization diseases, especially those caused by noise, stress and pollution, overcome the losses from industrial protests.

Modern urbanization as a global process is characterized by three common features characteristic of most countries.

The first feature is rapid growth of urban population.

For example: At the beginning of the 19th century, about 14 % of the world's population lived in cities, in 1950 — 29 %, and in 1990 this index was 46 %. On average, the urban population increases annually by about 50 million people (Fig. 14.1).

In Ukraine in 2016, the urban population made up about 70 % (Fig. 14.2).

The second feature is the concentration of population and household mainly in large cities. This is primarily due to the nature of production and the complexity of its links with science and education. In addition, large cities usually more fully meet the spiritual needs of people; better provide an abundance and variety of welfare and services as well as an access to information repositories.

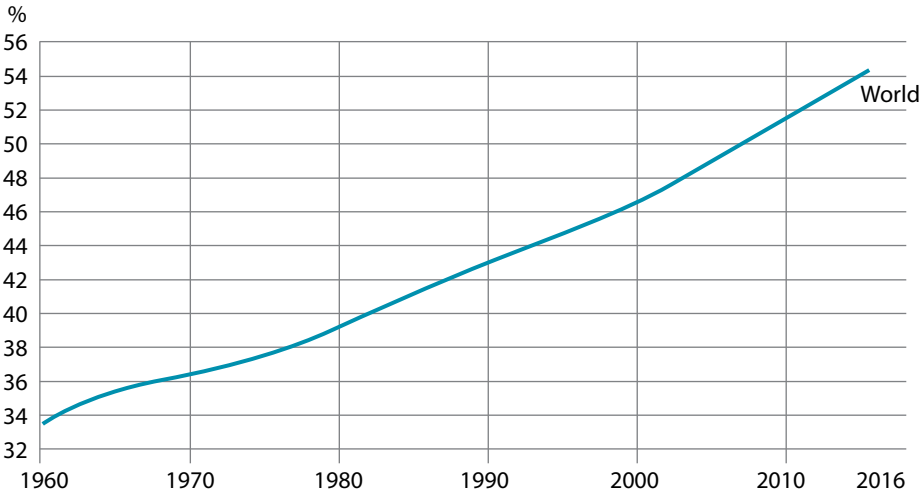


Fig. 14.1. Dynamics of the share of urban population in the world for the period from 1960 to 2016 (% of total)

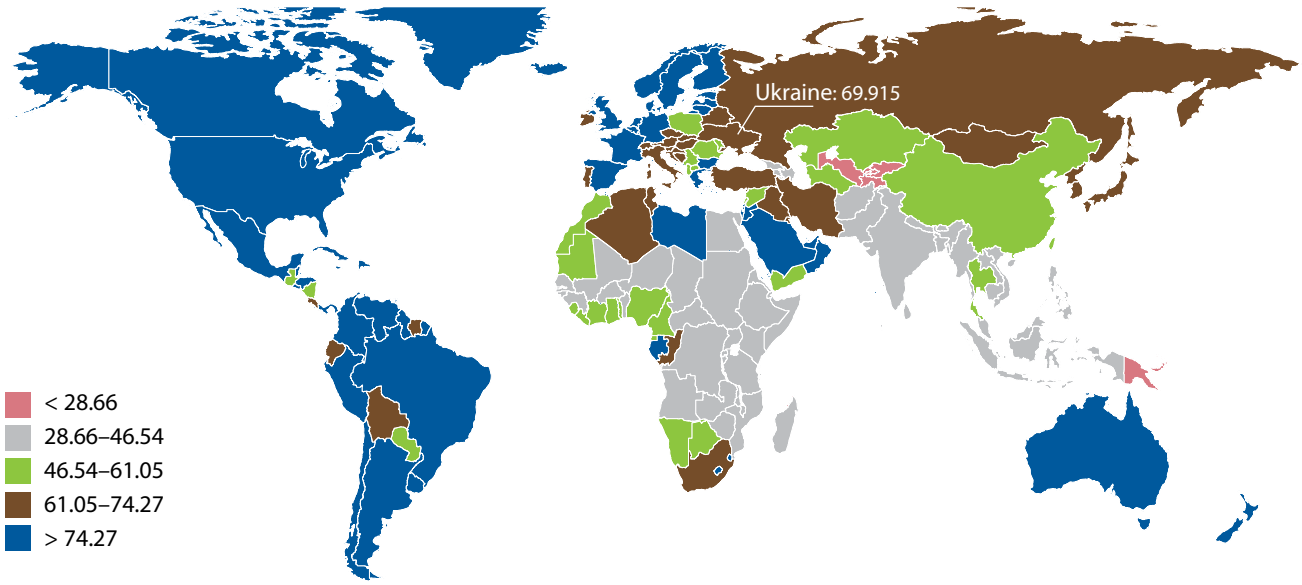


Fig. 14.2. Share of urban population as of 2016 (% of total)

In modern city, people feel more comfortable, have more opportunities to study and improve their skills in professional activities, they can use better employment opportunities.

For example: it is usual to distinguish the largest cities among large cities, "millionaire" with a population of over 1 million inhabitants. At the beginning of the 20th century, there were only 10 of them, in the 80s — more than 200.

At the beginning of the 20th century there were 360 large cities in the world (with a population of over 100.000 inhabitants), in which only 5 % of the total population lived. At the end of the 1980s, there were already 2.500 such cities, and their share in the world population exceeded ¼. In the Soviet Union, according to the 1959 census, there were 148 large cities, and according to the 1989 census, about 300.

The third feature is expansion of the territory of cities. Modern urbanization is especially characterized by the transition from simple settlement to group urban settlement — from the usual "isolated" city to urban agglomerations — compact territorial groups of urban and rural settlements.

The nuclei of the largest urban agglomerations are mainly capitals, the most important industrial and port centers (Fig. 14.3).

According to the last population census (2001), there were 5 "millionaire" cities in Ukraine (Kyiv, Kharkiv, Odesa, Dnipro, Donetsk). Large cities were: Lviv, Zaporizhia, Kryvyi Rih, Mykolaiv, Mariupol, Luhansk and others.

In developed countries, the level of urbanization averages 72 %, and in developing countries — 32 %. The pace of urbanization largely depends on its level. Today, the urban population in developing countries is growing three times faster than in developed countries. They now account for 1/6 of the total annual growth of urban residents.

The process of urbanization provides its residents with many economic, social and subjective benefits:

- availability of work places and the possibility of switching jobs;
- concentration of scientific and cultural institutions;
- provision of highly qualified medical care;
- opportunity to create better housing, social and living conditions;
- development of international and regional culture.

Despite the positive effects, the process of urbanization can lead to a negative impact on public health in the modern city.

In a big city, a specific of urban environment is formed. In a modern city the following environmental changes may be observed:

- the intensity of solar radiation decreases by 15–20 %;
- the intensity of UVR decreases by 60–70 %;
- 10 % more cloudy days;
- the average daily air temperature in the city is 2–3 °C higher, and the air speed is 2 times lower than in the countryside;
- the noise level in cities is approaching 80 dB;
- the content of CO in the atmospheric air of large cities is more than 50 times, and sulfur dioxide — more than 1000 times higher than in the village;

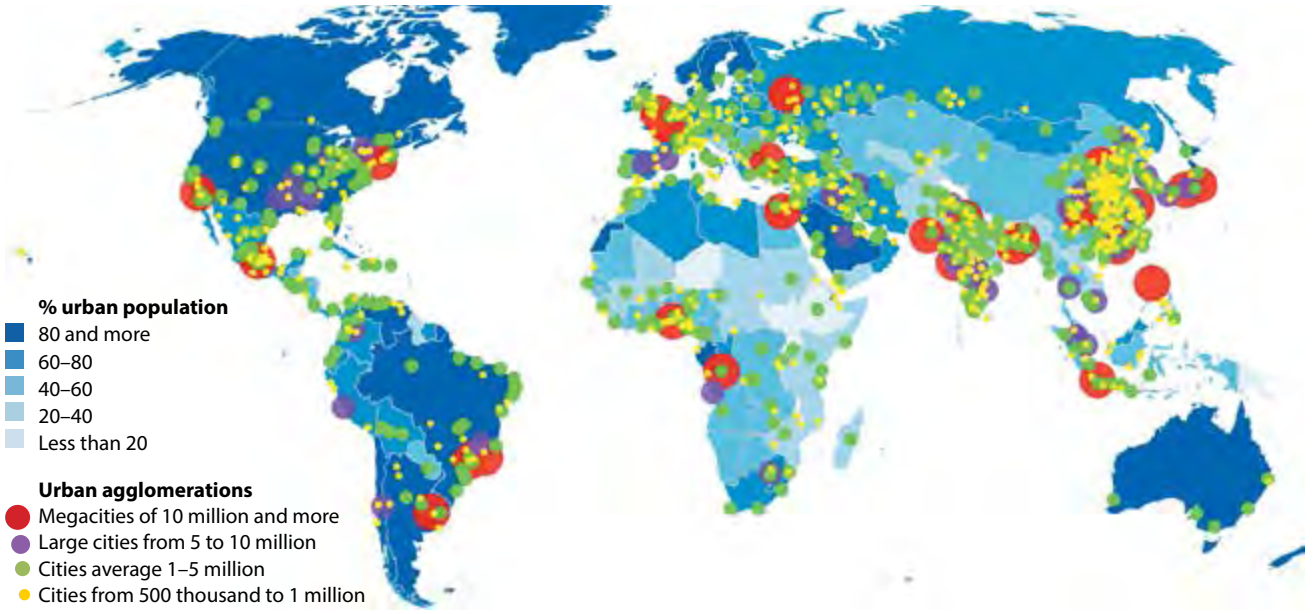


Fig. 14.3. Percentage of urban population and locations of urban agglomerations, 2014

- social conditions in city change significantly, namely:
  - people are more likely to encounter stressful situations;
  - excess information;
  - large time loss for travel to work.

As a result of the polyetiological impact of the urban environment, negative conditions for the human health are created, which leads to the constant "diseases of civilization" growth. The incidence of hypertension and its complications is increasing; the myocardial infarction mortality increases; occurrence of neurosis and vegetative-vascular dystonia is high; there is extreme incidence of the traffic accidents mortality; oncological morbidity increases; the share of allergic diseases and hearing defects increases; disorders of physical development of children in puberty period are observed. Recently in large Ukrainian cities many children aged 6–7 show retarded developmental patterns, with both excessive and insufficient body weight. Such children are more prone to future health problems. The increase in birth defects as well as numerous disorders of unknown origin are appearing.

To ensure proper sanitary and hygienic conditions in human settlements, it is necessary to plan and build them properly.

Each settlement, especially the city one, is a complex of various elements of industrial activity (enterprises, transport), culture and life of the population (housing, cultural and household institutions). All these elements must be properly located in a certain area as well as functionally interconnected to provide the population with more favorable working and living conditions. Some of these elements play a leading role in city planning and are listed among the main city factors.

Main principles of city building:

1. The choice of healthier territories for the settlement.

The most important issue in the construction of settlements is the territory selection. The land plot should be situated in the favorable microclimate region, it must be well insulated and protected from winds. The soil should not be contaminated with waste, and there should be a slope for the flow of atmospheric water. Sources of water on the land must be available and the air should not be polluted. The land must be epidemically healthy.

2. The city should have high level of sanitary and technical welfare. Centralized water supply, sewerage, electricity, gas supply systems, etc. are to be fit out.
3. It is necessary to maintain a high rate of landscapes (up to 60 %).

Green areas are an integral part of large cities and towns, residential areas and neighborhoods. The hygienic significance of the vegetation features is great, expressed as sanitary and hygienic, medical and ecological, recreational, architectural, structural and planning, decorative and artistic, social and cultural one.

First, they positively impact on sense organs and functional state of central nervous system, leading to the aesthetic pleasure feelings; they also have a beneficial effect on mood, psyche and health. *Second,* green areas help to improve microclimate of residential areas and the city. *Third,* green areas provide for the wind and noise protection. And most importantly — they are a powerful reservoir of clean air for the settlement, as they reduce concentration of dust and chemical toxic impurities, purify the air and enrich it with oxygen.

Standardization of green areas is carried out depending on climatic conditions, the size of the city, its purpose and building density. The level of landscaping of residential areas should be at least 24 %, industrial enterprises — 30 %, school and children's preschools — 45–55 %, health care facilities — 55–65 %.

4. Development of each city must be planned: general plans should be developed for cities.
5. Limiting the city population to optimal limits. It is better to expand cities by creating satellite cities.
6. It is necessary to do zoning of the city.

The main zones are:

- living area;
- industrial;
- sanitary-protection;
- transport;
- municipal;
- suburban.

7. Using the most progressive building construction system.

Quarterly construction systems are (Fig. 14.4):

- perimeter;
- line;
- group.

In recent years, a mixed system of building has become increasingly common. It is characterized by a combination of different methods of arrangement of houses, their big length and complex configuration of facades.

1. Town building is carried out by microdistricts or large arrays (in Kyiv: Rusanivka, Bereznyaki, Obolon, Troieschyna, etc.).
2. Creation of an appropriate economic base.

Implementation of the urban planning principles will provide comfortable living conditions for population in the modern city and prevent the emergence of diseases associated with violation of these principles.

In addition to the problems of rational urban planning, municipal hygiene deals with the issues related to the hygiene of air, water, soil, lighting and microclimate in settlements.

14.2. Soil: definition, composition, soil types

Soil is the surface layer of the solid shell (the lithosphere) of the Earth's crust.

Soil is a complex multicomponent low-dynamic dispersed system in which the dispersion medium is represented by minerals (crystalline quartz, aluminosilicates, clay minerals, natural macro- and microelements), and the dispersed phases are organic substances, all types of soil moisture (hygroscopic, membranous, capillary, free gravitational), air, micro- and macroorganisms.

Soil is a huge natural laboratory in which various complex processes of destruction and synthesis of organic substances and photochemical processes constantly take place. It also produces new various inorganic and organic compounds. Pathogenic bacteria, viruses, protozoa and helminths' eggs die in the soil. It is used for purification and disinfection of liquid polluted sewage, garbage of settlements, it affects the district

1. Perimeter **2. Line** **3. Group**



Fig. 14.4. Quarterly construction systems

climate, being important for the settlements planning as well as their welfare. Soil can be an infectious diseases transmission factor.

There are three types of soils according to their purpose (Fig. 14.5).

The soil consists of biotic part (autochthonous (inherent) microflora) and abiotic part. Abiotic part includes soil solid substance (mineral and organic substances and organic-mineral complexes), soil moisture and soil air.

60–80 % of soil mineral (inorganic) substances are represented by crystalline silica or quartz. The significant position among mineral compounds is taken by the aluminosilicates, i.e. feldspar and mica. Secondary clay minerals belong to alumina-silicates, i.e. those of montmorilonite group (montmorilonite, notronite, beidelite, saconite, hectorite, stevensite). They are hygienically important as they define the absorbing capacity and volume of cations' absorption (i.e. heavy metals) by soil.

Beside silica and alumina-silicates, almost all elements of Mendeleyev's table are present in soil mineral composition.

Organic substances of soil are represented by both soil organic (humic acids, fulvic acids etc.) compounds, which are created by soil microorganisms and which are called humus, and by "foreign" soil organic substances, which came into the soil from outside as the result of natural processes and technogenic (anthropogenic) pollution.

Soil moisture can be present in both solid and liquid forms, as well as the vapour. From hygienic point of view, liquid moisture is the most significant. It can be in the form of:

- hygroscopic water, which is condensed on the surface of the soil particles;
- membranous water, which remains on the surface of soil particles;
- capillary water, which is kept by capillary forces in thin pores of soil;
- gravity free water, which is influenced by gravity or hydraulic pressure and fills in soil big pores.

Soil air is a mixture of gases and vapour, which fills in soil pores. According to its composition, it differs from atmospheric air and constantly interacts with it by diffusion and concentration gradient. Soil air and water are antagonists relative to the pore space. Natural composition of soil air is controlled by oxygen utilization rate and carbon dioxide generation as the result of microbiological processes of organic substances mineralization. As the depth increasing, the content of carbon dioxide in soil air increases as well, but the oxygen content decreases.

Basic physical properties of soil are:

- *texture* — percentage of soil particles according to their sizes. It is determined by screening through Knop' sieves. There are 7 types (called "numbers") of such sieves with apertures of different diameters from 0.25 to 10.0 mm (see Fig. 18.1). Soil texture comprises the following elements: stones and gravel (size > 3 mm); coarse sand (3–1 mm), medium (1–0.25 mm), fine (0.25–0.05 mm); coarse dust (0.05–0.01 mm), medium (0.01–0.005 mm), fine (0.005–0.001 mm); silt (< 0.001 mm). According to texture, soils are classified based on specific weight of physical sand (particles of size > 0.01 mm) and of physical clays (particles of size < 0.01 mm);
- *porosity* — total volume of pores in the unit of soil volume, which is expressed in percent. The bigger is the size of separate mechanical elements of soil, i.e. its granularity, the bigger is the size of pores in homogeneous soil. The biggest pores are in rocky soil, smaller ones are in sandy soil, very small pores are in clay soil, and the smallest ones — in peat soil. At that total volume of pores, expressed in percent, increas-

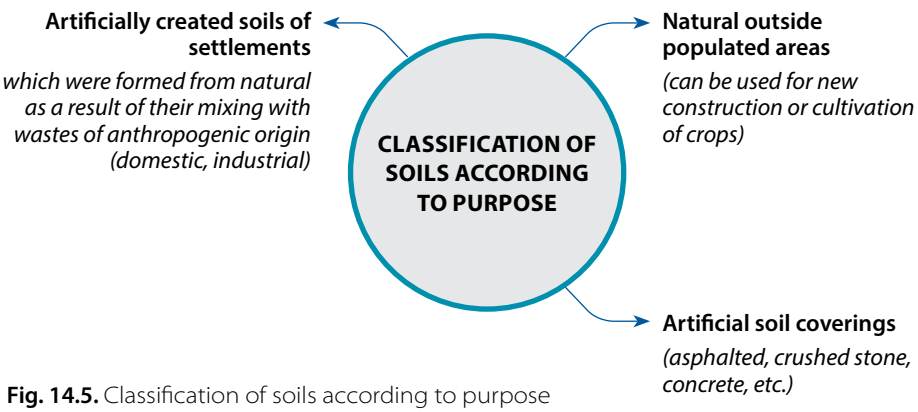


Fig. 14.5. Classification of soils according to purpose

es, i.e. soil porosity is as higher as smaller is the size of some elements of soil. Thus, porosity of sandy soil is 40 %, and peat soil — 82 %;

- *air permeability* — soil ability to pass air through its thickness. It increases when size of pores is bigger and doesn't depend on their total volume (porosity);
- *water permeability* — the ability of the soil to absorb surface water and pass it through itself. Permeability process includes two stages: imbibition, when free pores gradually get filled with water till total saturation of soil and filtration, when, as the result of total water saturation of soil, water starts moving in soil pores because of gravity;
- *moisture capacity* — amount of moisture, which soil is capable to retain due to sorptive and capillar powers. The smaller is the size of pores and the bigger is their total volume, i. e. porosity — the bigger is the moisture capacity. The finer is soil texture, the higher is its moisture capacity;
- *soil capillarity* — soil ability to lift water via capillaries from the bottom layers up. The smaller is the size of soil texture particles, the bigger is soil capillarity, but in such soil water goes up higher and slower.

In soils of soft texture (sandy, clay sandy, light loamy) compared to heavy soils (clays, heavy loams) physical sand prevails, pores are larger in size, porosity isn't high, air and water permeability, filtration capacity are considerable, capillarity and moisture capacity are low. On the one hand, processes of soil bio-decontamination run rather quickly in such soils, on the other hand, migration of chemical substances from soil into ground and surface water reservoirs, ambient air and plants is more considerable.

14.3. Hygienic, epidemic and endemic significance of soil

The soil has great hygienic significance for the health of the population and the improvement of settlements:

1. Soil is the leading link in the cycle of substances in nature.

Migration of substances of both natural and anthropogenic origin is brought into effect in short (for example: soil — plant — soil, soil — water — soil) and long migration chains (for example: soil — plant — animal — soil, soil — water — plant — soil).

2. Role in the formation of the chemical composition of drinking water, food, air.

Soil forms the chemical composition of food of plant and animal origin and drinking water, which are closely related to its chemical composition. Various physicochemical properties of chemical compounds, which saturated the soil due to man-made pollution, by evaporation enter the atmosphere, accumulate in the surface layer to concentrations exceeding the maximum allowable, i.e. reach levels harmful to human health.

It should be noted that the soil has pores, and if it is dry, they are filled with soil air. Concentrations of gases and vapors that form ground air are not the same as in the atmosphere. Therefore, diffusion is constantly ongoing, i.e. the movement along the concentration gradient: gaseous substances, many of which are in the soil air (e.g. carbon dioxide), enter surface layer of the atmosphere, and, conversely, gases which partial pressure in the atmosphere is higher (e.g. oxygen), move into the ground.

3. Epidemic significance of soil.

Soil can be a transmission factor of the following pathogens of infection diseases and invasions to people:

- enteric infections of bacterial (typhoid, paratyphoids A and B, bacillary dysentery, cholera, coli-entheritis), viral (virus A hepatitis, enterovirus infections: poliomyelitis, Coxsackie virus infection, ECHO) and protozoa etiology (amebiasis, lambliosis);
- spore-forming clostridia — pathogens of tetanus, gas gangrene, botulism;
- zooanthroponosis (types of leptospirosis: infectious jaundice or Weil's disease, anicteric leptospirosis, brucellosis, tularemia, anthrax);
- mycobacteria of tuberculosis;
- geohelminthosis — ascaridiasis, trichocephalosis, ankylostomiasis (Fig. 14.6).

Microorganisms persist in the soil for a long time. The survival time of some microorganisms in the soil is given in Table 14.1.

Pathogens of infectious diseases can be transmitted by airdrop, alimentary, air-dust and through the wound surface. Ways of transmission of infectious diseases are shown in Figure 14.7.

4. Endemic significance of soil.

The chemical composition of the soil depends on the chemical composition of water, vegetation of the area, the chemical composition of food products of plant and animal origin. Excess and deficiency of certain natural microelements in the soil leads to their excess and deficiency in food or water, which, accordingly, affects the health of the population and is the cause of endemic diseases (endemic fluorosis and caries, endemic goiter, selenosis, endemic cardiomyopathy (Keshan's disease), molybdenum gout,



Pathogensn of intestinal infections



Spore-forming clostridia



Mycobacteria tuberculosis



Pathogens of zooanthroponoses



Helminths' eggs

Fig. 14.6. Pathogens that persist in the soil

Table 14.1. Terms of survival of some microorganisms in the soil

The etiologic agent of infection	Average term, week	Maximum term, months
Typhoid fever Salmonella	2–3	> 12
Shigella	1.5–5	9
Vibrio cholerae	1–2	Up to 4
Brucella	0.5–3	Up to 2
Tularemia pathogens	1–2	Up to 2.5
Plague pathogens	0.5	Up to 1
Mycobacteria tuberculosis	13	Up to 7
Enteroviruses: Coxsackie, ECHO	10–13	Up to 6

endemic osteoarthritis or Kashin — Bek disease, boric enteritis, endemic nephropathy etc.).

These diseases are discussed in the chapter on the hygienic significance of water.

5. Natural environment for disposal of liquid and solid industrial wastes.

Disposal of liquid and solid industrial wastes in the soil is implemented through self-purification processes.

Soil self-purification is a complex and relatively long biological process, resulting in the conversion of organic substances into water, carbon dioxide, mineral salts and humus, and pathogenic microorganisms die. Self-purification of the soil is due to the presence of saprophytic putrefactive, nitrile and nitrophic bacteria, protozoa, insect larvae, worms, fungi, viruses, bacteriophages, as well as its physicochemical properties.

14.4. Sources of soil pollution, their classification and hygienic characteristics

Advances in science and technology have led to the situation where the exogenous chemicals due to emissions into the air of industrial waste, thermal power plants, vehicles, pollute more and more soil every year.

Main sources of soil pollution are:

1. Mineral and organic fertilizers.
2. Pesticides application.
3. Industrial and domestic wastes of various types, used as fertilizers and for moisturizing.
4. Emissions into the atmosphere from industrial enterprises, motor transport.
5. Storage or permanent burial of household and industrial waste.
6. Biological pollutants (viruses, bacteria, worm eggs, protozoa).

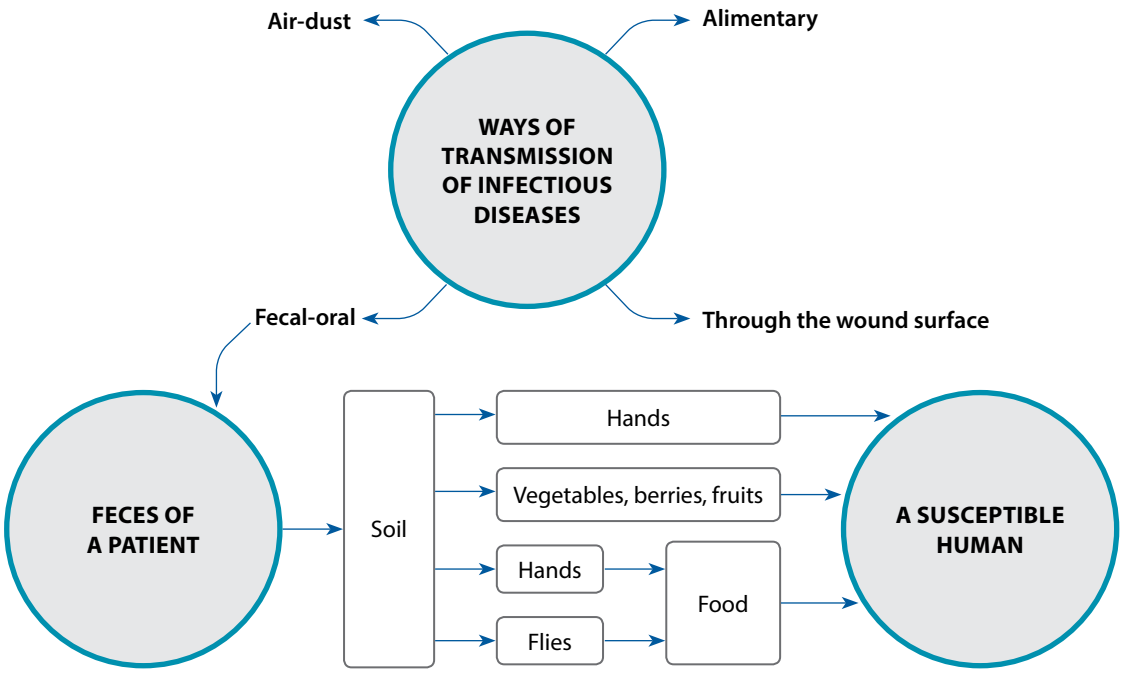


Fig. 14.7. Ways of transmission of pathogenic microorganisms through the soil

All soil pollutants can be divided into two groups: biological (viruses, bacteria, helminth eggs, protozoa) and chemical.

Chemical pollutants are also divided into two groups.

The first includes chemicals that are brought into the soil purposively, most often — in agriculture (pesticides, fertilizers, plant growth stimulants, etc.). The application of these substances to the soil is a controlled process, and they are dangerous only if they enter the soil excessively, when the hygienic regulations are not observed.

The second group includes polluting substances that are brought into the soil by accident with man-made (anthropogenic) liquid, solid and gaseous wastes.

In Ukraine, the problem of contamination with plastic bags is very acute. It should be noted that plastic bags are stored in the environment for a long time and are not biodegradable. There are 4 trillion packages used in the world every year.

There are some countries that have completely refused the use of plastic bags — Kenya, South Africa, Rwanda, Eritrea. In Denmark, a tax on the free distribution of plastic bags in commercial establishments was introduced in 1994, after which the use of these funds was reduced by 90 %. Also in San Francisco (USA), large supermarkets do not use plastic bags. Hawaii became the first state to abandon the use of packages. In 2003, plastic bags were banned in Singapore, Bangladesh and Taiwan because they blocked sewers and blocked riverbeds. This ban also applies to a number of Indian states.

However, our country cannot refuse plastic bags yet (The President of Ukraine signed the Law No1489–IX On Restricting the Circulation of Plastic Bags on the Territory of Ukraine. The law is expected to enter into force on January 1, 2022).

14.5. Indices of soil sanitary condition, classification and hygienic significance

Sanitary condition of the soil is a complex of indices that characterize the safety of the soil in chemical, epidemic and radiological terms. Indices of soil sanitary condition are divided into physical, physical-chemical, chemical, epidemiological and radiological ones (Table 14.2).

All indices are divided into the direct (that allow to assess the level of soil contamination and level of danger for population health directly from the results of laboratory analysis of taken samples Table 14.3) and indirect ones (that allow to draw a conclusion on the fact

Table 14.2. Indices of soil sanitary condition

Group of indices	Indices
Sanitary-and-physical	Texture of soil, filtration coefficient, air and water permeability, capillarity, moisture capacity, total hygroscopic moisture
Physical-and-chemical	Active reaction (pH), absorption capacity, total absorbed bases
Chemical safety criteria:	
• chemical agents of natural origin	Background content of total and movable forms of macro- and microelements of non-contaminated soil
• chemical agents of anthropogenic origin (soil pollution indices, exogenous chemicals)	Amount of pesticide residues, total content of heavy metals and arsenic, content of heavy metals movable forms, oil and oil products' content, content of sulphides, content of carcinogens (benzpyrene) etc.
Epidemic safety criteria:	
• sanitary-chemical	Total organic nitrogen, Khlebnikov's sanitary index, ammonia nitrogen, nitrite nitrogen, nitrate nitrogen, organic carbon, chlorides, soil oxidation
• sanitary-microbiological	Total number of soil microorganisms, microbial number, titer of bacteria of colibacillus group (coli-titer), titer of anaerobes (perfingens-titer), pathogenic bacteria and viruses
• sanitary-helminthological	Quantity of helminth eggs
• sanitary-entomological	Quantity of larvae and chrysalides of flies
Radiation safety indices	Soil activity
Soil natural purification indices	Titer and index of thermophile bacteria
Radiation safety indices	
Naturally occurring radioactive materials, artificial radionuclides	Soil activity

of soil contamination, its characteristics and duration by comparison of the results of soil laboratory analysis with clean soil test of the same type, which was taken as a sample from non-contaminated areas).

Most indices are indirect. The degree of soil contamination can be directly assessed by an index called Khlebnikov's sanitary index. *Khlebnikov's sanitary index* is a ratio of humus nitrogen (pure soil organic substance) to total organic nitrogen (consists of humus nitrogen and nitrogen of strange for soil organic substances that contaminate it). If soil is pure, Khlebnikov's sanitary index equals to 0.98–1.0.

Soil coli-titer is a minimal amount of soil measured in grams, where one bacteria of colibacillus group is found.

Soil anaerobe titer (perfingens-titer) is a minimal amount of wastes measured in grams, where an anaerobic clostridia is found.

Soil microbial number is a number of microorganisms in one gram of soil that grew up on 1.5 % beef-extract agar at temperature 37 °C *during 24 hours.*

14.6. Basics of sanitary purification of settlements from liquid and solid waste

The main soil pollutants are **waste** — these are the remains of substances and articles that have been created as the result of domestic, economic and industrial human activity, but which cannot be used anymore, so that their accumulation aggravate the environmental sanitary condition.

Wastes are divided into:

*Table 14.3. Scale for assessment of soil sanitary condition**

Danger level	Level of pollution	Criteria of epidemic safety					Pollution index of exogenous chemicals — times of MAC exceeding	Radiation safety index — soil activity	Natural purification index — thermophile titer
		Coli titer	*Anaerobe titer*	*Number of eggs of helminthes in 1 kg of soil*	*Number of larvae and chrysalides of flies on 0.25 m^2*	*Khlebnikov's sanitary index*			
Safe	Pure	1.0 and more	0.1 and more	0	0	0.98–1.0	≤ 1	Natural level	0.01–0.001
Relatively safe	Slightly polluted	1.0–0.01	0.1–0.01	Less than 10	Single specimen	0.86–0.98	1–10	Exceeding of natural level by 1.5 times and more	0.001–0.000 02
Dangerous	Polluted	0.01–0.001	0.01–0.0001	11–100	10–25	0.70–0.86	11–100	Exceeding of natural level by 2 times and more	0.00002–0.00001
Very dangerous	Heavily polluted	0.001 and less	0.0001 and less	More than 100	25 and more	< 0.70	> 100	Exceeding of natural level by 3 times and more	< 0.00001

** Under condition of soil sampling in the depth of 0–20 cm.*

1. Liquid wastes:
   - sewage from cesspool toilets;
   - slops (from cooking, dish and floor washing etc.);
   - waste waters: domestic, industrial, runoffs, municipal waste water.
2. Solid wastes:
   - garbage (domestic refuse);
   - rubbish (kitchen waste products);
   - waste from health care facilities (including specific ones — used dressing, used disposable autotransfusers and syringes, remains of medicines, remains of organs and tissues after surgical operations, dead bodies of laboratory animals etc.);
   - waste from other public institutions (schools, preschool institutions, high schools and academies, offices, etc.;
   - waste of public catering establishments;
   - waste of animal origin (dead bodies of animals, pus, forfeit foodstuff);
   - waste of commercial facilities;
   - industrial wastes;
   - slags from boiler houses;
   - construction wastes, urban soil;
   - street sweepings.

14.7. Ways and methods of removal, disposal and utilization of solid waste in modern settlements

There are the following waste disposal systems:

1. Flushing system is used in the settlements, which are provided with sewerage (pipe) system through which liquid and partially fine solid waste float to waste disposal plants; the rest of solid waste is removed by special motor transport.
2. Pick-up system is used in the settlements without sewerage systems. At that, both liquid and solid do-

mestic waste (SDW) is removed to areas of disposal and utilization by special motor transport. Such method of disposal of solid waste is called purification, and of liquid waste — sanitation.

3. Combined system is used in the settlements that are partially provided with sewerage system. According to combined system, liquid waste from the part of settlement, provided with sewerage system, are removed through this system and from the part of the settlement where there is no sewerage system — with the help of cesspoolage transport. All solid waste are removed by sanitary purification transport.

Sanitary purification of settlement includes three stages:

I — collection and temporary storage of solid domestic waste;

II — removal;

III — disposal and treatment.

All methods of SDW disposal have to meet the following basic hygienic requirements:

- must provide reliable disposal, transformation of waste into harmless substrate from epidemic and sanitary point of view;
- quickness: the best method is the one that makes possible effective waste disposal during the same period of time in which the waste is formed;
- should prevent flies from eggs blowing as well as larvae and chrysalides development in waste;
- must prevent access of rodents during waste disposal and make waste an unfavourable for the rodents medium;
- must prevent air pollution by volatile products of demolition of organic substances (SDW contain up to 80 % of organic substances, 20–30 % of which easily rot in summer and at the same time evolve stinking gases: hydrogen sulphide, indole, skatole and mercaptans);
- in the process of waste disposal neither surface nor ground waters may be polluted;
- must provide the best and safest for people's health usage of SDW properties, because they contain up to 6 % of utilizable waste; by its burn one can receive heat energy, by biothermal treatment — organic fertilizers, and food waste may be used for cattle feeding.

Methods of SDW disposal are divided into the following groups:

- **according to the final purpose:**
  - *utilizing* (waste processing into organic fertilizers, biological fuel, separation of secondary raw materials, e. g. scrap metal, for industry, used as a power-plant fuel);
  - *disposal* (land disposal, sea disposal, incineration without heat usage);
- **according to technological principle:**
  - *biothermal* (plough-lands, improved dumps, waste store grounds, waste composting fields, bio-chambers, plants for biothermal treatment; in rural area in farms — compost heaps, hotbeds);
  - *thermal* (combustion plants without or with utilization of heat energy, which is created in the result of this process; pyrolysis leading to formation of fuel gas and similar to mineral oil — lubricating oil);
  - *chemical* (hydrolysis);
  - *mechanical* (waste separation with further utilization, pressing into construction blocks);
  - *combined*.

14.8. Use of soil for neutralization of household and industrial waste

The most widely used methods are biothermal ones. They are based on the complicated processes of soil natural organic purification from pollutants (Fig. 14.8).

Biothermal disposal makes it possible to solve two tasks:

- to decompose complex organic compounds of waste and its metabolic products (urea, uric acid etc.) into simpler compounds in order to synthesize by special microorganisms in presence of ambient air a new, stable, safe from sanitary point of view substance, called humus;
- to destroy vegetative forms of pathogenic and opportunistic bacteria, viruses, protozoa, eggs of helminthes, eggs and larvae of flies, seeds of weeds. The scheme of biothermal decomposition of solid waste by biothermal method is shown in Figure 14.8.

Ukraine has a huge potential of non-traditional energy sources. Ukraine is considered a zone suitable for the active development of biogas technologies. The potential of landfill gas generated at large Ukrainian landfills for municipal solid waste (MSW) is 288 million cubic meters (0.19 ton p.p.). An important advantage of organic waste recycling is the low cost of energy produced.

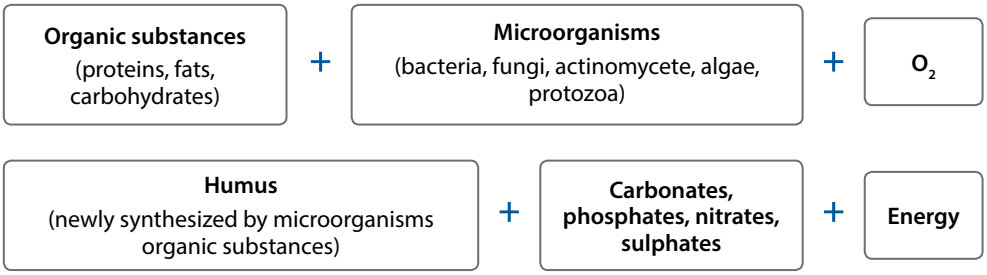


Fig. 14.8. Biothermal method of solid waste disposal

In Ukraine, 92 % of solid waste remains unprocessed, while in Western countries the share of biogas plants for processing this type of raw material is constantly growing and is quite significant.

High-temperature pyrolysis is one of the most perspective areas of solid waste processing in terms of environmental safety, as well as the production of secondary useful products — synthesis of gas, slag, metals and other materials. This technology of solid waste processing is waste-free, because the energy potential of waste is used as a synthesis gas, and the material resource — as an environmentally inert slag: raw materials for the construction industry, for the manufacturing of marketable products, such as insulation.

Industrial processing includes the requirements of ecology, resource conservation and economics. Today the following technologies are widely used for solid waste processing:

- thermal (mainly incineration);
- biothermal aerobic composting (with obtaining biofuel);
- anaerobic fermentation (to obtain biogas);
- sorting (with the removal of certain valuable components for secondary use by removing harmful components, the selection of individual fractions, the most suitable technically, environmentally and economically for processing by one method or another.

In European countries, incineration recycles 20–25 % of municipal waste, in Japan — about 65 %, in the US — about 15 % (in the US, incineration is considered one of the main ways to extend the life of landfills). It is known that the technology of direct incineration of solid waste poses an environmental hazard due to toxic emissions, which is why they are switching to integrated solid waste processing. An example is a waste processing plant with a capacity of 200 thousand tons per year in the Japanese city of Osaka.

14.9. Measures for sanitary protection of soil

A complex of measures is used to improve the state of the environment.

Sanitary protection of soil — a complex of measures (organizational, legislative, hygienic, or scientific, sanitary, technical, planning, land management, agrotechnical). These measures are aimed at limiting the soil contamination with mechanical, chemical and biological pollutants to values that do not violate the processes of soil self-purification. This complex of measures does not lead to accumulation of harmful substances in plants in quantities dangerous to human and animal health, does not pollute the air, surface and groundwater, and does not limit the use of soil in agriculture (Fig. 14.9).

The first group of measures for soil sanitary protection includes a group of legislative measures. Thus, from January 1, 2018, amendments to the Law "On Waste" came into force in Ukraine, which provide for the sorting of garbage and a ban on the disposal of unprocessed household waste. According to the document, big, repair and hazardous waste in the household should be collected separately from other types, and hazardous waste should be separated at the stage of collection or sorting. Then the waste should be transported to specialized companies licensed to carry out operations in the field of hazardous waste management. And thermal treatment (incineration) of household waste is allowed only at specially designated enterprises or facilities.

There are technological, planning, medical and preventive measures for soil protection (Fig. 14.9).

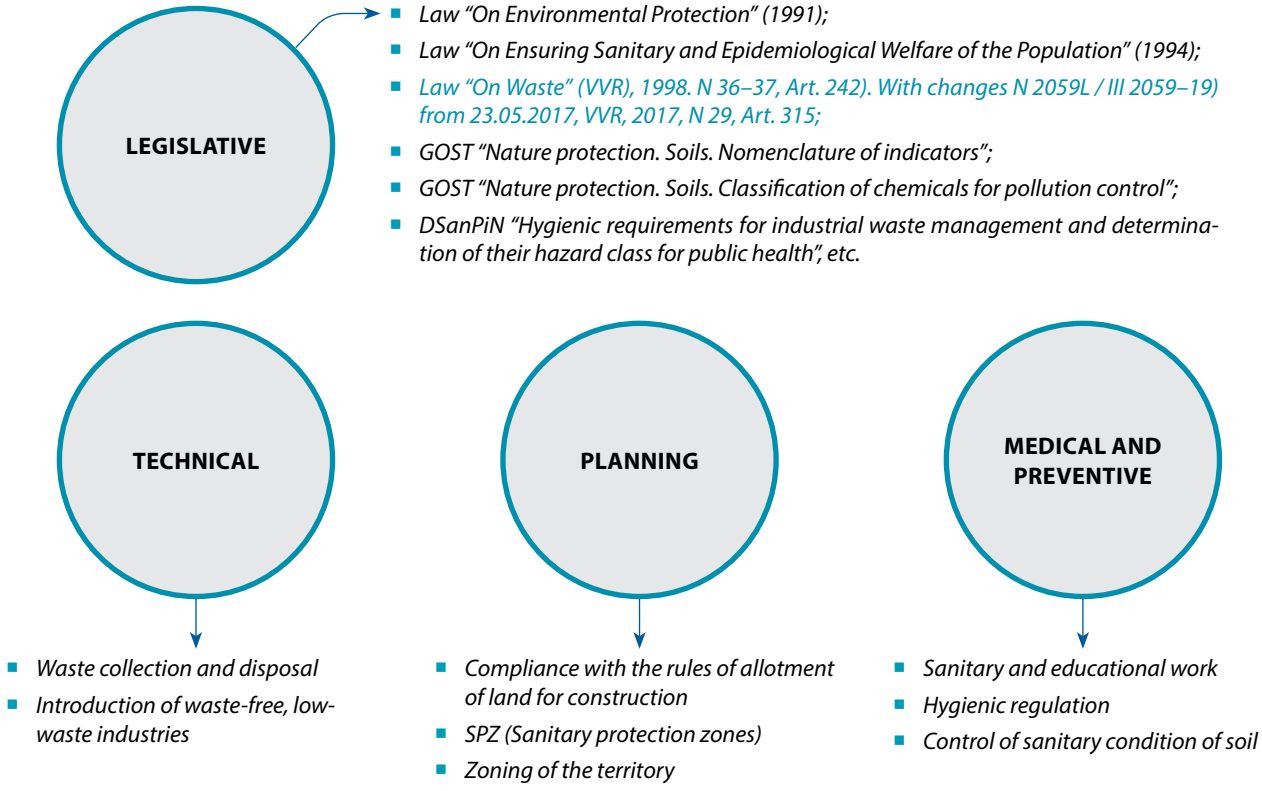


Fig. 14.9. Measures for sanitary protection of soil in Ukraine

Soil is the main link in the spread of infectious and non-infectious diseases. Advances in science and technology, the intensive pace of urbanization exacerbate the problem of pollution of soils and other objects of the environment. It is in large settlements a significant amount of liquid and solid waste is generated, which can pollute the environment.

Proper planning of settlements, organization of measures for sanitary protection of soil — the key to public health and comfortable stay in modern settlements. The introduction of new approaches to solving the problems of solid waste disposal will not only stabilize and improve the environmental situation in the country, but also form the foundations of sustainable development.

15

CHAPTER

WATER AND HEALTH. HYGIENIC SIGNIFICANCE OF DRINKING WATER

O. P. Vavrinevych, I. M. Pelo, E. M. Biletska, A. M. Antonenko

Water plays an important role in human life: it provides for physiological functions, is used for body strengthening and for personal hygiene. The chemical composition of water, namely the content of microelements, affects the activity of metabolic processes, and their lack or excess can lead to endemic pathologies. In addition, water is one of the factors that cause polyetiological infectious pathologies in the population.

15.1. Water and health as a hygienic issue

"Blessed healing waters!
Give us protection, quench our thirst,
Give us bliss and happiness.
Masters of priceless treasures,
Rulers of nations, healing waters!
We want to drink our healing balm", —
this is how the ancient inhabitants turned to the waters of the Nile

In ancient times, people knew that water is important for human life.

The hygienic significance of water is determined by the physiological needs of human.

WATER (from chemical point of view) — H_2O, a chemical substance that is a clear colorless liquid without odor and taste (under normal conditions, the pressure is 101.3 kPa (one atmosphere), temperature — 20 °C).

WATER (from hygienic point of view) is a complex disperse system, in which chemical substance H_2O in a liquid state is a dispersion medium, and the dispersion phase is represented with organic and inorganic chemicals as suspended particles (SiO_2), colloidal solutions (organic macromolecules — starch), molecular and ionic solutions (salts, alkalis, acids), and microorganisms.

Water possesses the unique anomalous properties:

- in nature it exists in three physical states: solid (ice), liquid (water) and gaseous (water vapor);
- it is the only substance in the world that increases in volume by 9 % when frozen;
- it has the highest value of surface tension (after mercury);
- it is a universal soluble medium;
- it is an inert solvent;
- it possesses the greatest heat capacity and thermal conductivity;
- at temperature from 0 °C to + 4 °C the structure and character of interaction of hydrogen bonds changes;
- at temperature 35–40 °C — the easiest to heat and the fastest to cool;
- ice is a unique state of water.

Water is an integral part of human existence and it performs a wide range of functions (Fig. 15.1).

No living organism on Earth can exist without water.

The Eastern proverb says: "Where the water ends, there ends the life".

It is known that without water a person can live only for 5–6 days, without air — for 5–6 minutes, without food — for 5–6 weeks.

Let us dwell in detail on each of the functions of water.

15.2. Hygienic significance of water

15.2.1. Physiological significance

Water is a structural element of the human body. The total water content in the body is about 60–65 % of the whole body. The human embryo contains 90–97 % of water. In newborns, the amount of water decreases slightly

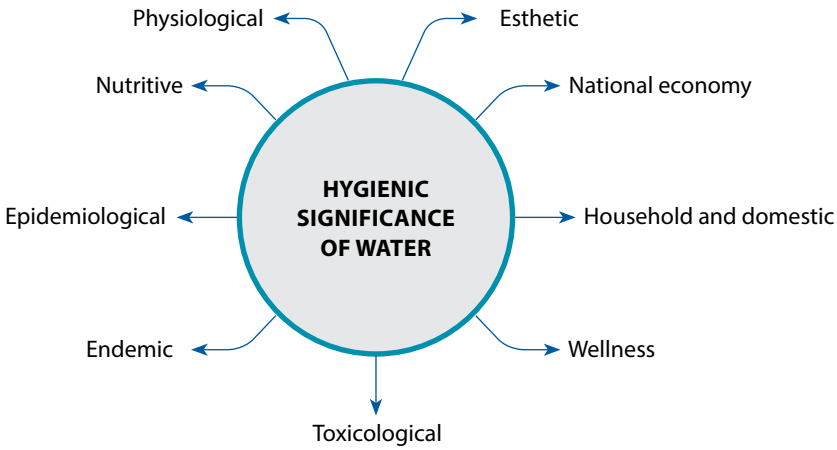


Fig. 15.1. Hygienic significance of water

and it equals 77–80 % of body weight. By the age of 50, a person seems to "dry out" and the share of water is only 55 % of body weight (Fig. 15.2).

The main part of water (70 %) is concentrated intracellularly, and 30 % is extracellular water. The water content in various human tissues is concentrated as follows: the skeleton contains 22–31 %, muscle tissue — 50–79 %, connective tissue — 80 %, blood plasma — 92 %, vitreous body — 99 %.

Water is important as a solvent — physical and chemical processes in the human body occur in aqueous solutions; body tissues are water-colloidal systems.

Water takes part in the processes of oxidation, hydrolysis and other metabolic reactions.

Water is component of the body's secretions and excretions.

Water takes part in the transport of nutrients throughout the body.

Evaporating from the surface of the skin and respiratory tract, it participates in the processes of thermoregulation.

Water takes part in metabolism, is continuously excreted from the human body through the kidneys, lungs, intestines and skin. Approximately 1–1.5 l of water per day is excreted in the urine, up to 0.2 l — in the excrements, approximately 0.4–0.5 l — in the lungs as vapors, and 0.5 l to 10 l — in the skin and sweat glands, depending on weather conditions and the nature of the work.

The human body reacts acutely to water deficiency. The physicochemical constants of blood and water-electrolyte metabolism change, the processes of decomposition of tissue proteins, fats and carbohydrates are intensified in case of dehydration.

The human body tolerates dehydration with difficulties (Table 15.1).

Clear clinical manifestations of dehydration appear if water loss is 5–6 % of body weight (increased respiratory rate, redness of the skin, dry mucous membranes, low blood pressure, loss of coordination, dizziness).

Water loss of 10 % of body weight can lead to irreversible changes, and water loss at the level of 15–20 % is fatal at an air temperature of 30 °C, at the level of 25 % — at a temperature of 20–25 °C.

"Without feeling the thirst, it is impossible to comprehend what precious good water is" (D. Byron).

The physiological need of the human body for water is provided with consumption of:

- water, tea, other beverages and liquid foods (1–1.5 liters);
- water contained in food (1–1.2 liters);
- water, which is formed in the tissues during the oxidation of nutrients (0.2–0.4 liters): by the complete oxidation of 100 g of fat, 107 g of water is formed, 55.5 g of water by 100 g of carbohydrates, 431 g of water by 100 g of proteins.

In the human stomach, in addition to water from the outside, there is 6–7 l of fluid: 3 l of saliva, 3 l of gastric and intestinal juice and up to 0.5 liters of bile per day.

Water is one of the most valuable gifts of nature. In addition, we must not forget how aptly expressed his passion for water, the French writer Antoine de Saint-Exupery. The Character of his story "Planet of the People" crashed while flying over the desert, experienced the death agony of dehydration and, seeing the healing moisture, felt incredible joy: *"Water! You have no taste, no color, no smell! You are impossible to describe! We enjoy you*

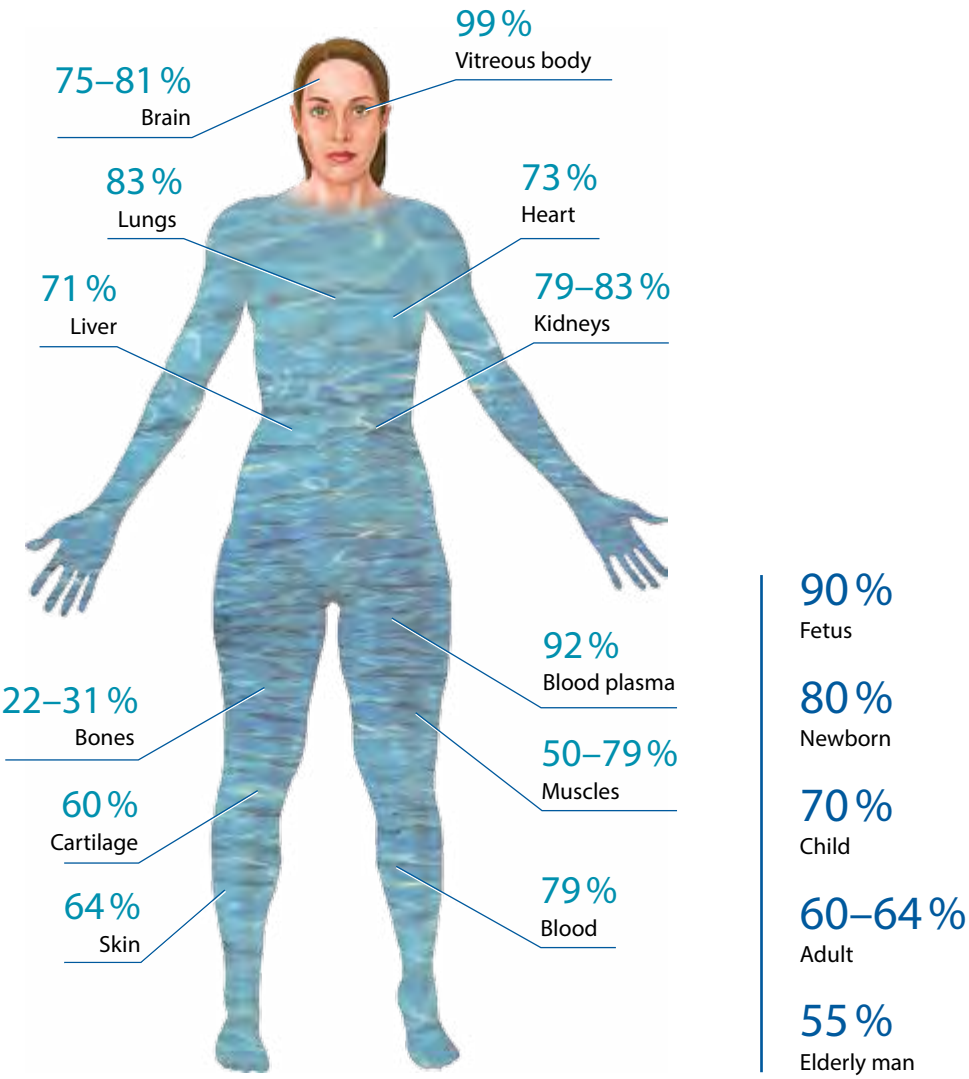


Fig. 15.2. Structural (plastic) function of water

Table 15.1. Symptoms of dehydration (E. Adolf, 1952)

With a decrease of water in the body (in % of body weight) is observed:	
1–5 %	Thirst, malaise, movements economy, loss of appetite, redness of the skin, irritability, drowsiness, fever
6–10 %	Dizziness, shortness of breath, a feeling of goosbumps in the extremities, decreased blood volume, cessation of salivation, cyanosis, slurred speech
11–5 %	Delirium, swelling of the tongue, difficulty swallowing, deafness, impaired vision, atony and numbness of the skin, painful urination, anuria
15–20 %	Lethal consequences at a temperature above 30 °C
25 %	The loss is fatal at any temperature

without knowing what you are. You cannot say that you are needed for life, you are life itself. You fill us with joy that cannot be explained by our feelings! With you we get forces which we had already lost... you are the greatest wealth in the world".

But there is a real danger of contracting infectious and noninfectious diseases by drinking of poor quality water.

WHO statistics shows that almost 3 billion people on the planet use poor quality water.

Of the more than 2.000 diseases of man-made origin, 80 % occur due to the consumption of poor quality drinking water.

That is why the hygienic significance of water and its importance for the prevention of infectious and non-infectious diseases is extremely important.

15.2.2. Epidemic water significance

Mankind realized the role of water in the mechanism of transmission of intestinal infections and emergence of endemics and pandemics much earlier, than pathogenic microorganisms where discovered.

However, even today, despite the spread of centralized water supply in settlements and the improvement of water disinfection methods, this problem remains extremely relevant.

Therefore, when solving the issue of providing the population with good quality drinking water, first of all it is necessary to prevent the emergence and spread of pathogens of infectious diseases that can be transmitted through water.

This is achieved only through the constant supply with good quality water in sufficient quantities.

Violation of hygienic requirements and sanitary rules, both during the organization of water supply and during the subsequent operation of the water supply system, can lead to an extremely dangerous, even catastrophic situation — an outbreak of water epidemic, when hundreds and thousands of people are infected.

Currently, the role of water in the mechanism of transmission of intestinal infections, epidemics and pandemics has been proven. The most widespread water epidemics with the most severe consequences of public health disorders are associated with the possibility of spreading intestinal pathogens with water, which are characterized by fecal-oral transmission. The possibility of spreading cholera, typhoid, paratyphoid A and B, salmonellosis, shigellosis and other pathogens of infectious diseases through water has been proved.

WHO experts have proposed a classification of water-borne infectious diseases:

1. Diseases that arise from the use of contaminated water for drinking:
   - intestinal infections (the leading mechanism of transmission is fecal-oral):
     - bacterial nature: cholera, typhoid fever, paratyphoid A and B, shigellosis, salmonellosis, choleenteritis;
     - viral etiology: viral epidemic hepatitis A, viral hepatitis E, polio and other enterovirus infections, rotavirus diseases;
     - protozoan etiology: amoebic dysentery (amebiasis), giardiasis;
   - respiratory organs infections, pathogens which can sometimes be spread by fecal-oral way:
     - bacterial in nature: tuberculosis;
     - viral etiology: adenoviral infections — rhinopharyngitis, pharyngoconjunctival fever, rhinitis;
   - skin and mucous infections, which may have a fecal-oral transmission mechanism: anthrax;
   - blood infections, which may have fecal-oral transmission mechanism: Q-fever;
   - zooanthroponoses, which may have fecal-oral transmission mechanism: tularemia, leptospirosis, brucellosis;
   - helmintoses:
     - geohelminthiasis: trichocephaly, ascariasis, hookworm;
     - biohelminthiasis: echinococcosis, hymenolepidosis.
2. Diseases of the skin and mucous membranes that arise as a result of contact with contaminated water (epidermophytia, mycoses, etc.).
3. Diseases that are caused by helminthes living in water: schistosomiasis, dracunculiasis, or scabies.
4. Transmissive infections spreading by insects-carriers those multiply in water: malaria, yellow fever.

History knows many examples of epidemics that broke out due to consumption of water contaminated with pathogenic microorganisms from reservoirs and aqueducts.

The connection between the water factor and the spread of cholera was noticed long time ago. The cholera epidemic in London was first recognized as waterborne in 1854.

But the largest epidemics of intestinal infections were registered in the second half of the 19th century, which coincided with a period of rapid development and construction of water mains.

This is due to the fact that the first water pipe-lines, which mostly used surface water, sometimes did not improve, but rather worsened the sanitary condition of settlements.

This is due to both the lack of treatment facilities on water mains and the pollution of water sources caused by high concentration of population in cities.

This explains epidemics of typhoid fever in Hamburg and London, cholera — In St. Petersburg, Rostov-on-Don and other settlements.

In modern conditions, there are many barriers to the spread of infectious diseases through water, in particular, facilities for treatment and disinfection of wastewater before discharge into reservoirs; facilities for water purification and disinfection at water supply stations.

It would seem that there are all preconditions to eliminate the waterway of infectious diseases. However, this has not been achieved for many years.

Today, the world's infectious disease incidence related to water supply reaches 500 million cases per year.

According to WHO, almost 5 million people die each year due to the low quality of drinking water.

For example, between 1995 and 2006, 70 outbreaks of acute intestinal infections related to the water-borne factor were officially registered in Ukraine, with 8.265 people affected, including 4.140 children. The main number of outbreaks is related to tap water pollution due to emergencies in water supply and sewerage networks.

In 2007, two outbreaks of hepatitis A virus were recorded (154 people became ill, including 75 children) related to the use of poor quality drinking water — in the Autonomous Republic of Crimea and Zakarpattia region.

In 2008 — an outbreak of rotavirus enteritis (30 people became ill, including 24 children) and an outbreak of viral hepatitis A (in the Lviv region — 92 people were ill, including 37 children.

In 2011, an outbreak of cholera was registered (16 people became ill) in Mariupol — 15 people, another case of cholera — in the Donetsk region. Six cases of the same vibrio pathogen carriers detection in clinically healthy individuals were registered.

The largest mass outbreaks of water-borne intestinal infections are shown in Table 15.2.

It should be emphasized that it is impossible to completely avoid the risk of intestinal infections, as they can spread not only through water, but also through contaminated food, hands, flies and so on. This maintains the reservoir of patients and carriers and the sporadic incidence.

However, statistics convincingly show that the rational water supply, purification and disinfection of water in water mains helps to reduce the incidence of intestinal infections by 8–12 times.

The spread of infectious diseases through water is theoretically and practically possible only in the simultaneous presence of three conditions.

First, pathogens must enter the water supply source. This threat is possible regarding the current state of drainage waters and parentage of infection patients and carries.

Secondly, pathogenic microorganisms must maintain virulence and viability in the aquatic environment for a long time (Table 15.3). (This ensures the preservation of the microorganism as a species).

Third, infectious agents must enter the human body with drinking water. This condition can be realized

Table 15.2 Outbreaks of water-borne intestinal infections in Ukraine

Region, settlement, year	Infection	Number of infected persons	
		adults	*children*
Donetsk (Donetsk region), 1998	Enterovirus meningitis	203	70
Odesa (Odesa region), 2000–2001	Rotavirus acute enterocolitis	866	2277
Torez (Donetsk region), 2003	Hepatitis A	33	21
Transcarpathian region, 2007	Hepatitis A	79	75
Lviv region, 2008	Rotavirus enteritis	6	24
	Hepatitis A	55	37
Mariupol (Donetsk region), 2008	Cholera	16	
Bortnychi microdistrict, Kyiv, 2015	Coli-enteritis (enteropathogenic *E. coli*)	34	121

Table 15.3. The survival time of microorganisms in water (days)

Microorganisms	Water			
	sterile	*tap water*	*shaft-well*	*river*
Enteropathogenic Escherichia coli	8–356	**2–262**	2–106	**21–183**
Bacteria of typhoid-paratyphoid group	6–356	**3–371**	12–107	7–157
The causative agent of hepatitis A	—	—	40	—
Shigella	2–72	5–27	2–19	19–92
Vibrio cholerae	3–392	4–28	1–92	4–92
Poliovirus	Up to 100	Up to 118	56	Up to 180
Leptospira	Up to 16	Up to 5	7–75	Up to 150
Tularemia bacillus	3–15	Up to 92	12–60	7–31
Brucella	6–168	5–25	4–122	Up to 10

through violation of the technology of water purification and disinfection or violation of the water supply system operation rules.

The following set of measures should be taken to prevent the water-borne epidemics (Fig. 15.3).

15.2.3. Endemic significance of water

One of the heroes of Antoine de Saint-Exupery's "Planet of the People" said: *"You are the world's greatest wealth, but also the most fragile — you are so pure in the bowels of the Earth. You can die at the source if it contains magnesium. You can die two steps from the salt lake. You can die, although there are two liters of dew, if it got any salts. You do not tolerate impurities, you do not tolerate anything foreign, you are a deity who is so easy to scare... but you give us infinitely simple happiness".*

Mass lesions may be non-infectious in nature, i.e. caused by presence in water of chemical — both mineral and organic — impurities.

The problem of the water chemical composition effect on public health has long been of interest to scientists, but the first scientifically ideas about it appeared was only in the early 20th century.

A significant contribution to the development of these phenomena has been made by Russian and Ukrainian scientists. Prominent soil scientists, geochemists and biogeochemists V. L. Vernadsky and O. P. Vinogradov during the study of the microelement composition of soils in different regions noticed that in some areas the content of certain elements in the soil is too high or, conversely, too small.

The lack or excess of certain elements in the soil led to a lack or excess of them in the water of surface and

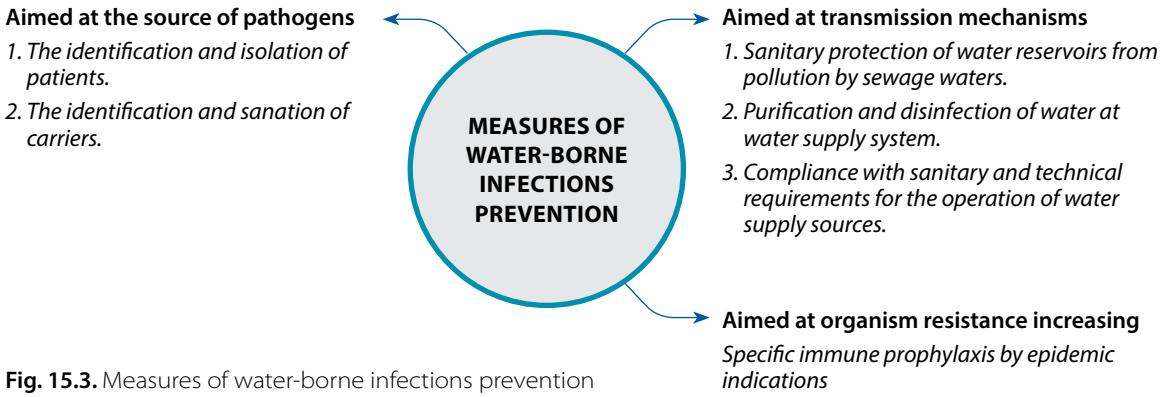


Fig. 15.3. Measures of water-borne infections prevention

groundwater sources formed in this area, and thus — in drinking water and food of plant and animal origin.

This had effect on the health of people who lived permanently in the area — they suffered from diseases that did not occur in other regions and were called endemic diseases.

Endemic disease is a disease that is caused by insufficient or excess content of natural chemical elements in the environment (water, soil, air), food of plant and animal origin and develops in certain areas, the so-called biogeochemical provinces.

Biogeochemical provinces — geographical areas where the etiological factor of the disease is the characteristic mineral composition of water, plant and animal organisms due to insufficient or excessive content of microelements in the soil, and diseases occurring in these areas are called endemic.

A significant contribution to the development of ideas about the hygienic value of the microelement composition of drinking water was made by Ukrainian hygienists R. D. Gabovich and G. P. Stepanenko (fluoride problems), B. P. Suchkov (problems of selenium and its effect on health), I. I. Schwaiko (iodine problems).

Table 15.4 summarizes information on the most common endemic diseases, their distribution areas, causes and main clinical manifestations.

Endemic fluorosis, endemic caries, water-nitrate methemoglobinemia, and endemic goiter are particularly closely related to water consumption.

To prevent the occurrence of endemic diseases the following set of measures should be taken (Fig. 15.4).

15.2.4. Toxicological significance of water

Today, man-made pollution of water sources with chemicals due to the discharge of untreated or insufficiently treated wastewater by industrial enterprises, surface runoff from agricultural lands, areas of industrial waste dumps (Table 15.5) represents significant danger for human health.

Toxic substances in the water, even in small amounts, can be dangerous to human health.

Table 15.4. Endemic diseases and their characteristics

Name	Cause	Biogeochemical province	Clinical symptoms
Endemic fluorosis	≥ 1.5 mg/l of fluorine in water	In mountainous areas with fluorine-containing minerals	Stage I — porcelain-like spots on teeth (dental fluorosis); II — pigmentation spots on teeth; III — erosion of enamel, dentin lesions, destruction of crown; IV — skeletal fluorosis (osteosclerosis), metabolic disorders, gastroenteritis, hepatitis, nephritis, myocarditis
Endemic dental caries	≤ 0.5 mg/l of fluorine in water	All continents	The destruction of tooth enamel and dentin (stage pigmented spots and cavity)
Water-nitrate methemoglobinemia	Nitrate ≥ 45 mg/l		Clinical manifestations of hemic hypoxia: acrocyanosis, cyanosis of the mucous membranes, tachycardia, shortness of breath, dizziness, seizures
Molybdenum gout	Mo content in drinking water is 0.25 mg/l daily requirement — 0.1–0.3 mg/l)	Armenia (Hankavan and Kajaran)	Increased activity of xanthine oxidase → intensification of purine metabolism enhances the formation of uric acid → deposits of salts (urate) in the joints → attacks of gouty arthritis: fever, severe pain, swelling and redness of one, sometimes several affected joints lasts 3–5 days → significant amount of urate excreted in the urine with → signs of osteoarthritis. The disease is accompanied by: atherosclerotic nephrosclerosis ("wrinkled gouty kidney"), urolithiasis, early coronarosclerosis and cerebral atherosclerosis, hypertension, anemia, leukopenia, abnormal liver function
Endemic goiter	Lack of iodine	Poltava region, Carpathians, Caucasus, Altai, Central Asia	Violation of the synthesis of thyroxin → thyroid hyperplasia → hypothyroidism → inhibition of metabolism. Symptoms: increasing the size of the thyroid gland, decrease in body temperature, obesity, apathy, hair loss, children mental development retardation, cretinism

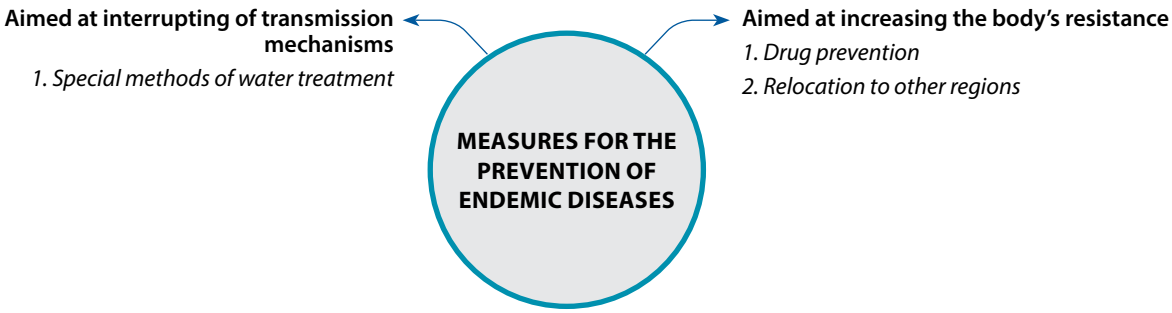


Fig. 15.4. Measures to prevent endemic diseases

Table 15.5. The main sources of water pollution

Industrial	Mining industry Oil and gas industry Plants and factories Industrial waste deposits Accidents at industrial enterprises
Household-domestic	Household Landscaping Waste deposits
Agricultural	Agriculture Animal farms Greenhouse economies
Transport	Land transport Water transport

This is facilitated by the fact that chemicals that pollute the water of reservoirs are not filtered by modern treatment plants of water supply stations.

The probability of adverse effects increases related to extremely toxic and highly toxic substances, presence of mutagenic and carcinogenic activity, embryotoxicity and teratogenicity, reproductive toxicity and sensitizing properties.

In addition, the risk of harmful effects is higher in substances that are poorly broken down in water due to both physical-chemical processes (hydrolysis and photolysis) and microbiological destruction. The resistant ones in the aquatic environment are heavy metals, organochlorine compounds DDT, HCH, etc.

According to the Central Geophysical Observatory named after B. I. Sreznevsky, the analysis of pollution levels of large rivers and reservoirs of Ukrainian regions showed that none of the rivers of Ukraine can be called crystal clean — at best, the water is relatively clean.

Table 15.6 summarizes information on the most common chronic intoxications associated with man-made water pollution by chemicals, causes and clinical manifestations.

To prevent the occurrence of non-infectious diseases, it is necessary to follow the following measures (Fig. 15.5).

15.2.5 Domestic and household role of water

The hygienic significance of water is not limited to its physiological role and direct impact on public health.

A large amount of water is used for hygienic, household and industrial needs.

Household water functions:

- water is used for cooking;
- water is used for washing of body, clothes, bedding, dishes, cleaning dwelling, public, industrial, premises;
- irrigation of green plantations within settlements;
- sanitary transport and disinfectant functions of water — removal of domestic, industrial waste by system sewage, self-cleaning of reservoirs;
- extinguishing fires, cleaning of air pollution (rain, snow).

The use of water in sufficient quantities contributes to the personal hygiene skills. Only clean skin performs physiological functions, namely, having bactericidal properties, it becomes a reliable barrier to the penetration of pathogens of many infectious diseases.

Water creates optimal living conditions in residential buildings, public institutions and industrial enterprises.

Economic functions of water:

- water is used for agriculture (irrigation, greenhouse farms, poultry and livestock complexes);
- water is used for industry (food, chemical, metallurgy);
- waterways (passenger, cargo).

Table 15.6. Chemical toxicity associated with man-made pollution of water with chemicals in concentrations exceeding MAC

Compound	Water concentration	Disease	Clinical symptoms
Polychlorinated biphenyls	natural clean water — up to 0.5 ng/l, moderately polluted — 0.5–50 ng/l, heavily polluted — more than 50 ng/l	Yusho oil disease	Nausea, vomiting, skin hyperkeratosis, chloracne, bronchitis, hepatitis, neurological disorders, carcinogenic effects. Penetrating through the placenta
Lead	groundwater — 0.1–20 mg/l, surface water — 0.3–5 mg/l, MAC — 0.03 mg/l	Saturnism	General weakness, poor appetite, tremor of extremities, weight loss, bad taste in the mouth, gingival lead "band", pain, anemia → paresis, paralysis, disturbance of hematopoiesis, encephalopathy, chronic hepato- and nephropathy, anorexia. "Lead colic"
Cadmium	natural water — 0.05–1 mg/l, MAC — 0.001 mg/l	Itai-Itai disease	Kidney proximal tubular dysfunction due to cadmium → extreme loss of bone minerals → osteomalacia and osteoporosis → multiple broken bones → skeleton deformation. + Iron hypochromic anemia, pancreatic dysfunction, enteropathy
Arsenium	groundwater — 0.002–0.8 mg/l surface water — 0.003–10 mg/l, MAC — 0.05 mg/l	Coffin disease	Nausea, vomiting, loss of appetite, headache, hyperkeratosis, dermatitis, hair loss, brittle nails, neuritis, paralysis, blurred tactile sensitivity, blurred vision, liver damage. Increased risk of cancer
Chromium	natural water — 0.001–0.012 mg/l, MAC: Cr^{6+} — 0.05 mg/l; Cr^{3+} — 0.5 mg/l		The greatest danger is Cr^{6+}, which causes allergenic, mutagenic and carcinogenic (cancer of the esophagus) effect. After contact with skin and mucous membranes, it leads to ulcers and dermatitis. With inhalation — lung cancer, maxillary sinus, prostate cancer.
Mercury	natural water — 0.001–0.1 mg/l, MAC: inorganic mercury — 0.0005 mg/l	Minamata disease (methylmercury)	Mercury — protoplasmatic poison, blocks the SH-group of thyol enzymes, and it has neurotoxic, nephrotoxic, hepatotoxic, gonadotoxic, embryotoxic and mutagenic effect on reproductive function and endocrine system
Trihalomethanes	MAC: THM — 0.1 mg/l chloroform — 0.06 mg/l, dibromchloromethane — 0.01 mg/l		General toxic effect in liver and kidney, neurotoxic and cardiotoxic effects. Chloroform and dibromchloromethane belong to the group 2B carcinogen
Dioxins: tetrachlorodibenzodioxin (TCDD), tetrahalogenated dibenzofuran (THDF)	MAC: 2,3,7,8-TCDD — 20 ng/l		Neurotoxic action: there are chloracne, disorders of the liver, kidneys, central nervous system, disruption of lipid and carbohydrate metabolism. Carcinogenic effect is very steady
Polycyclic aromatic hydrocarbons	MAC 3.4-benzpyrene 0.01 mg/l		General toxic effects: diseases of liver, kidney, central nervous system and blood. Carcinogenic effect

Water is used for wet cleaning, cleaning the household items and for house care, washing clothes, cooking, washing dishes, etc.

Water is used for production needs at all industrial enterprises without exception (Table 15.7 and Table 15.8). Sometimes technological processes involve the use of

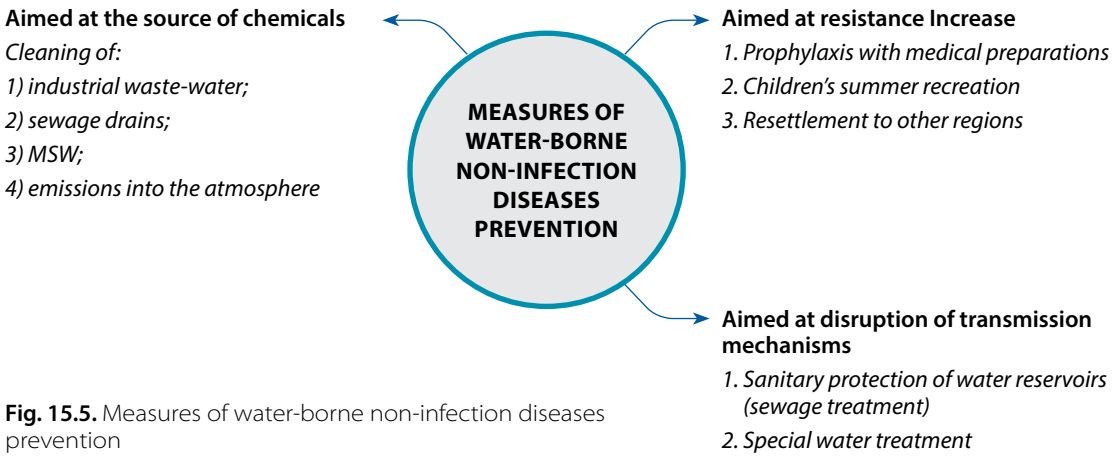


Fig. 15.5. Measures of water-borne non-infection diseases prevention

Table 15.7. Water consumption on one habitant in different cities in Europe (excluding industrial ones)

Cities	Water consumption per 1 inhabitant, dm^3/day
Rome	1000
Moscow	700
Tbilisi	500
Kyiv	400
St. Petersburg	400
Glasgow	250
Manchester	200
Hamburg	200
Munich	200

Table 15.8. Water consumption in industry

Product	Amount of water (m^3/t)
Rubber	1500
Aluminum	1500
Steel	150
Synthetic fiber	2000
Wheat	1500
Rice	4000
Meat	20000

not just tap water, but specially prepared — demineralized, deionized, softened, pyrogen-free water.

It is used a lot in agriculture for irrigation in greenhouses, poultry and livestock complexes. A lot of tap water is used for washing the streets, irrigating greenery. There must be a so-called fire water reserve.

15.2.6. Health significance of water

Water is used to strengthen the human body. The main principles of body strengthening are gradual and systematic.

Mineral water is used for rehabilitation of patients with pathology of the gastrointestinal tract and urinary system. About 500 sources of various mineral waters (Naftusya, Svalyava, Polyana Kvasova, etc.) have been discovered on the territory of Ukraine.

Therapeutic baths are popular in medical practice. There is such types of therapy as thalassotherapy — the use of sea air and sea water for therapeutic purposes.

Water as a component of the environment plays an important role in shaping the health of both an individual and the population and the provision of good sanitation in cities.

Thus, significance of water for human life, ensuring and strengthening the health of the population, ensuring a high degree of settlements sanitation, providing for sanitary conditions for life and meeting the economic needs of society is evident.

16

CHAPTER

PROBLEMS OF WATER SUPPLY OF SETTLEMENTS. HYGIENIC REQUIREMENTS AND METHODS FOR IMPROVING THE QUALITY OF DRINKING WATER

O. P. Vavrinevych, I. M. Pelo

The most urgent today's issues on which the future of mankind depends are environmental issues, in particular water-related ones.

All water reserves of the Earth are united by the concept of "hydrosphere".

The hydrosphere refers to the collection of water objects, including oceans, seas, rivers, lakes, reservoirs, groundwater, glaciers, snow cover, and dripping liquid water in the atmosphere.

The total volume of water on the planet is about 1.5 billion m^3. 93.96 % of water is concentrated in the seas and oceans (Table 16.1).

However, the high salt content (up to 35 g/dm^3) makes this water unsuitable for drinking and household needs. A human needs water, the salt concentration of which does exceed 1–2 g/dm^3.

Fresh water accounts for less than 6 % of all water resources on Earth. However, most of the world's freshwater reserves are concentrated in the glaciers of Antarctica, Greenland, the Arctic and other permafrost areas, making it inaccessible. Experts believe that only 0.2–0.3 % of all fresh water on the Earth can actually be used for drinking.

Despite relatively large reserves of fresh water, the 35th Session of the UN General Assembly noted that more than 1 billion people are in acute shortage of good water.

The first reason for the lack of good quality water is its uneven distribution across the Earth as well as in certain countries.

The second most important reason for the lack of fresh water is anthropogenic factor.

The problem of water shortage is the most significant in the areas on the sea and ocean shores. For example, groundwater in the southern regions of Ukraine is highly mineralized or with an excessive content of iron and other impurities, i.e. water is unfit for consumption, in addition, their resources are very limited, so the population uses imported water.

The main problems associated with the hydrosphere of the planet are the conditions of water supply, water quality and opportunities to improve it.

Until recently, these problems haven't been so urgent, given the relative purity of natural water sources and their number.

However, the situation has changed dramatically in recent decades.

Huge urban human concentration, a sharp increase in industrial, transport, agricultural, energy and other anthropogenic emissions into the environment have led to aggravated water quality, the appearance of water sources not inherent in the natural environment of chemical, radioactive and biological substances.

All this makes efficient water supply a leading problem of modern hygiene.

Table 16.1. Hydrosphere structure

Components of Hydrosphere	Water, %
World ocean	93.96
Land water	4.12
Areas of active water exchange	0.27
Glaciers	1.65
Lakes	0.019
Soil moisture	0.006
Steam atmosphere	0.001
Rivers	0.0001

16.1. Sources of water supply, their comparative hygienic characteristics

Not every water type can be used for both drinking and household purposes. The hygienic water functions are predisposed for its characteristics. Water quality largely depends on the nature of the water supply source. The formation of water sources is associated with the water cycle which is constantly moving on our planet.

334 thousand km^3 of water evaporates annually from the surface of the world oceans, which make up the surface of our planet. 297 thousand km^3, or 90 % of water, are sediments over the oceans and seas and 37 thousand km^3 of water, i.e. only 10 % of it, is represented with air currents and it falls over the continents.

Some part of this water, about a third, flows into open water — rivers, lakes; about the same amount of water enters the ground and the same amount evaporates from the surface of the Earth and water objects.

Three types of water supply sources are distinguished:

1. Atmospheric waters.
2. Groundwater.
3. Open reservoirs (surface waters).

Atmospheric water. Atmospheric water — rainwater and snow — is used for domestic water supply only in low-water regions. One drop of rain contacts with about 16 liters of air, so atmospheric water contains chlorides, sulfates and bicarbonates. The total amount of salts in atmospheric water is 20–95 mg/dm^3.

Atmospheric water is characterized by low mineralization, due to which it has an unpleasant taste, it does not contain organic substances and is almost free from pathogenic microorganisms. Atmospheric water is considered an unreliable source of water supply.

Groundwater: represents from the filtration of atmospheric water and condensation of water vapor present in the ground air.

There are three main types of groundwater:

1. *Bleak (perched groundwater)* is the groundwater that is the closest to the Earth's surface. It accumulates in the first small waterproof area of the Earth's surface as lenses. There isn't much perched groundwater and it is rarely used. This source of water contains many organic compounds, low-mineralized ones with low epidemiologic safety characteristics.
2. *Groundwater* is the water that during filtration reaches the first waterproof layer from the Earth's surface, represented with clay, granite, limestone, and, accumulating above it, makes the first aquifer. The quality of groundwater depends on its depth, mineral composition and soil purity. Groundwater is usually transparent and colorless. Its average mineralization ranges from 200 to 600 mg/dm^3. If the soil is fine-grained by its mechanical composition, then at a depth ≥ 5–6 m, groundwater is generally free from bacterial contamination.

Groundwater, with its good properties, is widely used in rural areas, obtained in shaft and tubular wells.

Shallow groundwater is not sufficiently protected from contamination from the surface. It is characterized by seasonal fluctuations in the water level, discharge, chemical and bacterial composition, which depend on the frequency and amount of precipitation, presence of open water, depth, nature of the soil. Groundwater is filtered through a layer of clean fine-grained soil, 5–6 m thick, and becomes transparent, colorless; it does not contain pathogenic microorganisms. Groundwater reserves are insignificant, so to use them as a source of centralized water supply, provide for their artificial replenishment with water through special engineering structures.

3. *Middle water* — the name itself suggests that it is the water that is between two waterproof layers. The one layer — the bottom — is a waterproof bed, and the second — the top — a waterproof roof. Middle water fills the entire space between the waterproof layers, depending on the terrain, it classified into the pressured and non-pressured one. The first pressured well was built in 1126 in France in the county of Artois, in connection with which the middle waters were called artesian.

Middle water, in contrast to groundwater, is characterized by low temperature, constant water level and

composition. It is transparent, colorless, odorless and tasteless. The amount of dissolved salts in it depends on the composition of the rocks in which it accumulated. Characterized by long filtration and the presence of a waterproof roof, the middle water differs from the others by almost complete absence of microorganisms, especially pathogenic ones. Middle waters are obtained by drilling wells.

Middle pressured (artesian) and non-pressured water is reliably protected from surface pollution as it is situated between waterproof layers. Replenishment of middle waters occurs in the supply zones — places where the aquifer emerges on the surface, which, as a rule, are considerably distant from the places of middle water intake. Middle water is characterized by stable low temperature (5–12 °C), constant physical-chemical composition, stable level and relatively significant flow rate compared to other underground sources.

4. *Spring water* is the groundwater that permanently reaches the Earth's surface. Both groundwater and middle water can come to the surface if the horizon is broken resulting from the terrain level decrease (mountain slope, deep ravine). The water sources are divided into the descending and ascending ones. The last appear presenting from the middle pressured water emergence. Water is used for economic needs from sources using the water intake structures — catchments.

Surface waters (open reservoirs)

Atmospheric water, soil surface precipitation, flows down the natural slopes, forming flowing and non-flowing reservoirs — streams, rivers, lakes. Open reservoirs can be partially fed by groundwater.

Water of open reservoirs in organoleptic terms possesses a number of disadvantages: the organic substances contained in it, predispose for the taste and color. In terms of its chemical composition, surface waters are low-mineralized, and from the epidemiological point of view they are potentially dangerous. Reservoirs are especially heavily polluted in areas near settlements and in places of wastewater discharge.

Surface waters are characterized by inconsistency in water quality, which varies depending on the season and even the weather.

The main advantage of open reservoirs as a source of water supply is that they contain large amount of water.

Water of open reservoirs used for drinking and economic needs must be properly treated.

16.2. Water supply systems of settlements and their hygienic characteristics

There are two water supply systems: 1) decentralized, or local, and 2) centralized — plumbing.

The locally supplied water is obtained directly from water supply sources, for example, from wells, catchments, and delivered to the place of consumption by various containers: buckets, barrels.

The certainly supplied water reaches the consumer through a network of pipelines.

Decentralized water supply

Most rural settlements use a decentralized (local) water supply system, in which the population takes water directly from the source. Groundwater (groundwater and spring water) is most often used as a source of water supply. Water is taken from underground sources by means of shaft and tubular wells and catchments.

Shaft well is an engineering structure that is a vertical construction with a large cross-sectional, round, square, rectangular or hexagonal shape, intended for the collection of groundwater.

Damming of the source is an engineering water-dam construction, intended for collecting spring water in the places of its spontaneous emergence on surface, which includes chambers of capture (receiving and illuminated water), a storage room or a pavilion.

In cities, the population mainly uses buvette water.

Buvette is an engineering water-dam construction (pumping station) used to provide consumers with untreated (except for disinfecting water by ultraviolet irradiation) interlayer pressured (artesian) or non-pressured groundwater, which includes a well, a distribution pump and a special room or pavilion.

When choosing a water source for local water supply, it is assumed that the water will be used for drinking purposes without pre-treatment. Therefore, the water must meet the general requirements for good quality drinking water. When choosing the location of the well, pay attention to the sanitary conditions of the area and the consequence of the well use.

The distance from the well to the consumer should not exceed 100 m. The wells are located on the slope of the terrain, which should be above all sources of pollution. The distance between the well and the source of contamination must be at least 50 m.

The results of research on the quality of drinking water from pumping stations in Kyiv showed that pumping water has been of consistently high quality for many years and in most respects it possesses better characteristics than drinking water from a centralized water supply system. The water of certain buvettes was characterized with poor organoleptic characteristics, which are natural and not related to external pollution (Table 16.2).

Centralized water supply

Centralized water supply system is a set of objects, buildings and water distribution networks connected by single technological process of purification and further transportation of drinking water to consumers.

The centralized water supply system is more advantageous than the local one, more convenient and it significantly improves the sanitary and epidemic well-being of settlements.

Its advantages are:

- the ability to choose the best source of water;
- ensuring sanitary protection of the source;
- prediction, if necessary, of the possibility of improving water quality;
- providing the population with the necessary amount of water;
- ensuring proper technological and hygienic control over the mode of preparation and quality of drinking water.

Water supply plumbing (conduit) is a set of engineering structures designed for centralized water supply, through which water is obtained from the source, water is treated and supplied to the settlement and distributed among consumers.

The main components of the water supply pipeline:

1. Source of water supply (underground or surface one).
2. Water intake structures.
3. Water-lifting devices (pumping stations).
4. Treatment plant.
5. Buildings for the accumulation of water resources.
6. Buildings for delivery and distribution of water (water pipes, water supply network, water collection facilities on the network).

16.3. General hygienic requirements for drinking water quality, water consumption standards, water quality indices

Hygienic requirements for water quality indices depend on the purpose of the water, i.e. on the purpose for which it will be used.

There are 7 types of water:

1. **Water supply,** which is provided to the population by a centralized drinking water supply, used as drinking water and for household needs.
2. **Water from shaft wells** and **water-dam constructions**, which is used by the population in the same way as water of type 1, but transmitted by decentralized (local) water supply.
3. **Water of underground** (middle pressured, or artesian, and non-pressured) and **surface** (rivers, freshwater lakes, reservoirs) **sources** of centralized drinking water supply.
4. **Hot water** supplied by centralized water supply system.
5. **Mineral water**, which is used to treat patients.
6. **Technical water** supplied by technical water supply at industrial enterprises.
7. **Special purpose water** used in the pharmaceutical industry for the preparation of drugs, in enterprises of microbiological synthesis, etc.

Table 16.2. Quality of drinking water from buvettes in Kyiv

Indicator	Standards	District of Kyiv			
		Obolonsky	*Shevchenkivsky*	*Podilsky*	*Desnyansky*
Number of buvettes that do not meet regulatory requirements (97)	—	4	7	5	2
Turbidity, mg/dm^3	< 0.58	1.2–1.25	6.71	3.2	—
Total iron, mg/dm^3	< 0.2	0.27–0.7	1.24–1.7	0.3–0.96	0.27–0.88
Ammonium, mg/dm^3	< 1.2	—	0.79–0.9	—	—

For each type of water, there is a set of hygienic quality indicators, but all the requirements are divided in 3 groups of indicators that characterize the **organoleptic** (physical-chemical), **chemical** and **epidemiological** properties.

"Drinking water" intended for human consumption is water which organoleptic, physical, chemical, microbiological, parasitological and radiation characteristics corresponding to the requirements of the State Standards and sanitary legislation (water supply — tap water, packed water, from buvettes, shaft wells and source catchments), providing for physiological, sanitary, household and economic population needs (State Sanitary Code (SSC) DSanPiN 2.2.4–171–10 "Hygienic requirements for drinking water intended for human consumption").

Water will be safe for human health if it corresponds the following hygienic requirements:

1. *It is characterized by satisfactory organoleptic properties*: odorless, tasteless, clear, colorless, without visible impurities, of optimal temperature.

Such water will not have a negative impact on the nervous and mental state of a person; the person will not refuse to drink it or look for different water sources.

2. *Toxicologically safe:* the content of toxic chemicals does not exceed MAC, the water is safe for health and the biomicroelements content is close to optimal one.

Today, MAC of more than 1500 chemicals has been scientifically substantiated.

3. *Epidemically safe:* it does not lead to the spread of infectious diseases due to the content of pathogens in it.
4. *Radiologically safe.* That is, it contains a safe amount of naturally occurring radioactive materials with total activity (α- and β-emitters) that does not exceed MAC.
5. *Physiologically complete:* its mineral composition, content of individual biomicroelements (fluorine, iodine, selenium, etc.) must be adequate to the biological needs of the organism.

All indices of water quality, based on their hygienic value, can be divided into the following groups:

1. Organoleptic indices.
2. Indices of safety by chemical composition.
3. Indices of epidemic safety.
4. Radiation safety indices.
5. Indices of physiological completeness.

Hygienic requirements apply not only to the quality of water supplied to the population, but also to its quantity. The amount of water required to provide one person with water supply is called the **rate of water consumption** (Table 16.3).

Table 16.3. Standards of water consumption in peacetime

The degree of improvement	Norms of water consumption, L per 1 person/day
Shaft wells	40–60
Conduit (centralized water supply)	90
Conduit + sewerage	150
Conduit + sewerage + bath with heating in the column	250
Conduit + sewerage + hot top water	400–500

Daily water use — 150 l/day (O. M. Marzeev and V. N. Zhabotinsky):

- face washing three times a day — 5 liters;
- daily hygienic shower — 25 liters;
- taking a bath once a week — 250 liters;
- cooking — 5 liters;
- floor washing — 1 l per 1 m^2 (10 liters/day)

The standards of water consumption depend on the availability of water, the method of its delivery to the home and its sanitation.

According to the calculations of O. M. Marzeev and V. N. Zhabotinsky, on average, 5 liters are required for washing face three times a day, 25 liters for a daily hygienic shower, and 250 liters for taking a bath once a week. For cooking we spend 5 liters, for washing the floor — 1 liter per 1 m^2 (average 10 liters per day).

According to DBN V.2.5–74: 2013 "Water supply, external networks and structures. Basic design provisions" the specific rate of water consumption in cities is 230–285 liters per day, in rural areas — 25–60 liters per day per capita. This rate can vary by 10–20% depending on climatic conditions, as well as the degree of improvement.

In order to prevent water-borne diseases one should follow measures aimed at interrupting the transmission mechanism (Fig. 16.3).

To ensure the high quality of tap water, not only the proper arrangement of the water supply, but also sanitary protection of water sources from pollution is important. Zones of sanitary protection of water supply systems and water supply sources are established.

Sanitary protection zone (SPZ) of water supply pipelines and water supply sources *is a territory and wa-*

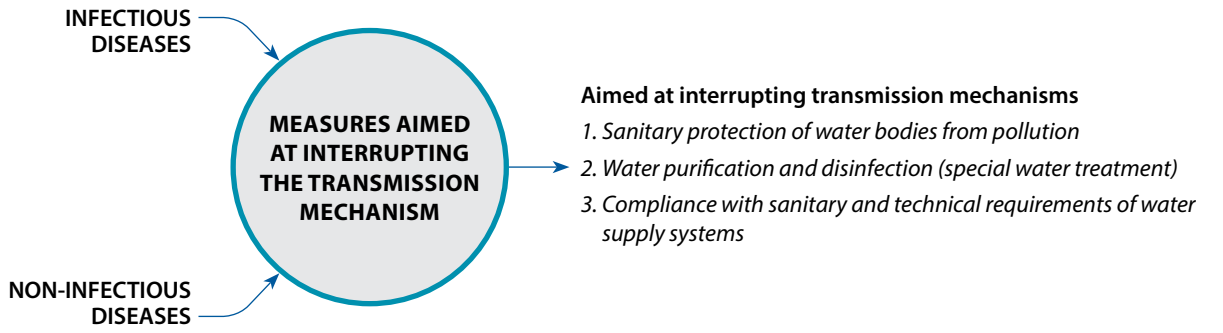


Fig. 16.3. Measures to prevent water-borne diseases

ters, where special sanitary-epidemiological regime is introduced to prevent deterioration of the quality of centralized drinking water supply and to ensure the protection of water purification facilities.

There are 3 SPZs:

1. Zone of strict regime: a territory, which includes a certain part of the water area of the reservoir at the place of water intake and upstream, the area around water treatment facilities.
2. Zone of restrictions: an area where the construction and use of facilities that may pollute this area and the reservoir is prohibited.
3. Zone of observation: a territory that includes the entire water supply network.

SPZs are created around objects where there are underground and open sources of water supply, water intake and water treatment facilities, etc.

Any risk-associated activities are prohibited within the SPZ.

The legal regulation of the lands of SPZ is determined by the legislation of Ukraine.

16.4. Methods of water treatment

Water quality of water supply sources does not always meet the requirements of the standard for drinking water, so the water supply is purified and disinfected.

All methods of improving water quality are divided into three main groups:

- mechanical;
- physical-chemical;
- biological.

Also, methods of water treatment (mechanical, physical-chemical) are divided into basic — those used in the vast majority of water treatment plants, and special ones — those used only when necessary to achieve a specific goal: fluoridation, defluoridation, deironing, demanganization, decontamination, etc. (Fig. 16.4).

Basic methods include 2 groups:

1. Lighting and discoloration
2. Disinfection.

Lighting is the elimination of suspended particles from water*; discoloration* — the removal of colored colloids or solutes. Lighting and discoloration of water are achieved by settling in special settling tanks, coagulation with coagulants (aluminum and iron salts) and filtration through different types of filters.

Water disinfection is destruction of vegetative forms of pathogenic microorganisms.

Chlorination has found the widest application among the various methods of water disinfection. The relative affordability, simplicity of the equipment and reliable operation has made chlorination of water a recognized method of water disinfection in water mains around the world. Liquid chlorine is most often used for chlorination of water; chlorinated lime, calcium and sodium hypochlorite, chlorine dioxide, chloramines, etc. can also be used. Disinfection of water by chlorination is conducted in special installations — chlorinators.

Despite the fact that water chlorination is the most common type of disinfection, the method has a number of significant disadvantages, the most common of which are the following:

- about 260 (according to scientists of the USA) organochlorine compounds are formed as a result of chlorination in water (especially at insufficiently effective removal from it before input of chlorine of humic and fulvic acids). Organochlorine compounds are a variety of halogen-containing compounds. The use of water containing halogen-containing compounds leads to the immune system suppression, diseases of the liver, kidneys, pancreas, thyroid gland, central ner-

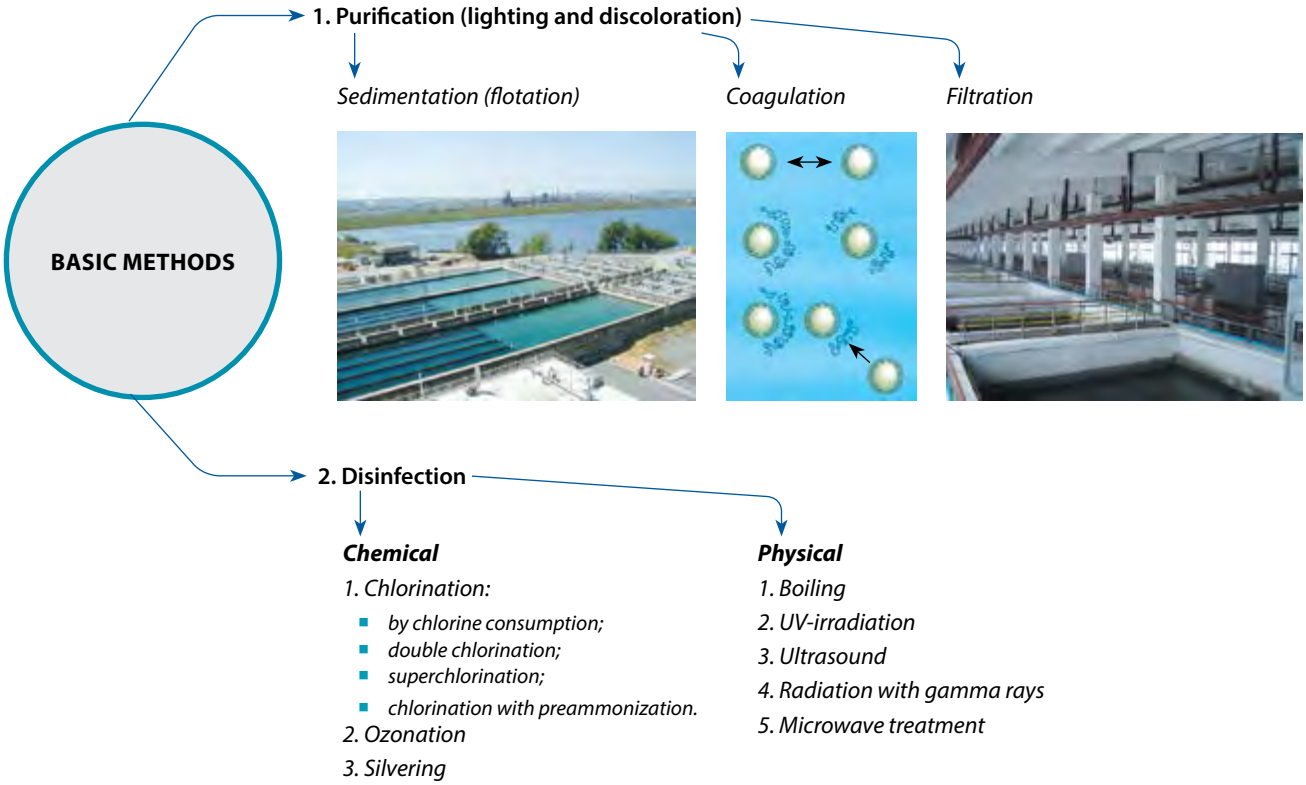


Fig. 16.4. Basic methods of improving the quality of drinking water (lighting, discoloration and disinfection)

vous system, but most important — numerous halogen-containing compounds are carcinogenic;

- traditional chlorination schemes often don't provide reliable barrier to the penetration of certain bacteria and viruses into drinking water;
- chlorine is a highly toxic substance, and during its transportation, storage and use it is necessary to take special measures for the safety of service personnel, the population and the environment;
- working solutions of chlorine-containing reagents and water treated with them are corrosive, that is the cause of rapid failure of equipment and pipelines.

Recent studies have shown presence of chlorination products, HCC, produces by water chlorination at water stations in drinking water of the counties using chlorination.

Numerous authors evidence about cancerogenic character of certain water chlorination by-broducts, though they refer only to their isolated body action. At the same time, the drinking water usually contains an HCC complex.

Ukrainian scientists (I. O. Chernichenko, N. V. Balenko, V. F. Babiy) calculated the additional risk of human cancer caused by the effects of water chlorination, which is considered to be significant.

Ozonation is one of the progressive methods of water disinfection. Today, almost 1.000 water supply stations in Europe, mainly in France, Germany and Switzerland, use ozonation in their water treatment technology. In Ukraine, ozonation is used at the Dnipro water supply station in Kyiv.

As a disinfectant, ozone is much more effective than chlorine. The contact time required for the bactericidal effect of ozone in water is about 10 minutes. The high virucidal effect of ozone occurs at real concentrations of 0.5–0.8 mg/dm^3 at an exposition time of 10–15 minutes. Ozone is known for its high efficiency against the water-present protozoan cysts. The ozone bactericidal action mechanism is the inactivation of bacterial enzymes by irreversible destruction of the cell DNA structure, by affecting the atomic oxygen obtained during ozone breakdown. Free radicals OH^-, HO_2^- and some others, the release of which accompanies ozone depletion, are also important. The advantage of ozone over chlorine in water disinfection is that ozone improves the water organoleptic properties and provides a shorter bactericidal effect with less contact time. It is characterized with a stronger oxidizing potential, and a wider range of

biocide activity, including that one targeted at the protozoan cysts.

However, when water is treated with ozone, it produces the products of ozonolysis of organic compounds such as carboxyl compounds (aldehydes, ketones, low molecular weight carboxylic acids, bromates). Of all the compounds formed by ozonolysis, formaldehyde and bromates deserve the most attention because they have toxic and carcinogenic properties.

Recent scientific studies have shown that substances with mutagenic properties are found in water after ozone treatment, especially in the case of ozonation accompanied with subsequent chlorination.

Other disadvantages of ozonation are: lack of aftereffects, release of organic compounds in water, which are easily biodegradable, being a source of carbon for bacteria. All this predisposes for secondary growth of microorganisms in water distribution networks, causes active corrosion of equipment and materials, pipelines.

There are the following physical methods of water disinfection (except chemical methods): water treatment with UV radiation, ultrasound, thermal disinfection.

Among the newest methods of water disinfection one should mention photolytic ozonation — a simultaneous treatment of water with ozone and ultraviolet rays, which increases the dissolved organic oxidation rate molecules by 100–10.000 times; at the same time mutual intensification of ozone action and UV radiation is observed.

The other special methods of water treatment are deodorization, deferrization, softening, desalination, distillation, decontamination, degassing, defluorination, fluorination (Table 16.4).

16.5. Sanitary legislation in the field of water hygiene and water supply

State policy in the field of drinking water and drinking water supply is based on the principles of:

- public administration and regulation of relations in the scope of drinking water and drinking water supply;
- guaranteed priority supply of drinking water to the population to meet drinking, physiological, sanitary and hygienic and household needs;
- scientific substantiation of drinking water quality;
- approximation of the requirements of state standards for drinking water, drinking water production technologies, as well as measuring and evaluation methods to the relevant standards, technologies, tools and methods adopted in the EU;
- preventive measures to protect sources and systems of drinking water supply;
- inevitability of liability in case of violation of legislation in the scope of drinking water and drinking water supply;
- ensuring free access to information on drinking water quality;
- prohibitions on disconnection of drinking water supply and sewerage facilities from the energy, gas and heat supply systems as objects of life support and strategic importance.

State sanitary and epidemiological inspection of drinking water supply is carried out in two forms: preventive and regular sanitary inspection. During it the hygien-

Table 16.4. Special methods of water treatment

1. Deodoration	Water treatment to make it tasteless and odorless
2. Deferrization	Removal of iron from water
3. Softening	Reducing the natural hardness of water
4. Desalination	Reducing the amount of dissolved salts contained in natural waters
5. Deactivation	Reducing the content of radioactive substances in water
6. Decontamination	Removal of dissolved gases from water
7. Defluorination	Removal of excess fluoride from water
8. Fluorination	Enrichment of water with fluorine

ist should keep to the following legislative documents (on Ukrainian legislation example):

1. The Constitution of Ukraine. Approved Resolution of the Verkhovna Rada of Ukraine No30 of June 28, 1996.
2. Fundamentals of the legislation of Ukraine on health care. Approved Resolution of the Verkhovna Rada of Ukraine No2802–12 of 19.11.1992.
3. Law of Ukraine "On Ensuring Sanitary and Epidemic Welfare of the Population". Approved Resolution of the Verkhovna Rada of Ukraine of February 24, 1994.
4. Law of Ukraine "On Environmental Protection". Approved Resolution of the Verkhovna Rada of Ukraine of June 25, 1991.
5. Water Code of Ukraine. Approved Resolution of the Verkhovna Rada of Ukraine of 06.06.1995.
6. Law of Ukraine "On Drinking Water and Drinking Water Supply". Approved Resolution of the Verkhovna Rada of Ukraine of January 10, 2002.
7. State sanitary rules and norms "Hygienic requirements for drinking water intended for human consumption" (DSanPiN 2.2.4–400–10). Approved Order of the Ministry of Health of Ukraine No400 of 12.05.2010. Registered at the Ministry of Justice of Ukraine No452/17747 of July 1, 2010.
8. State hygienic standards "Permissible levels of 137CS and 90Sr radionuclides in food and drinking water" Approved. Order of the Ministry of Health of Ukraine No256 of 03.05.2006 Registered at the Ministry of Justice of Ukraine No845/12719 of 17.07.2006.
9. DBN V.2.5–74: 2013 "Water supply, external networks and structures".
10. DBN V.2.5–64: 2012 "Internal water supply and sewerage".
11. Resolution "Legal regime of sanitary protection zones of water bodies". Approved Resolution of the Cabinet of Ministers of Ukraine No2024 of 18.12.1998.

In Ukraine, the National Program "Drinking Water of Ukraine" for 2006–2020 was approved by Law of Ukraine No2455-IV on March 3, 2005.

The purpose of the Program is to improve the Ukrainian population provision with drinking water of standardized quality within the limits of scientifically substantiated standards of drinking water supply; reforming and developing the water supply and sewerage network, increasing the efficiency and reliability of its operation; improvement of the population health and the social and ecological situation in Ukraine; restoration, protection and rational use of drinking water supply sources.

As it can be seen from the materials presented in the section, water as a component of the environment plays an important role for the health of both an individual and the population of the state; providing for good sanitary living conditions in populated cities.

Future doctors should do everything necessary in their practice to ensure that water as a source of water supply always fulfills its main hygienic value, namely — it should not be the cause of morbidity.

17 CHAPTER

HYGIENE OF HEALTH CARE FACILITIES. FEATURES OF PLANNING, IMPROVEMENT AND EQUIPMENT OF MEDICAL FACILITIES

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17.1. The importance of hospital hygiene knowledge for a doctor of curative specialty

The term Health care facilities (HCF) refers to a large group of medical institutions that provide professional and specialized medical care to the population. In this section, a hospital is considered as an institution for inpatient treatment.

A hospital is a main HCF of health care service. It performs the following functions: diagnosis, treatment, rehabilitation, prevention, sanitary education, training of doctors and nursing personnel.

Currently, the main types of HCF are:

1. *Multi-field hospitals* — regional, central city, city, district, children's regional, emergency care, etc.
2. *Specialized hospitals* — infectious, psychiatric, tuberculosis, rehabilitation treatment, ophthalmology, narcology, etc.
3. *Hospitals at dispensaries* — oncologic, psychoneurological, antituberculosis, endocrinological, etc.

The need to combine providing of highly qualified specialized assistance with the development of scientific issues has promoted the creation of specialized medical centers (cardiological, oncological, etc.), an integral part of which is a clinical inpatient facility.

For hundreds of patients, a hospital is a temporary residence with a canteen, a bath and a laundry. In point of fact, it is a residential unit in which a certain population segment, first of all patients, i.e. people with decreased functions of organs and systems, must voluntarily or under necessity stay for a certain period of time (2–4 weeks or more), i.e. receive medical treatment. A sick person noticeably differs from a healthy one. A patient is usually a person with movement difficulty, inhibited functions, disrupted oxidation-reduction processes, and severe hypoxia, who needs constant supervision. Patient is consequently a person who sometimes needs isolation from the impact of environmental factors and, conversely, needs sequestration to protect the environment and healthy people from infection.

In addition to medical care, a patient needs careful nursing, well-illuminated and well-ventilated ward, comfortable bed, quiet atmosphere, adequate dietary nutrition, regular body washing, rational day regimen, walking on fresh air in green areas, conditions for healthy sleep.

It is no coincidence that the prominent Russian therapeutist V. A. Manassein believed that therapy starts with patient hygiene, and that therapy is weak without appropriate hygienic conditions for a patient. It follows, that hospital hygiene is one of the important factors of treatment effect for a patient.

A hospital at the same time is a public building for a professional activity of doctors, medium-grade and junior medical personnel, sanitary-education work, study of students of medical educational institutions, research practice on the evaluation and implementation of the latest treatment methods.

A hospital can be more dangerous than other public facilities in terms of the spread of infectious diseases, especially in the case of infectious diseases hospitals, tuberculosis and dermatovenerologic dispensaries, as well as hospital-acquired (nosocomial) infections. This requires solving hugely complex problems of hospital sewerage system, treatment and disinfection of waste waters, solving the issues of solid waste clearing, especially regarding specific waste generated in surgical theatres, delivery wards, dressing and procedure rooms.

A hospital is consequently a multidisciplinary object, in the conditions of which the doctor-hygienist has to comprehensively address issues of municipal, social, nutrition and occupational hygiene, epidemiology.

A hospital employs medium-grade personnel and doctors, and their health can be adversely affected by various factors.

Hygienic requirements to a hospital follow from its hygienic value. Namely, a hospital should:

1. Provide optimal living conditions for a patient depending on the type of disease — a sufficient ward area, optimal microclimate parameters, adequate ventilation and insolation, proper natural and artificial lighting, etc.
2. Provide a set of medical-preventive activities and contribute to compliance with the treatment-and-protective regime.
3. Ensure prevention of the occurrence and spread of NCI (nosocomial infection) and other diseases during inpatient stay in hospital or during a visit to the out-patient clinic.
4. Become a school of hygienic education and habit formation. Patients are especially susceptible to hygienic education and healthy lifestyle promotion.
5. Support the principle of scientific management of work and compliance with conditions of work for medical personnel.
6. Become a school for medical personnel training. The appropriate hospital-based conditions should be created for this purpose.
7. Not be a source of environmental pollution.
8. Meet up-to-date requirements of urban construction and general architectural concepts of the city or microdistrict.

Based on the above, the factors that determine compliance with a hygienic regime in a hospital can be grouped as follows:

1. Placement of a hospital in the best natural and environmentally safe conditions of the settlement, which ensure protection of patients from noise, vibration, electromagnetic radiation, air pollution, and promote the creation of a favorable microclimate with optimal insolation, etc.
2. The other aspect is the scientific development and implementation of measures for the NCI prevention.
3. Protection from pollution generated at the hospital site and from psychological discomfort.
4. Provision of sanitation facilities for hospitals (water supply, sewerage, heating, ventilation, lighting).
5. Occupational hygiene of medical personnel (creation of safe working conditions, observance of the work-rest regimen and personal hygiene rules).

When actively considering each of these hygienic aspects, it can be concluded that they are important for creating an optimal treatment-and-protective regime in the hospital and for the NCI prevention.

The process of creating optimal hygienic conditions in medical and preventive treatment facilities is largely determined by the peculiarities of land planning and development, interior layouts of buildings, sanitary engineering improvement, as well as sanitary state while in service.

17.2. Hygienic requirements for the land plot allocated for the hospital construction

1. The land allotted for the construction of a hospital at least should not be worse than the residential construction lots, or even better. There must be clean air and soil. It is forbidden to build medical facilities on sites that were once used for landfill deposits, sewage disposal fields, cemeteries, etc., as well as on those with soil contaminated by organic, chemical and other substances.
2. The conformation of the land area should ensure the optimal location of hospital complexes taking into account the hygienic, medical and technical aspects. A rectangular area with an aspect ratio of 1:2–2:3 is considered to be the best.
3. The land area for development must be sufficient. The criteria for determining the area of the land plot are the profile and size of a hospital, and building construction system.
4. The land plot should have a convenient communications with service area.
5. The land plot should be properly insolated, dry, rich in vegetation, located on an elevated area with a natural slope of 1–6° for free movement of patients, ensuring runoff of precipitation, connection of underground utility systems, adaptation of access roads.
6. Areas of hospitals and maternity hospitals should be distant from railways, airports, urban freeways and other intense sources of noise, vibration, EMFs and industrial emissions. On the territory of the site adjacent to the treatment blocks, the noise equivalent level from 7.00 a.m. to 11.00 p.m. (or 23:00) should not exceed 45 dBA, and from 11.00 p.m. to 7.00 a.m. — 35 dBA.
7. The groundwater level must be at least 1.5 m from the ground.

8. The hospital site should be located on the windward side relative to the industrial zone, sources of environmental pollution.
9. The territory of the hospital site, maternity hospital or other inpatient facility should be landscaped. The green area and grass-plots should be at least 60% of the total area of the site, and the garden and park area is calculated as per standard, i.e. 25 m^2 per hospital bed.

Around the perimeter, the hospital's land plot should have a strip of greenery at least 15 m wide consisting of two rows of high trees and shrubs.

An important medical-technological and hygienic requirement for the HCF land plot should be considered as ensuring the principle of functional zoning, i.e. the allocation of the following functional zones in the hospital site: treatment blocks zone for non-infectious patients, specialized departments zone (infectious, psychoneurological, obstetrics and gynecology, pediatrics, radiological, tuberculosis, etc.), out-patient clinic zone, garden and park zone, zone of morbid anatomy department with a morgue and the utility (household) zone.

A mandatory requirement for the functional zoning of the territory is the separate access way (at least three). Separate access ways to the treatment blocks zones, morbid anatomy department zone and utility zone are mandatory.

In modern hospital construction, there are such types of building systems for hospital complexes as decentralized (pavilion), centralized, mixed or centralized-block.

Decentralized system (Fig. 17.1). It is characterized by the location on the site of several, typically low-rise, buildings that are used for departments of one profile (therapeutic, surgical, etc.). The hospital can include several buildings of the same profile. Ancillary services are located in separate buildings. This system became widespread in the late 19th and early 20th centuries. Its positive aspects are the possibility of isolation of individual buildings, strict compliance with the sanitary and anti-epidemic regime, proximity to nature.

However, the main disadvantages of the pavilion system are: unsatisfactory communications of diagnostic-treatment and ancillary services, lack of certain conditions for their full use, prolonged time schedule for movement/communication between services, comparative distance of all services from each other, necessity of transportation of patients, food, bedclothes, medicines through the territory of the hospital complex.

Centralized system (Fig. 17.2). Under this system, almost all structural elements of a hospital are located in one high-rise building.

Advantages of the centralized system:

1. Efficient use of diagnostic and treatment equipment by all departments.
2. Possibility of mutual consultation of medical professionals of different fields.
3. Convenient internal communications between departments by means of a vertical lift; it is especially convenient under poor weather conditions.
4. Reducing the path of movement of patients, medical personnel, and food delivery.
5. Cost effectiveness. Due to the smaller site area and the non-duplication of facilities, functional units and utility systems, the construction and technical equipment costs are reduced.

However, this system also has significant disadvantages: loss of efficiency of measures for the NCI prevention, increasing the intrahospital noise level, underuse of the garden and park zone.

Mixed system (Fig. 17.3). Such a building system is characterized by a tendency to reduce the number of buildings to two or four and to centralize hospital diagnostic-treatment and ancillary services, and there is main building allocating for these services. The mixed system allows reducing the distance of patients transportation, to ensure a treatment-and-prophylactic regime and to use hospital equipment much more effectively. This system prevailed in the first half of the 20th century and was mainly used in construction of district hospitals.

Nowadays, a centralized block system is more often used, in which the hospital consists of several buildings (therapeutic, surgical, etc.), interconnected into one whole. In this case, the positive aspects of a centralized construction system are better used. Patients, mobile diagnostic and treatment equipment, etc. are transported on transport carts through underpass, overland pass or link buildings, which allow using the possibilities of a medical facility more effectively.

The main element of the architectural composition of the centralized block system is a main building, i.e. diagnostic and treatment building that is joined by in-patient building and out-patient clinic building. This design therefore provides both the centralization of medical processes and the use of equipment and the implementation of the isolation principle of certain hospital departments. The centralized-block system allows to unite functionally homogeneous departments and to create corresponding complexes (surgical, sterilization, radiodiagnostic, laboratory, etc.).



Fig. 17.1. General layout of the decentralized system of hospital construction: 1 — administrative building; 2 — out-patient clinic; 3 — therapeutic building; 4 — surgical building; 5 — dermatovenerologic building; 6 — phthisiological building; 7 — building for otolaryngology and ophthalmological departments; 8 — building for infectious disease department; 9 — pediatric building; 10 — maternity building; 11 — nutrition unit; 12–17 — maintenance building; 13 — pathological-morbid building; 19 — entrance point

In Western countries, due to the limited land area, centralized-block hospitals (Fig. 17.4) are often built in the form of buildings with several above-ground and 2–3 underground floors, which house the surgical unit, sterilization department, bomb-proof and gas-proof shelter, maintenance and ancillary services, etc. At the same time, technical and engineering capabilities for today allow to fully ensure air conditioning, rational heating and lighting and to create stable safe and healthy working conditions at all facilities.

Hospitals of all systems in equal measure operate in Ukraine. Considering that science and technology, including medicine, medical practice technology, and sanitary engineering, are constantly being improved, deepened, and scientifically developed, Ukrainian hospital buildings are constantly being rebuilt and added.

In front of the main entrance (or entrances) to hospital it is necessary to provide equipped areas for visitors calculated as 0.2 m^2 per bed, but not less than 50 m^2, as well as parking for vehicles of hospital employees and visitors at a distance not closer than 100 m from ward buildings.

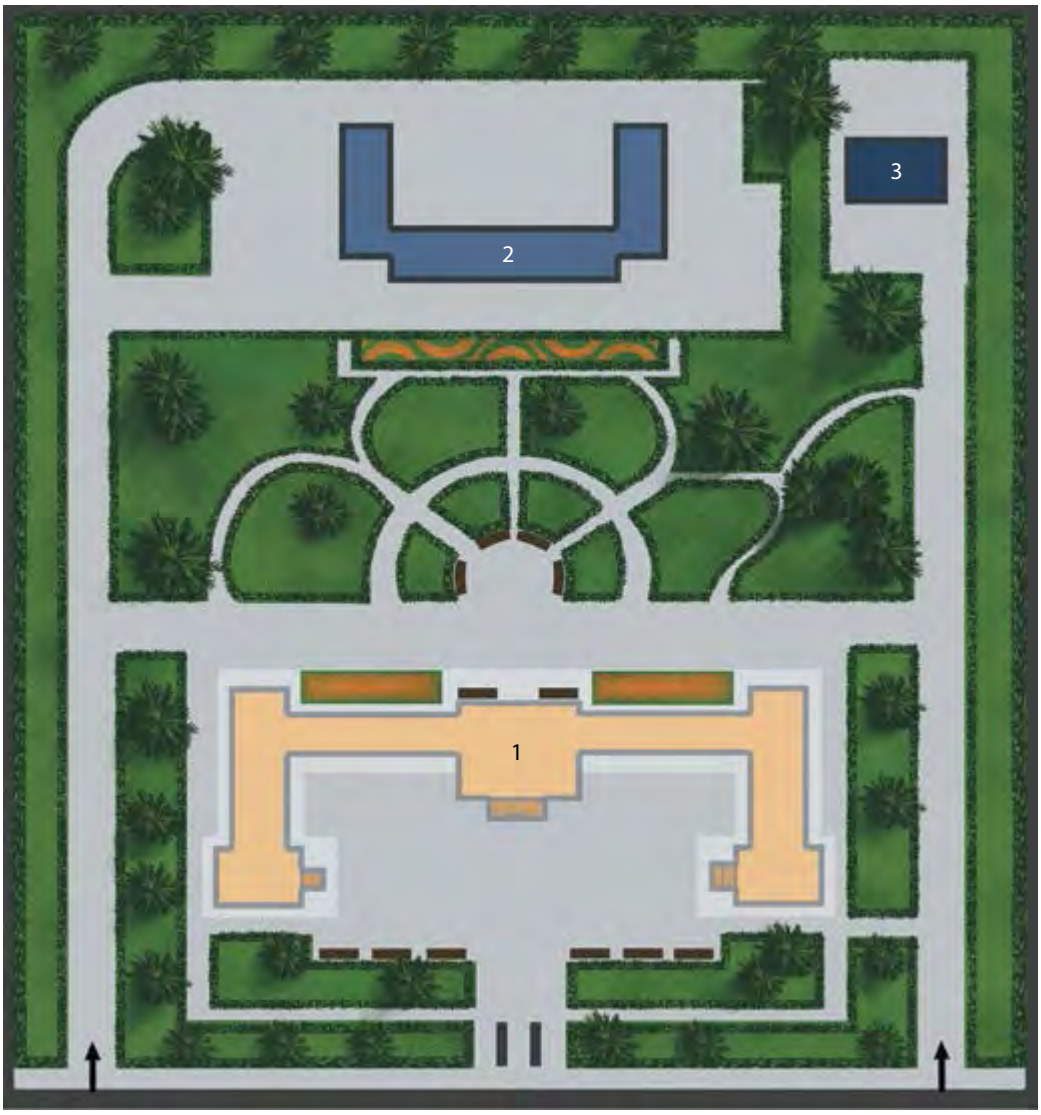


Fig. 17.2. General layout of the hospital with 400 bed: 1 — main building; 2 — maintenance building; 3 — pathological-morbid building

When conducting a hygienic assessment of the development of the hospital site, the following important objective criteria should be taken into account: land use ratio, which depends on the building system, profile and location, and ranges from 10 to 18 %; green area must be at least 60 %. The garden and park area is calculated on the basis of 25 m^2 per 1 bed. Green areas around the radiological buildings, buildings for infectious disease departments and along the X-ray departments are necessary to be 3 m wide for preventing patients from being near these buildings.

When building arrangement is carried out on the site, it is necessary to keep the following minimum distances between buildings: between the window walls of ward buildings — 2.5 height of the opposite building, but not less than 25 m; between ward buildings and pathological-morbid building — not less than 30 m; between the radiological building and other isolated objects — not less than 25 m.

17.3. Features of internal layout of the main hospital sections

Depending on the functional purpose, rooms can be conditionally formed into the following groups:

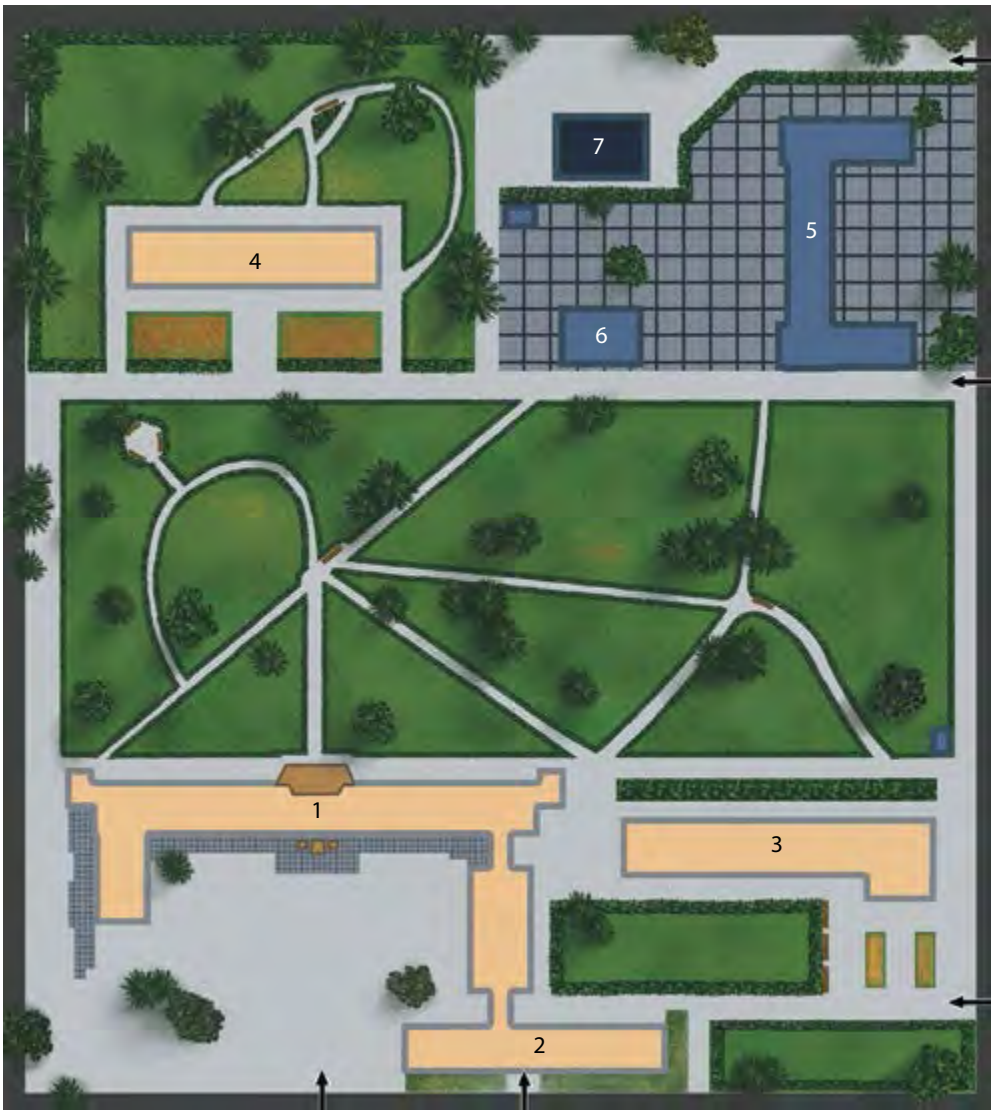


Fig. 17.3. Mixed system of a hospital complex construction: 1 — main building; 2 — out-patient clinic; 3 — obstetrics and gynecology building; 4 — building for infectious disease department; 5 — nutrition unit; 6 — maintenance building; 7 — pathological-morbid building

1. For admission and discharge of patients.
2. For permanent stay of patients (wards).
3. Diagnostic and treatment.
4. Service rooms for medical purposes.
5. Nutrition service.
6. Administrative (office) and utility rooms.
7. Rooms for services and facilities of engineering, sanitary, electrical, repair support.

The procedure of patient management begins with an **admission department**. It is a "mirror" of the hospital. A patient has the first impression of a hospital in this department, and it is of great importance for his/her psychological state of mind and the success of treatment. Therefore, patients should be treated with care, and the department should ensure work accuracy, perfect order, comfort.

The main functional tasks of this department are as follows:

- admission, registration and allocation of patients;
- determination of a provisional diagnosis;
- decision on inpatient or outpatient treatment;
- medical care;
- sanitary treatment of non-infectious patients;
- implementation of measures to prevent infectious disease dissemination;



Fig. 17.4. Hospital of centralized-block construction system

- transportation of patients when treatment in other medical institutions is needed;
- discharge of patients and issuance of medical clearance certificate (doctor's note).

Admission departments and discharge rooms should be separate for pediatric, obstetric, gynecology, dermatovenerologic, infectious, tuberculosis and psychiatric departments.

Admission rooms of other departments should be designed in combined form and located in the main building of the hospital or in the building with the largest number of beds, so that they have a convenient connection with the ward and diagnostic-treatment departments of the hospital.

Admission and discharge departments should be located on the first floor in an isolated section of the building and, if possible, near the main entrance to the hospital. A vehicle ramp with a shed for 1–2 cars should be provided for the access of ambulances to the department.

The operation of the admission department is connected with the entrance of ambulances, so it is not allowed to be located under the windows of the ward departments.

The main premises of the admission department are a patient examination room and a room for a sanitary-hygienic treatment of a patient. The exam room is designed for examination and survey of patients, and to establish a provisional diagnosis, and, if necessary, to provide medical care. The examination room should be arranged near the admission department. Preferably next to sanitary pass. The size of the exam room must ensure free passage of a wheeled bed/ambulance cart.

The sanitary pass is intended for hygienic treatment of patients who get into the in-patient department (wards); also, personnel receive patient personal items and issue hospital clothes to patients there.

In addition to these rooms, the admission department includes an entrance hall, record room, duty doc-

tor's room, toilet unit for personnel and patients, storage rooms for patients' clothes, wheelchairs/wheeled beds, and cleaning equipment, etc. The admission department should be designed to avoid cross-infection of patients. That is, the flows of patients who are admissioned and those who are discharged should not intersect.

Corridor planning calls for special attention. They can be of three types:

- with two-sided construction (central corridor);
- with one-sided construction (side corridor);
- with partial two-sided construction.

From a hygienic point of view, corridors with two-sided construction are the worst, because they have poor natural lighting and ventilation. They usually are quite dark and have "close" air. Adequate hygienic conditions are inherent to the side corridors, in which one side has sufficient quantities of windows. However, they are inconvenient in organizational terms. All rooms are stretched in one row, as a result of which the time schedules of both patients and hospital personnel are significantly extended. The best variant is the corridors with partial two-sided construction, which arrange the so-called light space break (hall), which can meant to be a room for patients' daytime stay. Nevertheless, when arranging such a corridor, it is necessary to adhere the ratio between the built-up part and the light corridor. The last of these spaces must be at least 40 % of the total length of the corridor.

Ward department is the main functional element of an in-patient facility. This department is intended for diagnosis of diseases, treatment, supervision over the patients and medical attendance. Most often, a ward department has 60 beds. In some cases, they are increased to 90–120 or reduced to 15–45 beds. In the case of more than 30 beds, the ward unit consists of ward sections, common premises and specialized rooms.

The *ward section* is the main architectural-planning and functional unit of the hospital. It is an isolated complex of wards and treatment-auxiliary rooms intended for patients with homogeneous diseases. The number of beds in the ward section should be not less than 20 and not more than 30. The standard ward section for adults is designed for 30 beds. In each ward section, there should be 60 % of wards with 4 beds and 20 % — each with 1 and 2 beds. The structure of a section with 30 beds: 6 wards per 4 beds, 2 wards per 2 beds, and 2 wards per one bed. In addition to the wards, the ward section includes the following treatment and auxiliary rooms: doctor's room, procedure room, daytime stay room, canteen with dining room, bathroom, and utility rooms.

The main task in the designing of ward sections is to ensure hygienic comfort and ease in provision of services. Therefore, the wards should have close-together arrangement. The service rooms should be separated. The nurse unit should be arranged in the center relative to the wards, and the sanitary facilities should be moved to the periphery of the section.

According to the architectural and planning decision, the ward sections can be walk-through or unpassable. The walk-through section is of course the worst option because there is much higher bacterial contamination and 4–5 dBA higher noise level.

A very important hygienic index of the ward section is the ratio of the auxiliary rooms area to the area of the wards. What ratio will be the best for the patient? Definitely higher ratio will be better — more auxiliary facilities will contribute to better service. Therefore, this ratio should be not less than 1. In old hospitals, the area of wards is up to 60 %, i.e. 0.6.

The paths of patients and medical personnel should be as short as possible and not intersect.

Sanitary legislation prohibits changing the internal layout of the premises of the department, placing beds in corridors or other rooms, as well as using the premises for other purposes.

Wards (Fig. 17.5). More than 90 % time of the patient's stay in a hospital falls on the ward and recreational facilities. Therefore, a hospital cannot have a more important room than a ward. For most patients it is a place for receiving visitors, a dining room, a library, a bathroom.

Hygienic requirements for its maintenance therefore should be high.

A ward should have enough space to provide adequate ventilation and furniture. According to normative documents: the minimum area of a ward per 1 bed without a personnel airlock must be at least 9 m^2, with a personnel airlock — 12 m^2, with a personnel airlock and a toilet — 14 m^2, with a personnel airlock, a toilet and a shower — 16 m^2, box and semi-box — 22 m^2. An extremely important hygienic index is the number of beds in the ward and their arrangement. Sanitary norms adopted the best option — 4 beds. This is confirmed by psychological research. Patients were asked in which wards they were better. The answers were following:

- 60 % of patients — wards with 4 beds;
- 15 % of patients — 2–3 beds;
- only 5 % of patients — 1 bed.

The minimum height of the ward should be not less than 3 m, depth — not more than 6 m, the minimum width of the ward per 1 bed — not less than 2.9 m, the

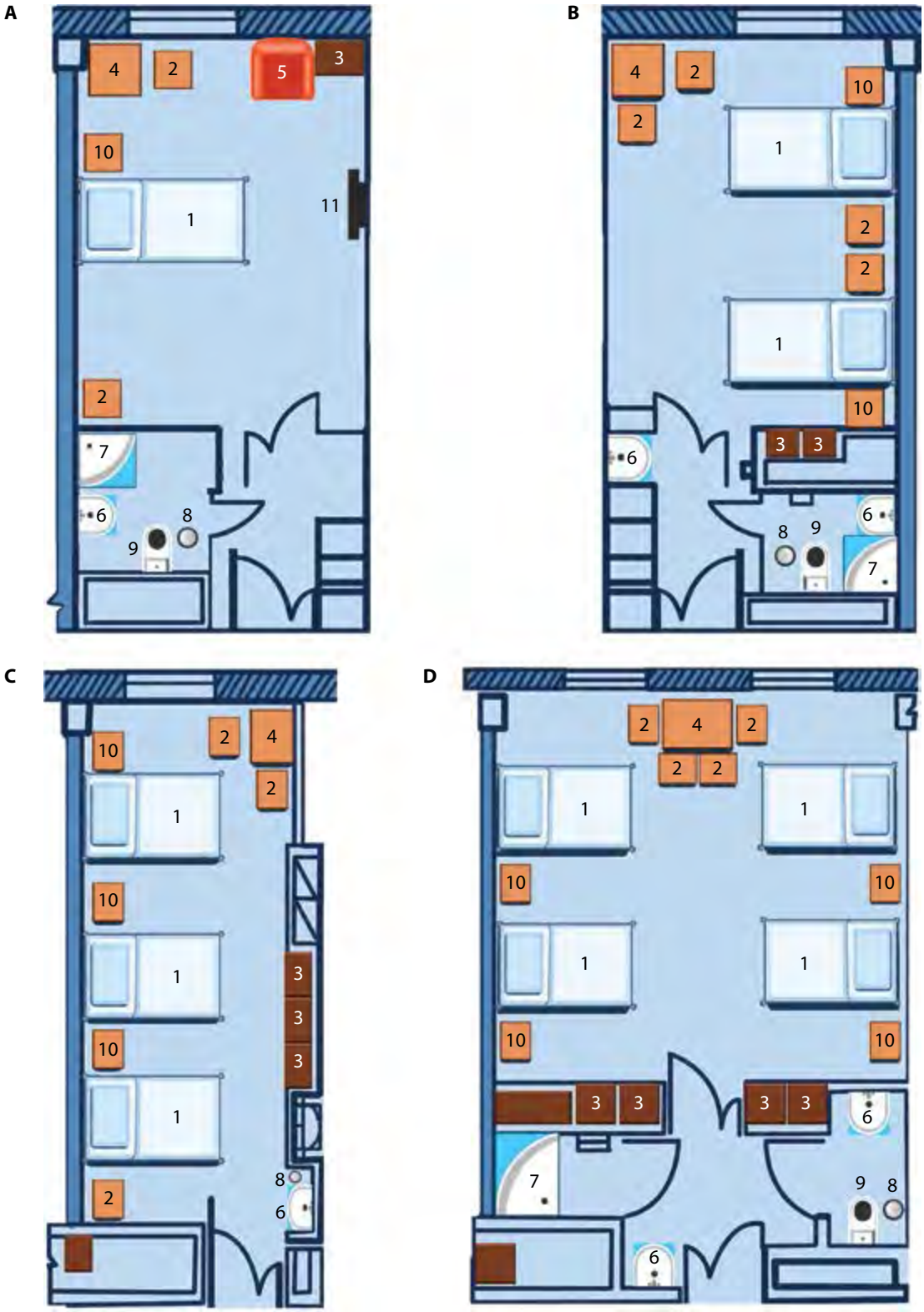


Fig. 17.5. Options for layout and equipment of hospital wards (A — 1 bed. B — 2 beds. C — 3 beds. D — 4 beds). 1 — bed; 2 — chair; 3 — wardrobe; 4 — table; 5 — armchair; 6 — wash-stand; 7 — shower; 8 — bucket; 9 — toilet; 10 — bed-side table; 11 — TV set

ratio of depth to width of the ward should be not more than 2. Otherwise, there will be unfavorable conditions for natural lighting and ventilation.

The color of the ward walls is of great hygienic importance. Until recently, there was a notion that everything in a hospital should be white. However, from the standpoint of basic hygiene and physiological perception, white is not the best color. A survey of patients showed that most of them prefer light green or light yellow. The visual analyzer better perceives a portion of the spectrum with a wavelength of 550–560 nm, and this wavelength is due to green and greenish tones. Others believe that it is optimal to paint the walls in warm colors. The ceiling is covered with lime or water-based paint.

The main hygienic factors that shape the living conditions of patients in the ward are microclimate, air quality, lighting and insolation, levels of hospital and street noise. Hygienic requirements for the microclimate and air quality of the wards will be discussed in detail in the next section.

The requirements to *infectious diseases departments* (Fig. 17.6). Given that infectious patients are admitted to the infectious department not only for treatment but also for isolation, the internal layout and sanitary conditions of this department have a number of features for NCI prevention. They begin with the admission of patients. Infectious patients, bypassing the central admission department, enter the admission and examination box of the infectious department. After thermometry and examination, patients undergo sanitary treatment, and their clothes are sent to the disinfection department. After patients leave the examination box, it is cleaned, ventilated, and disinfected with bactericidal lamps.

The infectious diseases department should have two entrances: one for patients, the other for personnel, food and clean clothes delivery, etc. The layout of the infectious department should include its division into several separate sections designed for admission of patients with various infections. Each section must have its own airlock as well as a sanitary facility. Another feature that distinguishes infectious diseases is that to improve the isolation of patients, wards include mainly one and two beds (maximum is 4).

For individual admission of patients, wards per 1 bed with a lock, semi-boxes and boxes are used. The semi-box consists of a ward, an airlock and a bathroom. The disadvantage is that patients come through the ward corridor. Individual full box guarantees the prevention from respiratory infection. It consists of an outside entrance airlock, a bathroom, a ward and an airlock.

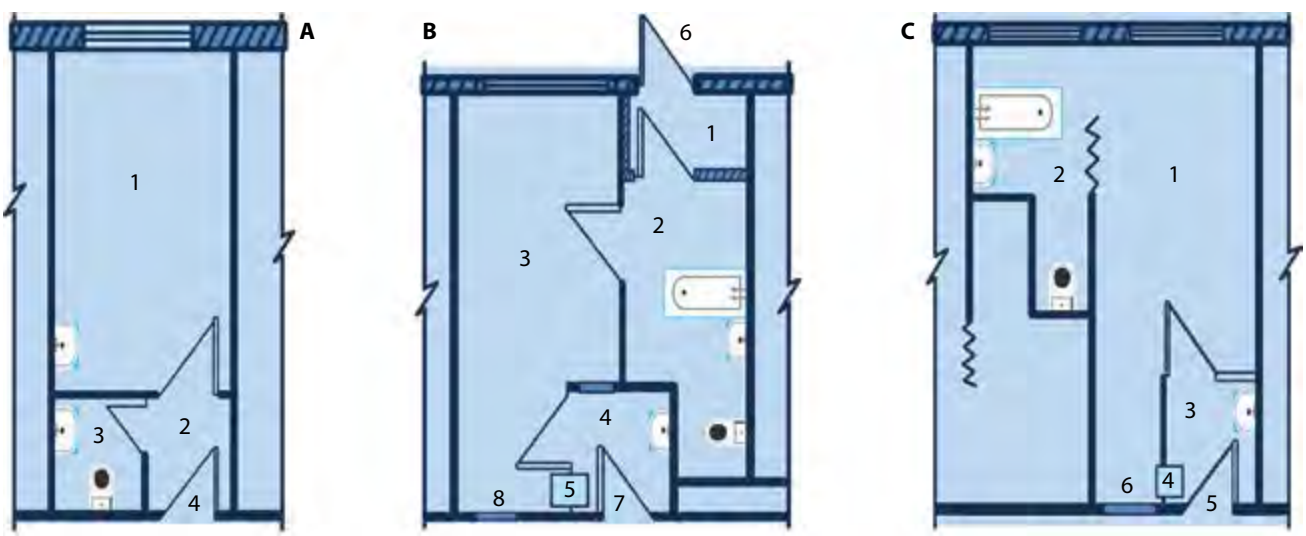


Fig. 17.6. Layout concepts for infectious diseases departments.

A — layout of a ward with an airlock: 1 — ward; 2 — airlock; 3 — sanitary unit; 4 — entrance from the department corridor.

B — layout of a box: 1 — outside entrance airlock; 2 — sanitary room; 3 — ward; 4 — department entrance airlock; 5 — window for food delivery; 6 — outside entrance; 7 — entrance from the department corridor; 8 — inspection window.

C — layout of a semi-box: 1 — ward; 2 — sanitary room; 3 — department entrance airlock; 4 — window for food delivery; 5 — department entrance; 6 — inspection window

17.4. Microclimate, air environment and lighting of hospital premises

Among the factors that determine the hygienic, sanitary and anti-epidemic regime of hospital facilities, the parameters of the microclimate and air environment are of great importance. This is, in particular, due to: limitation of motor activity of a patient, stay (sometimes a long stay) in rooms with low dynamic microclimate and air environment, violations of thermoregulatory and oxidation-reduction processes, as well as manifestations of hypoxia, the presence of airborne substances (volatile, organic, medicinal) and pathogenic microorganisms that create a specific background of the air environment of a closed hospital room, increased and sometimes distorted sensitivity/reactivity of a patient in response to external influences.

Therefore, ensuring comfortable microclimatic conditions in the hospital should be considered one of the priority tasks of medical personnel.

For patients of all ages, depending on the type, form and state of the disease, age, thermoregulatory system state, time of day and season, as well as some external circumstances, the range of optimal air temperature can be quite large: from 15 to 27 °C.

The optimal air temperature in the wards of cardiac inpatient department should be considered 21–24 °C, in the wards for pulmonology patients — 21–22 °C, in the wards of burn care facilities — 24–26 °C.

In winter, the temperature of the walls and the air near the outer walls can be 8–12 °C lower than the temperature of the indoor air, which should be taken into account when assessing the microclimate of the wards and the location of the beds.

Requirements for microclimate parameters are based on the purpose and operational characteristics of the premises and may have significant differences. Based on the fact that in the temperate climate belt the thermal comfort zone is within 20–23 °C, the following parameters are recommended:

- the difference in air temperature vertically should not exceed 2–3 °C, horizontally — 2 °C;
- the difference between the surface temperature of the inner walls and air — no more than 5 °C;
- air velocity — up to 0.15 m/s;
- relative humidity — 60 %.

The warm feeling of patients with different types of pathologies and the objective indicators of their thermal state can be very different from the above. Such differences are especially pronounced in the case of endocrine disorders, cardiac and pulmonary deficiency, burns and other diseases and conditions.

The creation of optimum parameters of temperature and humidity of hospital rooms is provided mainly by rational heating. Centralized systems (convection or radiation) with the possibility of regulation and shutdown are usually used for heating of buildings. Hot water should be used as the heat carrier in convection systems. The average surface temperature of heating devices should be 80 °C for wards departments, surgical units, etc.

The air exhaled by the patient plays an important role in the formation of the composition of the air environment of hospital rooms. It is established that the exhaled air is sometimes characterized by a very high (2–5 times higher than in healthy people) content of underoxidized organic substances. If in healthy people the oxidation of exhaled air does not exceed 16–20 mg/m^3, then in patients with pathology of the endocrine system (diabetes mellitus), cardiovascular, renal and other diseases it can reach 150 mg/m^3 and more. It was found that the air in the wards can be polluted by radon exhaled by patients after radionuclide myeloradiometry, and under certain conditions this can pose a sanitary danger.

Oxidation is a very important objective index of air pollution by organic substances and, along with the CO_2 content and the degree of bacterial contamination, it should be considered as a mandatory element of hygienic research of the air environment of wards, surgical units and other hospital rooms. For hygienic assessment of the level of air pollution of hospital wards with organic substances, the following approximate oxidation standards are recommended: clean air — up to 6 mg O_2/m^2, moderately polluted — from 6 to 10 mg O_2/m^2, polluted — more than 10 mg O_2/m^2.

The process of design and construction of healthcare facility should therefore provide appropriate sanitary and other devices that could create the necessary microclimate and composition of the air environment.

Hospital inpatient buildings must be equipped with mechanically driven supply and exhaust ventilation systems. Natural ventilation should also be provided by means of windows or devices in window frames, as well as ventilation ducts (not mechanically driven).

Rooms, medical and technological process in which is accompanied by the release of harmful substances into the air, if necessary, should be equipped with local exhaust fume hoods.

Rational natural and artificial lighting is no less important for the organization of the optimal hygienic regime in the rooms of the hospital.

Given the biological, psychophysiological, thermal and bactericidal effects of solar radiation, it is necessary to ensure sufficient insolation and the level of natural light in the wards. Irradiation with UV rays increases the immunobiological reactivity of the body, accelerates wound healing processes, and reduces the duration of the postoperative period.

Indicators that characterize lighting include: duration of continuous insolation, orientation of windows, LC, DF, lighting level. The orientation of the wards to the southern and eastern rhumbs is optimal. The duration of continuous insolation should be at least 3 hours a day from March 22 to September 22, LC 1:5–1:6, DF not less than 0.5 %.

In terms of natural lighting, all hospital rooms can be divided into three groups:

1. Rooms, where good insolation is required, but without overheating (wards, rooms for patients day stay, waiting rooms). For such rooms the south and south-east orientation is appropriate, and south-west orientation is allowable.
2. Rooms in which insolation is inappropriate:
   - due to the possibility of dazzling effect (surgical unit, dressing room, procedure room, laboratories);
   - due to the possibility of overheating (morgues, kitchens, food pantries).

North and northeast orientation is recommended for this group:

3. Rooms for insolation of which there are no specific requirements, but without overheating (administrative rooms, physiotherapy rooms, utility rooms, bathrooms, etc.).

Various functional and technological requirements apply to artificial lighting of hospital premises. As a source of artificial lighting, fluorescent lamps are becoming widespread. Such lamps are usually used for general lighting, but recently they are widely used for local lighting. Wall lamps should be provided next to each bed at a height of 1.7 m from the floor. All wards must be equipped with regular night lighting. Moreover, its switches must be installed outside the ward.

Standardized values of the minimum illumination of surfaces at the general illumination are different for different rooms. For example, doctor's rooms — 300–500 lux, wards — 100–150 lux, corridors — 150 lux, surgical units — 400 lux.

Hospitals provide night, standby, emergency and evacuation lighting of two systems: general and combined. Emergency lighting should be provided in the following rooms: surgical units, intensive care units, maternity departments, procedure rooms, admission departments, dressing rooms, treatment rooms, emergency rooms, time-urgent test laboratories, nursing units.

18 CHAPTER NOSOCOMIAL INFECTIONS, PREVENTIVE MEASURES. OCCUPATIONAL HYGIENE OF MEDICAL PERSONNEL

S. M. Tkachenko, A. M. Hrynzovskyi

18.1. The actuality of the nosocomial infection problem in modern health care facilities

The WHO Expert Committee (1981) set up the following definition: *nosocomial infection (NCI) is any clinically apparent microbial disease that affects a patient resulting from his/her admission or visit to a medical institution, or affects medical personnel during execution of the work regardless of whether there are any manifestations of the disease during the stay of such persons in the hospital.*

This definition has four important points for a doctor:

- firstly, it is a clinically apparent microbial disease, i.e. an infectious disease;
- secondly, the infection of a patient takes place in a specific place — health care facilities (HCF) — either during admission or visits to outpatient clinics for diagnosis or treatment;
- thirdly, the medical personnel infection can be associated with professional activities (occupational infection), i.e. during the provision of medical care to patients;
- fourthly, the symptoms onset of this infectious disease can be both during hospital stay and outside a hospital, because each infectious disease has a latent period. This is the period from the moment of infection, i.e. the microorganism entry into the human body, until the appearance of the first clinical manifestations (symptoms) of the disease. In specific disease cases, it can range from a few hours to several days (flu), weeks (hepatitis) and even months and years (AIDS).

At the present stage, it is necessary to pay attention to some more points of NCI formation:

1. Today, NCI are caused not by a single pathogen, but by the combination of nosocomial strains of microorganisms.

The formation of nosocomial strains occurs in each hospital or even department. This is facilitated by: the circulation of microorganisms among patients, i.e. persons with depressed body resistance and suppressed constitutive immunity; inefficient use of antibiotics, failure to follow antibioticograms, unreasonable prescription of broad-spectrum antibiotics, exceeding/step-down in dosage and failure in timing, violation of disinfection and sanitation, i.e. the use of improperly prepared desinfectants, violation of storage conditions, shelf-life, method of use. It should be noted that in modern hospital complexes, under the above stated conditions, there is a specific selection of microorganisms resulting in the formation of nosocomial strains. For example, it has been proven that different types of medical institutions are dominated by 1–2 (rarely up to 5) so-called nosocomial staphylococcal phagotypes.

2. The most common forms today are suppurative-septic. They occupy the first place in the structure of NCI. Their share reaches almost 85 %, and only 15 % are typical infections (salmonellosis, viral hepatitis type B, AIDS virus, etc.). Moreover, most suppurative-septic complications (almost 92 %) occur in surgical profile patients, i.e. in surgical departments and inpatient departments. The second place is occupied by maternity hospitals (almost 8 %).
3. Occurrence and spread of NCI takes place only in case of violation of sanitary and hygienic conditions regarding the maintenance, equipment and operation of the hospital premises, as well as sanitary-hygienic and anti-epidemic regimes of a hospital.

Today, the NCI incidence remains high. For example, the incidence of suppurative complications associated with surgery reaches 20 %.

According to WHO, 6–7 % of patients, who seek medical care in HCF, have NCI. Diseases such as viral hepatitis type B and AIDS are especially dangerous. NCI aggravate the postoperative course and therefore increase the duration of patients stay in a hospital by

15–18 days (according to domestic authors) or by 5–7 days (according to foreign scientists). Sometimes such infections negate the advantages of complex surgeries (heart, great vessels, kidneys, lungs, etc.), also complicate the postpartum period, lead to severe pathology in newborns.

The structure of NCI has quite essential features related to both the profile of the inpatient hospital department and the specific sanitary and anti-epidemic conditions of stay in it.

What exactly are the reasons for the growth of the NCI incidence rate?

1. Increasing the high risk cohort. WHO experts consider people with depressed body resistance for various reasons to be the most susceptible segments of the population. Namely: a) senior citizens; b) newborns, especially premature newborns and newborns with congenital abnormalities or birth injuries; c) patients with chronic somatic diseases at the stage of compensation and subcompensation.
2. Recently, the population has been experiencing suppression of constitutive immunity and allergies. This is due to the effects of adverse environmental factors, primarily chemical (chemical pollution) and physical (ionizing radiation, non-ionizing, noise, vibration, etc.). This health situation was discovered by scientists in the population of Ukraine in general and, in particular, in the regions affected by the Chornobyl accident.
3. There is a formation and spread of NCI strains, and their stable associations are formed.
4. Extremely complex medical and diagnostic methods have been introduced into medical practice. There was a time when a doctor during the diagnosis questioned a patient, performed examination, palpation, percussion, auscultation. Today, there are bronchoscopy, cystoscopy, colonoscopy, gastroduodenoscopy, etc. methods, i.e. intervention in the patient's body. This increases the risk of NCI.
5. Surgical interventions have become significantly complex, especially in cardiology, neurosurgery, transplantation. Medical care is provided to patients who were previously considered doomed (a large number of medical workers, long-term surgery).
6. When providing medical care in some cases of diseases (blood diseases, cancer) therapeutic agents that suppress the immune system are used.

Finally, the most important thing is that the spread of NCI is facilitated primarily by some self-complacency of medical personnel, weakening of attention to the sanitary and anti-epidemic regime. Reliance on antibiotics sometimes leads health care workers to fail to meet sanitary and anti-epidemic requirements, violating asepsis and antiseptics rules, noncompliance with disinfection and sterilization regimes. The uncontrolled prescription of antibiotics contributes to the emergence of highly virulent and very resistant microorganisms and the deterioration of the normal bacterial flora of the human body.

What infections are most often found in hospitals?

As already mentioned, in the first place in surgical hospitals, maternity hospitals are suppurative-septic infections. They are caused by combination of microorganisms, in particular Staphylococcus aureus or other opportunistic pathogenic bacteria. The ratio of different nosological forms in different surgical hospitals is more or less the same. Thus, it was found that in 33.3 % of cases there was an urinary tract infection, in 18.3 % — a wound infection, in 16.4 % — infectious complications of the respiratory tract, in 8.7 % — sepsis.

Second place — acute intestinal infections in children, especially in the first year of life (salmonellosis, escherichiasis).

Third — parenteral infections: hepatitis, AIDS.

Who can be the source of NCI pathogens?

1. Patients who visit a hospital.
2. Medical personnel (hands, hair, upper respiratory tract).
3. Visitors, students... (patients, carriers).

All these categories of people can become a source of NCI if they are either suffering from acute, slight or chronic infectious disease, or are carriers of various types of pathogenic and opportunistic microorganisms.

Transmission routes:

- airborne;
- contact and household;
- fecal-oral;
- artificial.

Prevention is carried out by organizing and carrying out a set of measures aimed at the source of the pathogen, the mechanism of its transmission and the susceptible organism.

The main areas of prevention of NCI in modern conditions include architectural and planning measures, sanitary and anti-epidemic regime and increasing the body resistance of patients and medical personnel to the effects of adverse factors.

18.2. Prevention of nosocomial infections

1. *Architectural and planning measures:*
   - optimal location of the land plot and building system, functional zoning of the hospital territory;
   - separation of functional and technological flows;
   - isolation of restricted access departments, wards and premises;
   - ensuring regulatory requirements for selection and sanitation of premises;
   - balanced mutual arrangement of the main departments of a hospital.
2. *Sanitary and anti-epidemic regime:*
   - ventilation, air conditioning;
   - providing an optimal microclimate;
   - regular air sanitation;
   - personal hygiene of personnel and patients;
   - medical control of the health state and infection of the personnel;
   - compliance with the requirements ensuring sanitary anti-epidemic regime in the hospital;
   - high-quality disinfection and sterilization of various items;
   - detection and isolation of infectious patients;
   - objective control of bacterial contamination of the environment and products.
3. *Increasing the body's resistance to adverse factors*:
   - balanced nutrition;
   - planned immunization;
   - emergency immunization.

18.3. Occupational health of medical personnel

Among the leading problems of HCF in recent years, the issues of occupational health of medical personnel are becoming increasingly important. The work of medical workers is combined with the possibility of negative impact of various specific occupational factors:

- high nervous and emotional stress associated with feelings of empathy, responsibility for the health and life of the patient;
- contact with infectious diseases, risk of infection and trauma during procedures, examinations, operations, stay in the environment where carriers and vectors of diseases live;
- unfavorable chemical and physical properties of environment in the workplace;
- forced body position, eyestrain, physical activity during most procedures and operations;
- violations of the physiologically optimal structure of the day, associated with work at night and off-duty hours.

Numerous studies show that in real conditions of professional activity of medical personnel, these hazards can reach values that are close to the values allowed by sanitary legislation or even exceed them. For example, in operating rooms, the air temperature can reach 28–30 °C and more, relative humidity — 85–90 %, creating conditions of pronounced thermal discomfort for a surgical team. Significant excess of permissible concentrations of medical drugs can be determined in treatment rooms, pharmacies. This situation causes a high level of morbidity among health professionals. The structure of this disease is dominated by coronary heart disease, hypertension, allergic and gynecological diseases, complications of pregnancy and the postoperative period, diseases of the musculoskeletal system, visual and hearing impairments, etc.

19

CHAPTER

CURRENT ISSUES OF OCCUPATIONAL HYGIENE

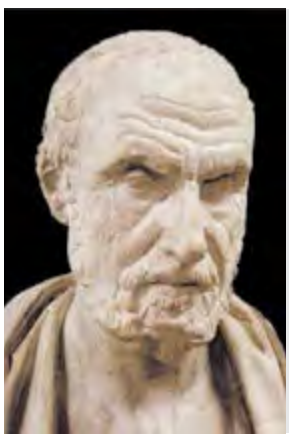
Ye. M. Anisimov, V. O. Korobchanskyi

19.1. Historical aspects of occupational hygiene development

The consequences of the adverse effects on workers in various types of work and recommendations for compliance with certain regimes in the performance of work operations are found in ancient documents.

Thus, the treatises written by a prominent ancient Greek physician, who is recognized as the "father of medicine", Hippocrates (460–377 BC) "On airs, waters and places", "On a healthy way of life", etc., contain considerations regarding human health and the environment.

Based on medical observations and generalizations, Hippocrates identified two main groups of factors that affect human health: general (climate, soil, water, etc.) and individual (lifestyle, nutrition, heredity and working conditions). Hippocrates described occupational pathology, compiled a list of existing so-called lead occupations at the time, and described the clinic of lead poisoning and the adverse effects of mine dust on miners.



"On Airs, Waters and Places"

"On a healthy way of life"

- A list of lead professions compiled.
- Lead poisoning clinic described.
- The adverse effect of ore dust on mining workers described

Hippocrates (460–377 BC)

During the Renaissance, Paracelsus dealt with occupational health. In 1530, a three-volume monograph by the eminent physician and chemist Paracelsus "On the mountain-consumption and -sickness" was published, in which he elaborated on working conditions and described the occupational diseases of miners due to effects of dust, sulfur, mercury vapor and other metals.

An attempt to systematize data on the effects of working conditions on the health of workers and to describe occupational diseases known at the time was first made by the Italian physician Bernardino Ramazzini (1633–1714). He published a number of works on hygiene and occupational pathology, and in 1700 — his main work "Diseases of Workers", which later brought him worldwide fame. The book describes the working conditions in all crafts and manufactories that existed at the time. The causes and course of diseases caused by the professional activities of workers, the impact of harmful substances used in the process of activity on the human body are presented. It should be noted that this date (1700) is considered the beginning of occupational hygiene as a new scientific and practical field of medicine.

Attention to the preventive aspects of public health in Russia has increased significantly during the period of state transformations carried out by Peter I and in the post-Petrine era. A great contribution to this area of public life was made by the founder of Russian science M. V. Lomonosov, who laid the foundations of occupational health in the mining industry in his treatise "The Fundamentals of Metallurgy, or Mining" (1763). In this work, he covered in detail the issues of hygiene and labor protection of miners, in particular, expressed his views on rational uniform, reliable fastening of workings and safe movement in them, removal of mine water, ventilation of mines.

Great influence on the development of occupational health as a scientific and practical discipline was made



"Handbook of Hygiene" (3 volumes)

"Public Hygiene"

"Occupational hygiene, or hygiene of mental and physical work"

"Materials on the survey of factories and plants of the Moscow province" (19 volumes)

F. F. Erismann (1842–1915)

by representatives of rural medicine, among whom the most famous is F. F. Erismann.

F. F. Erismann's activity in the field of hygiene had a wide scientific range. In addition to many experimental works, for the period from 1872 to 1874 he wrote a three-volume "Handbook of hygiene" and the book "Public hygiene". The manual "Occupational hygiene, or hygiene of mental and physical work", published by F. F. Erismann in 1877, was very popular.

In Ukraine, the first Department of Occupational Health and Occupational Diseases was organized in 1923 at the Kyiv Medical Institute. It was called the "Department of Professional Hygiene". It was headed by Professor Volodymyr Yakovlevych Pidhayetskyi.

V. Ya. Pidhayetskyi's scientific activity was aimed at studying the problems of occupational health in agriculture, at industrial enterprises in Kyiv and the mechanism of fatigue. He is the author of the first textbook in Ukraine "Occupational Hygiene" (K., 1929), the first curricula and work programs on occupational health, a course of lectures and methodological developments for practical classes in this discipline.

V. Ya. Pidhayetskyi summarized his research in the field of occupational hygiene in a number of thorough monographic works: "Factory Hygiene" (1923); "What is the scientific organization of labor" (1924); "Scientific organization of labor in agriculture" (1924); "Workforce Management in Agriculture" (1925); "Scientific Labor Organization and Workforce Management in Agriculture" (1930). Thanks to these and many other works, in which the doctrine of the scientific organization of labor in agriculture was comprehensively substantiated, the name of the Ukrainian scientist-hygienist entered the history of world science.

G. A. Shkavera, O. I. Cherkes, L. I. Medved and others played an important role in the formation of the Kyiv school of industrial toxicologists. Thus, in 1932, the Kyiv Institute of Occupational Hygiene and Occupational Diseases began research on the toxicology of pesticides used in agriculture.

The main areas of scientific activity of the department are: priority patterns of formation of working conditions, features of biological action of newly synthesized chemical compounds of different classes on the body of workers; dependence of toxicity, allergenicity, mutagenicity, embryo- and gonadotoxic properties of chemical compounds on quantum chemical, physicochemical characteristics and molecule structure; combined and complex action of ionizing radiation, salts of heavy metals and pesticides; industrial noise and vibration; quantitative characterization of summation, potentiating effects and assessment of the risk of their impact on the body of workers.

It should be noted that the introduction into the national economy of a large number of new chemical compounds requires a very important practical problem — the hygienic regulation of these substances, taking into account their combined and complex action with physical and other factors of the production environment. In this regard, hygienists have developed the concept of maximum allowable concentration (MAC) of harmful substances in the work area and methods of its establishment. Currently, the MAC has been approved for all chemicals widely used in industry and agriculture.



"Factory Hygiene" (1923)

"What is the scientific organization of labor" (1924)

"Scientific organization of labor in agriculture" (1924)

"Workforce Management in Agriculture" (1925)

"Scientific Labor Organization and Workforce Management in Agriculture" (1930)

Textbook "Occupational health" (1929)

V. Ya. Pidhayetskyi (1889–1937)

19.2. Occupational hygiene (definition of the concept), signs of occupational hygiene, subject of study and purpose of occupational hygiene

Work can be unprofessional if it aims to meet one's own needs — that of a housewife, a summer resident, a peasant. More often, work is professional, which aims to create such a production value, in exchange for which a person can meet all their own needs. That is, the profession arises where social production and the exchange of manufactured goods or products of labor appear. The higher the differentiation of social work, the more professions appear.

In addition, labor can be considered and characterized as a social and biological category. Work as a social category is a process in which a person through his conscious activity mediates, regulates and controls the metabolism between himself and nature, creates an additional value. Labor as a biological category is an important function of the organism, characterized by a certain physiological value.

Occupational hygiene (health) is a preventive discipline that studies the impact of work and production environment on the body of workers in order to develop on this basis a set of sanitary, hygienic, preventive and organizational measures aimed at creating healthy working conditions and increase productivity.

Occupational hygiene, like any other independent scientific discipline, has the following attributive features: the object of study; the subject of study; the aim of the study; objectives of the study; research methods.

The object of occupational health can be: a working person; teams of working people; the entire working population of the country and working conditions at production facilities.

The subject of the study of occupational health are working conditions, which include a set of production factors that are formed by specific socio-economic processes and affect the health of workers:

1. Labor processes and physiological reactions of the body of workers during their implementation (for the development of rational modes of work and rest).
2. Production processes and adverse (physical, chemical, biologically harmful and dangerous) factors of the production environment that arise during their implementation (for hygienic regulation and development of health measures).
3. The state of health and morbidity of workers who are exposed to harmful and dangerous factors in the conditions of production (to study the pathogenesis of occupational and industrial diseases and to develop prevention measures).

The aim of occupational health is:

- preserving and strengthening the health of working people;
- prevention of occupational and work-related diseases;
- increasing the efficiency and productivity of workers;
- prolongation of working life.

19.3. Objectives and methods of research of occupational hygiene

Objectives of occupational health:

1. Qualitative and quantitative assessment of working conditions (factors of the labor process and factors of the production environment). The study of their impact on the body of workers, including the study of occupational health, on the basis of which preventive measures are developed to obtain maximum productivity in the absence of harmful effects on health.
2. Scientific substantiation and development of hygienic standards of harmful physical, chemical and biological factors of the production environment (MAC, TS(E)L, MAL, etc.); recommendations on the rational organization of labor processes and workplaces, modes of work and rest; sanitary rules of arrangement and maintenance of industrial enterprises.
3. Evaluation of the effectiveness of scientifically sound hygienic standards and recommendations (through the assessment of individual and population health).
4. Hygienic assessment of new types of energy, the latest technologies and new adverse production factors.

Occupational health research methods

1. Physical and chemical.
2. Physiological.
3. Clinical-statistical and sanitary-statistical.
4. Experimental studies.

Physical and chemical methods are used to comprehensively assess the state of the production environment (determination of parameters of physical factors such as vibration, noise, ultrasound, meteorological factors, various types of radiation; determination of harmful

substances in the air in solid, gaseous, vapor and other states; study of the state of contamination of skin, overalls, footwear; assessment of the effectiveness of various sanitary devices).

Physiological methods allow us to judge the functional state of organs and systems of the body in the process of work and under the influence of factors of the production environment.

Clinical and sanitary-statistical methods are used mainly to study the health, general disease incidence and occupational morbidity of workers.

Experimental studies are conducted to determine the nature of the effects of a factor in the production environment or the labor process on animals and other biological objects using physical, physicochemical, biochemical, physiological, biophysical, toxicological, pathomorphological and other research methods.

It should be noted that the study of the pathogenesis of occupational diseases in order to develop methods of pathogenetic therapy and their prevention, as well as hygienic regulation of harmful factors in the production environment are carried out together with clinicians, pathomorphologists and other specialists. This increases the scientific level and practical significance of the obtained data.

Occupational health is divided into.

1. General occupational hygiene (main sections):
   - physiology and psychology of work;
   - factor occupational hygiene;
   - industrial toxicology;
   - sanitary chemistry, etc.
2. Special occupational hygiene.

General occupational hygiene (propaedeutics of occupational health) studies the general patterns of influence of factors of the labor process and production environment on the body of a working person, and on this basis, develops general principles for the prevention of their adverse effects. The main sections of general occupational hygiene: physiology and psychology of work, factor occupational hygiene, industrial toxicology, sanitary chemistry and others.

Special occupational hygiene studies the impact of working conditions and the labor process in specific areas of industrial and agricultural production (mining, metallurgy, engineering, textile, chemical, crop, livestock, etc.), and on this basis, develops specific preventive measures — technological, organizational, sanitary-biological, individual and others.

19.4. Factors of labor process (severity and intensity), ergonometric and physiological indicators of labor

Working conditions are a set of factors of the labor process and factors of the production environment in which human activity is carried out.

Factors of the labor process:

Work hardness — a characteristic of the labor process, which reflects the predominant load on the musculoskeletal system and functional systems of the body (cardiovascular, respiratory, etc.), providing its activities.

Work intensity — a characteristic of the labor process that reflects the load mainly on the central nervous system, senses, the emotional sphere of the employee.

According to the degree of intensity of physiological functions, the categories of hardness and intensity of work are determined: degree I — light, non-tense; degree II — moderately hard, moderately intense; degree III — hard, intense; degree IV — very hard, very intense.

The main principle underlying the classification of labor by indices of hardness and intensity is the principle of differentiation of working conditions depending on the actual levels of factors of the production environment and labor process compared with hygienic standards, as well as taking into account their possible harmful effects on health.

Ergonometric and physiological methods are used to assess the hardness and intensity of work.

Ergonomic indices of the work hardness: the weight of the load being lifted, labor power, the type of the working posture, the magnitude of the static load.

The magnitude of the static load is calculated by multiplying the amount of force by the holding time and is expressed in kg/sec.

The characteristics of the working posture and movement in space are based on observational data by measuring the angle of inclination of the torso, the length of the path of movement, timing, and so on.

Ergonometric indices of work intensity:

1. Number of objects of simultaneous observation.
2. Duration of concentrated observation or time of active actions (% of the total working day).
3. Density of signals (announcements) for 1 hour.

4. Emotional tension.
5. Variability.
6. The intensity of the functions of the analyzers.
7. Short-term memory (STM) capacity.
8. Intellectual tension.
9. Monotony and others.

The main indicators of the severity of work are the power and magnitude of static load, as well as intensity (density of muscular effort per unit time).

In determining the intensity of work, the main indicators are: indicators of attention, the density of signals of processed information, the characteristics of emotional tension, and other criteria are additional. It is necessary to determine to which category this or that work belongs according to one, the most informative basic indicator or two additional indicators.

Classification of severity and intensity of work according to physiological indicators, as well as physiological norms of stress of the organism are used to assess the work of certain groups of workers (by sex, age, state of health) taking into account their physiological features and characteristics. The scale for assessing the severity and intensity of work, developed by the State Institution "Kundiev Institute of Occupational Health of NAMS of Ukraine", provides for the determination of heart rate, energy consumption, endurance to static efforts, latent period of sensorimotor reactions, memory, attention and others. At the same time physiological indicators are determined at the beginning and at the end of the working day (Table 19.1).

19.5. Forms of work, features of the influence of factors of the production environment on the body of workers

It should be noted that among the various options for work are the following forms of work:

1. Forms that require significant muscle activity.
2. Mechanized forms of labor.
3. Semi-automated production.
4. Automated production.
5. Group forms of work (conveyor).
6. Forms related to remote control.
7. Forms of intellectual (mental) work.

Working capacity — a human condition in which a combination of physical, mental and emotional capabilities allows the employee to perform work of a certain content, volume and quality.

There are specific and nonspecific work capacity. Assessment of efficiency is carried out on production indices and on a functional condition.

Work capacity is non-stable index. It changes during the work shift and during the working week (Fig. 19.1).

In addition, during the performance of work the worker shows signs of fatigue and overfatigue.

Fatigue is a temporary decrease in efficiency in terms of quantity and quality of work performed, caused by intensive or prolonged work. Even such an indicator as the height of the work surface when performing different types and different accuracy of work, contributes to the development of fatigue and the formation of fatigue (Fig. 19.2).

Types of fatigue: primary (develops rapidly) and secondary (develops gradually).

Table 19.1. Estimation of intensity of physiological functions at physical work

The degree of tension	Average value	Medium frequency	Change of functions at the end of the working day (changes), %				
			reduction		increment		
			muscular endu-rance	*STM capacity*	*latent period of SVMR*	*latent period of CVMR*	*distinction time (concentration)*
I	Up to 174	Up to 80	Up to 10	Up to 5	No increase	Up to 5	Up to 5
II	175–290	81–95	11–30	6–25	1–25	6–30	6–25
III	291–406	96–110	31–50	26–50	26–50	31–60	26–50
IV	≥ 407	≥ 111	≥ 51	≥ 51	≥ 51	≥ 61	≥ 51

SVMR — a simple visual-motor reaction; **CVMR** — a complex visual-motor reaction

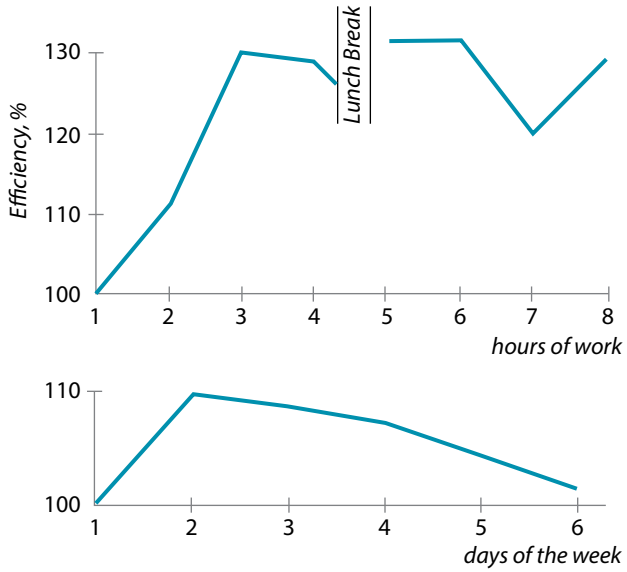


Fig. 19.1. Dynamics of working capacity during the working day and dynamics of the working week in terms of production indicators (M. I. Vynogradov)

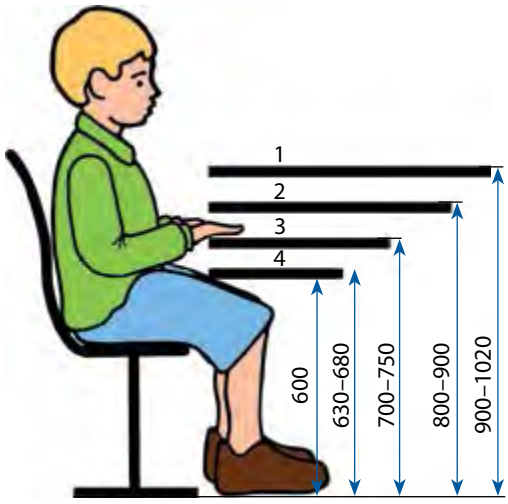


Fig. 19.2. Height of a working surface at performance of different types and various accuracy of work: 1 — very exact and thin works; 2 — exact works; 3 — design works; 4 — printing (S. I. Gorshkov)

Among theories of fatigue, as a rule, one considers the humoral-localist concept (Pflüger, Lindgard, Weinhardt) and central-nervous (I. M. Sechenov).

In order to assess the degree of fatigue in mental work on physiological indicators the following indicators are used: standard muscular effort (SME), short-term memory (STM), simple visual-motor reaction (SVMR), complex visual-motor reaction (CVMR), attention (A), critical flicker-fusion frequency (CFF). The gradation of these indices for different degrees of fatigue is given in Table 19.2.

Overfatigue is a pathological condition that is accompanied by a sharp decrease in labor productivity and requires treatment and rehabilitation measures.

These issues are considered by students in more detail in independent studies.

19.6. Measures to improve work capacity and prevent fatigue

Measures to improve efficiency in various forms of work:

1. Technological and sanitary-technical measures: mechanization and automation of production operations, application of technologies and technical means, which prevent the occurrence of harmful factors or reduce their levels to the permissible sanitary norms.

Table 19.2. Assessment of the degree of fatigue on physiological indicators in mental work (O.O. Navakatikyan et al., 1987)

Degree of fatigue	Change of functions at the end of the working day (changes),%					
	1	*2*	*3*	*4*	*5*	*6*
Minor fatigue (1)	Up to 5	Up to 5	Up to 3	Up to 3	Up to 5	Up to 2
Moderate fatigue (2)	6–20	6–20	4–15	4–15	6–20	3–8
Expressed fatigue (3)	21–35	21–35	16–30	16–30	21–40	9–15
Very pronounced fatigue (4)	≥ 36	≥ 36	≥ 31	≥ 31	≥ 41	≥ 16

1 — standard muscular effort; 2 — short-term memory; 3 — simple visual-motor reaction; 4 — complex visual-motor reaction; 5 — attention; 6 — critical flicker-fusion frequency

2. Ensuring hygienic, ergonomic and aesthetic levels of production equipment: compliance with the design of machines and mechanisms, workplace, control systems, safety devices, means of displaying information, as well as static efforts.
3. Organizational measures: introduction of scientifically substantiated rational modes of work and rest — intra-shift, daily (schedules), weekly, annual; application in work modes of alternation of works with different kinds and working conditions; measures to reduce monotony; use of functional music; introduction of industrial gymnastics; rational organization of breaks for rest during the working day and after work; active recreation.

Measures to improve performance and prevent fatigue during mental work (M. E. Vvedensky):

- gradual entry into work at a slow pace with a gradual increase in load;
- uniformity and rhythmicity in work, individual rhythm of work is possible;
- consistency and systematicity in the work, which ensures the formation of a working dynamic stereotype;
- correct alternation of periods of work and rest with the change of some forms of work, the use of regulated breaks after 3–4 hours of mental work, the use of functional music;
- increasing the social significance of the results of work, the formation of a positive emotional state in the employee.

20 CHAPTER HARMFUL AND DANGEROUS OCUPATIONAL FACTORS, PREVENTION OF THEIR INFLUENCE

E. M. Anisimov, V. O. Korobchanskyi

20.1. Hygienic classification of working conditions

The previous section discussed the concept of "working conditions". It will be useful to recall this definition.

Working conditions are a set of factors of the labor process and factors of the production environment in which human activity is carried out.

Hygienic classification of working conditions involves their division into the following classes:

Class 1: Optimal working conditions

conditions under which not only the health of workers is preserved, but also the preconditions are created for maintaining a high level of efficiency.

It should be noted that the optimal hygienic standards of production factors are set for the microclimate and some indices of the severity of the labor process (exercise, weight). For other factors, working conditions are considered optimal, in which unfavorable factors of the production environment do not exceed the levels accepted as safe for the population.

Class 2: Allowable working conditions

are characterized by such levels of factors of the production environment and labor process, which do not exceed the established hygienic standards, and possible changes in the functional state of the body are restored during the regulated rest or before the next change and do not adversely affect the health of workers and their offspring in the near and distant future.

Observance of hygienic standards under acceptable working conditions does not exclude health disorders in people with hypersensitivity.

Class 3: Harmful working conditions

are characterized by levels of harmful production factors that exceed hygienic standards and can adversely affect the body of the worker and/or his offspring.

Harmful working conditions according to the degree of exceeding hygienic standards and the severity of possible changes in the body of workers are divided into 4 degrees:

1st degree (3.1) — working conditions are characterized by such levels of harmful factors of the production environment and labor process, which usually cause functional changes that go beyond physiological fluctuations (the latter are restored with a longer break in contact with harmful factors than the beginning of the next shift) and increase the risk of deteriorating health;

2nd degree (3.2) — working conditions are characterized by such levels of harmful factors of the production environment and labor process, which can cause persistent functional disorders, in most cases lead to an increase in production-related morbidity, the appearance of certain signs or mild forms of occupational pathology (usually without loss of professional capacity for work) that occur after prolonged exposure (10 years or more);

3rd degree (3.3) — working conditions are characterized by such levels of harmful factors of the production environment and labor process, which lead, in addition to the growth of occupational diseases, to the development of occupational diseases, usually mild and moderate (with loss of ability to work during employment);

4th degree (3.4) — working conditions are characterized by such levels of harmful factors of the production environment and labor process, which can lead to a significant increase in chronic pathology and morbidity with temporary disability, as well as the development of severe occupational diseases (loss of general ability to work).

Class 4: Dangerous (extreme) working conditions

arecharacterized by such levels of harmful production factors of the production environment, the impact of which during the work shift (or part of it) poses a threat to life, a high risk of severe forms of acute occupational injuries.

This section is devoted to the factors of the production environment as an integral part that determines working conditions. In addition, here it is necessary to clearly distinguish which production factors are harmful and which are dangerous. Make a definition of "harmful factor of production".

20.2. Factors of the production environment

Harmful factor of production — environmental factor and labor process, the impact of which on the worker under certain conditions (intensity, duration, etc.) can cause occupational disease, temporary or permanent disability, increase the incidence of somatic and infectious diseases, lead to impaired health of offspring.

An example of a harmful production factor may be the effect of the heating microclimate on the body of the worker, which can cause acute or chronic overheating of the body.

In addition, there is the concept of "Dangerous factor of production".

Dangerous factor of production — factor of the working environment and labor process, which can cause acute illness, sudden sharp deterioration in health or death.

Examples of hazardous production factors include working at heights that are dangerous to fall and working with toxic substances.

Depending on the quantitative characteristics of the levels and duration of action, some harmful production factors can become dangerous (for example, heavy metals — lead and mercury).

20.3. Classification of harmful and dangerous production factors

Harmful and dangerous factors of the production environment by the nature of the impact on the body of a working person are divided into 4 groups:

1. Physical.
2. Chemical.
3. Biological.
4. Psychophysiological.

Let us consider what harmful and dangerous factors belong to these groups. Thus, the group of physically harmful and dangerous production factors includes 29 names: moving machines and mechanisms; moving parts of production equipment; products, blanks and moving materials; collapsing structures; rocks that collapse; increased dust and air pollution of the working area; increased or decreased temperature of surfaces of equipment, materials; increased or decreased air temperature of the working area; increased noise in the workplace; increased vibration level; increased level of infrasonic oscillations; increased level of ultrasound; increased or decreased barometric pressure in the working area and its abrupt change; increased or decreased humidity; increased or decreased air mobility; increased or decreased ionization of air; increased level of ionizing radiation in the working area; increased voltage levels in the electrical circuit, the short circuit of which can occur through the human body; increased level of static electricity; increased level of electromagnetic radiation; increased electric field strength; absence or lack of natural light; insufficient lighting of the working area; increased brightness of light; reduced contrast; direct and reflected brilliance; increased pulsation of light flux; increased levels of ultraviolet radiation; increased levels of infrared radiation; sharp edges, burrs and roughness on the surfaces of workpieces, tools and equipment; location of the workplace at a significant height relative to the ground, floor; weightlessness.

Chemical factors — substances of chemical origin, some substances of biological nature, obtained by chemical synthesis and/or for the control of which methods of chemical analysis are used.

According to the nature of the impact on the human body, chemical factors are divided into: toxic, irritating, sensitizing, carcinogenic, mutagenic and those that affect reproductive function.

By entering the human body, chemical factors are divided into substances that enter through the respiratory system, through the gastrointestinal tract, through the skin and mucous membranes.

Biological dangerous and harmful production factors: pathogenic microorganisms: bacteria, viruses, rickettsia, spirochetes, fungi, protozoa and products of their activity.

Psychophysiological dangerous and harmful production factors:

1. Physical overload: static, dynamic.
2. Neuropsychiatric overload: mental strain, overload of analyzers, monotony of work.

Classification of chemicals by hazard classes takes into account the following indices (Table 20.1).

20.4. Main types of effects of factors of the production environment on the human body

Depending on the specific conditions, the factors of the production environment can have different types of action on the human body (Fig. 20.1).

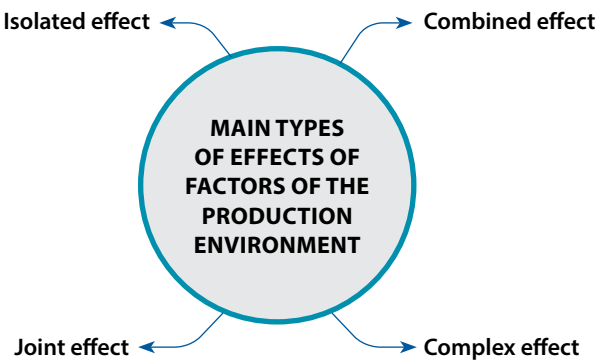


Fig. 20.1. The main types of effects of factors of the production environment

The main types of such effects can be: isolated, combined, complex and combined actions.

Isolated effect characterizes the impact on the human body of any one factor of the production environment. In real conditions, the influence of the production environment occurs in forms that are more complex. Namely — in the form of combined, joined and complex effect.

Combined effect is the action of several chemical (or biological) substances (combinations) that simultaneously enter the human body from any one object of the production environment (air, water, soil).

Complex effect is manifested when any-either one chemical substance enters the human body from different objects of the environment at the same time.

Joint effect is observed at simultaneous influence on a human body of physical, chemical and biological factors of a production environment (ie factors of the different nature).

Thus, characterizing the production environment in terms of its impact on health, it should be emphasized that the environment that surrounds a person can have both favorable and adverse (pathogenic) effects. From this point of view, a comprehensive program of primary prevention of occupational diseases provides:

- on the one hand, eliminating or reducing of the impact of hazardous and harmful factors of the production environment through their hygienic regulation;
- on the other hand, in practice environmental factors (primarily environmental factors) are widely used for preventive and health purposes.

Table 20.1. Classification of chemicals by hazard classes

Level of fatigue	Value according to hazard classes			
	1	*2*	*3*	*4*
MAC of hazardous compounds in air of the working area, mg/m^3	< 0.1	0.1–1	1.1–10	> 10
Medium lethal dose under oral intake, mg/kg	< 15	15–150	151–5000	> 5000
Medium lethal dose under percutaneous intake, mg/kg	< 100	100 –500	501–2500	> 2500
Medium lethal concentration in air, mg/m^3	< 500	500–5000	5001–50 000	> 50 000
Zone of acute effect	< 6	6 –18	18.1–54	> 54
Zone of chronic effect	>10	10–5	4.9–2.5	< 2.5
Coefficient of possible inhalation poisoning	> 300	300–30	29–3	< 3

20.5. The concept of occupational morbidity and production-induced morbidity. List of occupational diseases

Thus, poisoning can occur due to the influence of harmful and dangerous production factors. There are the following types of such poisonings.

Occupational intoxication (poisoning) is a separate type of occupational diseases that have arisen under the influence of harmful chemicals on the body.

Acute occupational poisoning occurs immediately after a single exposure or a short period of time after contact with a toxic substance (hydrocyanic acid, carbon monoxide, chlorine, etc.).

Chronic occupational poisoning is a disease that develops slowly after systematic long-term exposure to low concentrations of chemicals (lead, manganese, mercury vapor).

Occupational disease is a disease in the emergence of which the decisive role belongs to the influence of adverse factors of the production environment and labor process.

Indices used for statistical reporting and analysis are occupational morbidity and production-induced morbidity.

Occupational morbidity is an indicator of the number of patients diagnosed for the first time during the year with occupational diseases or poisonings, calculated per 100, 1000, 10.000, 100.000 workers who are exposed to harmful production factors.

Production-induced morbidity is the incidence (standardized by age) of common (not classified as occupational) diseases of various etiologies (mostly non-polyetiological), which tends to increase with increasing length of service in adverse working conditions and exceeds that in occupational groups which do not come into contact with harmful factors.

The list of occupational diseases includes **7 groups.** Let's look at these groups.

1. ***Diseases arising under the influence of chemical factors (27 codes for ICD-10):***
   - acute, chronic intoxications and their consequences, the course of which is characterized by isolated or combined damage to organs and systems (18 disease codes according to ICD-10);
   - skin diseases (epidermatosis, contact dermatitis, toxicoderma, photodermatitis, onychia, paronychia, toxic melanoderma, lubricating folliculitis, vitiligo);
   - metal, fluoroplastic (Teflon) fever.
2. ***Diseases caused by exposure to industrial aerosols (8 codes for ICD-10):*** pneumoconiosis, coniotuberculosis, bisinosis, chronic bronchitis, emphysema-bronchitis, emphysema, chronic rhinopharyngitis and laryngitis.
3. ***Diseases caused by physical factors (13 codes for ICD 10).*** Diseases due to the action of ionizing and non-ionizing radiation, vibration disease, sensorineural hearing loss, upper limbs vegetative-sensory polyneuropathy, electroophthalmia, cataracts, decompression sickness and its consequences, acute and chronic overheating, obstetrics.
4. ***Diseases associated with physical overload and overexertion of organs and systems (8 names, 18 disease codes according to ICD-10):*** writer's cramp, diseases of the peripheral nervous and musculoskeletal systems and connective tissue, omission of internal organs, varicose veins on the legs.
5. ***Diseases caused by biological factors (12 codes for ICD-10):*** infectious diseases and parasitosis, mycosis, dysbacteriosis, visceral candidiasis.
6. ***Allergic diseases (10 codes for ICD-10):*** conjunctivitis, rhinopharyngitis and laryngitis, rhinosinusitis, asthmatic bronchitis, bronchial asthma.
7. ***Malignant neoplasms (occupational cancer) — 9 names, 10 codes for ICD-10:*** tumors of the skin, mouth, respiratory organs, liver, stomach, bladder, bones, mesothelioma, leukemia.

The state of health of the occupational group is assessed by the following indicators: frequency, severity and duration of occupational diseases; production frequency due to general morbidity; morbidity with temporary disability (TD); mortality; disability; biological age of the worker (Table 20.2).

20.6. Prevention of occupational diseases

The Law of Ukraine "On labor protection" contains the basic principles of state policy in the field of labor protection:

- priority of life and health of employees in relation to the results of production activities of the enterprise;
- full responsibility of the employer for creating appropriate, safe and healthy working conditions;
- increasing the level of industrial safety by ensuring continuous technical control over the state of production, technology and products;

Table 20.2. Scale of assessment of indicators of sickness with hourly second rate

Morbidity level	Temporary disability per 100 workers	
	In cases	*In days*
Very high	150 and more	1500 and more
High	120–149	1200–1499
Higher than average	100–119	1000–1199
Average	80–99	800–999
Lower than average	60–79	600–799
Low	50–59	500–599
Very low	Less than 50	Less than 500

- obligatory social protection of workers, full compensation of victims of accidents at work and occupational diseases;
- use of economic methods of labor protection management;
- comprehensive solution of labor protection problems on the basis of national, sectoral, regional programs on this issue and taking into account other areas of economic and social policy, achievements in science and technology and environmental protection;
- introduction of uniform standards on labor protection for all enterprises and business entities, regardless of ownership and type of activity;
- informing the population, conducting training, professional training and advanced training of workers on occupational safety;
- cooperation and consultations between employers and employees (their representatives), between all social groups when making decisions on labor protection;
- international cooperation in the field of labor protection, use of world experience of work organization to improve working conditions and increase labor safety.

20.7. Priority objectives of national and world occupational medicine

The main priorities of occupational medicine:

- development of technologies that prevent the impact of adverse factors of the production environment on the health of workers;
- search for optimal models of organization of medical care for employees, especially in conditions of increased risk;
- radical improvement of the system of detection and registration of occupational diseases, creation of the National Register of Persons with Occupational Diseases;
- development of the concept of assessment of occupational risks and their management for the health of workers, improvement on this basis of the hygienic classification of work;
- introduction of existing and development of new information technologies for specialists in occupational medicine, improvement of the training system for employers and workers.

The main functions of WHO (in the field of occupational health) set out in Article 2 of its Charter include the promotion of better working conditions and other hygienic conditions of the environment. Recognizing that occupational health is closely linked to public health and the development of health systems, WHO is addressing all determinants of the health of working people, including the risks of disease and injury in the workplace, social and individual factors, as well as access to health services.

WHO implements the Global Plan of Action on Workers' Health, approved by the World Health Assembly, to achieve the following goals:

- development and implementation of occupational health policy instruments;
- protection and promotion of health in the workplace;
- increasing the efficiency of work and expanding the access to occupational health services;

- providing and disseminating factual data in the interests of action and practice;
- incorporating a health component into the policies of other sectors.

Priority areas and research programs in occupational medicine (NIOSH):

1. Diseases and injuries: allergic and contact dermatitis, asthma and chronic obstructive pulmonary disease, fertility and pregnancy abnormalities, hearing loss, infectious diseases, back disorders, musculoskeletal disorders of the upper extremities, traumatic injuries.
2. Production environment and labor force: new technologies, premises environment, mixed exposures, labor organization, high-risk groups.
3. Research methods and approaches: cancer research methods, control methods and personal protective equipment, exposure assessment methods, health services research, assessment of the effectiveness of measures, risk assessment methods, socio-economic consequences of occupational diseases and injuries.

21 CHAPTER

THE IMPORTANCE OF HYGIENE IN SOLVING PROBLEMS OF PROTECTION AND PROMOTION OF CHILD AND ADOLESCENT HEALTH

S. M. Tkachenko, I. V. Serheta

21.1. The importance of hygiene in solving problems of protection and promotion of child and adolescent health

At present, the issues of hygiene of children and adolescents is highly relevant, particularly given the trend of breakdown in health of child population due to the current socio-economic and environmental problems in Ukraine. Pediatric hygienists are particularly concerned about the conditions for schoolchildren in educational institutions, which are becoming increasingly severe with regard to the health of schoolchildren.

Studies indicate that the hygienic principles of the educational process are violated in modern educational institutions: the students load and maximum number per class/group are constantly increasing, this leads to a significant deterioration of microclimatic conditions and increased chemical and bacterial air contamination in classrooms. New pedagogical teaching technologies, programs and textbooks do not always have a hygienic assessment of their safety for the physical and mental health of schoolchildren.

As a result, only 33.7% of primary school children are healthy; 30.4% have chronic diseases, and the rest of children have functional disorders of different nature. On average, only 10% of school graduates in Ukraine can be considered healthy, 52.6% have morphofunctional disorders, and 36.0–40.0% of high school seniors suffer from chronic diseases. Only half of modern schoolchildren have harmonious physical growth and development. Only 18% of general educational institutions in Ukraine have medical stations that meet regulatory requirements; approximately 9% of schools are provided with school doctors.

A serious problem is *school-readiness of six-year-old children*, because 46.4% of first-graders are not functionally ready for regular schooling, and among seven-year-old children — 22.5% (according to the study).

Rational nutrition is an important condition for unimpaired health at all stages of a child's life. Due to inadequate nutrition, the incidence of gastric ulcer among schoolchildren aged 15–17 has increased by 41% since 1991, the incidence of the endocrine system diseases has increased 6 times, and the number of obese patients has increased by 73%. Inadequate nutrition in the early stages of growth and development often has an impact on all subsequent human life. The results of unhealthy nutrition are obesity, CVD, some types of tumors, etc. (Data from Austria: 12–22% of children aged 10–15 are overweight, 5–10% are obese, and 2% are extremely obese). According to the Ministry of Health, the survey of schoolchildren found that every third schoolchild does not eat fruit at all. At the same time, almost half of children aged 11–12 tried alcohol. Every fourth child under 11 smokes. Girls start smoking at the age of 14–15.

Another problem of modern children is *hypodynamia*. Motion activity, which is a leading factor in the growth and development of the child's organism, is not provided at the required physiological level.

That is, the deterioration of the health of school-age children and adolescents is based on aggregate socio-economic factors that exacerbate the effect of medical and biological risk factors. This defines the problem of preserving the health of the younger generation as a complex one. Consequently, the way to solve this problem is impossible without the active cooperation of the government, family and school. The role of hygiene of children and adolescents as a science and practice area is to identify common and specific to a particular educational institution negative environmental factors, control the health of schoolchildren, development and

implementation of preventive measures, assessing their effectiveness, and school administration assistance on the issues of rational organization of the teaching and educational process and hygienic education of schoolchildren.

Tasks of hygiene for children and adolescents:

1. Research of regularities of formation of children's health under the influence of aggregate factors (training and education environment, ecological and social factors, etc.).
2. Identification of patterns of physical and biological development of children and adolescents in Ukraine.
3. Physiological and hygienic substantiation and development of preventive measures aimed at preservation and promotion of the children's health in the context of education reform in Ukraine.
4. Substantiation of scientific bases of formation of healthy lifestyle of adolescents under the current conditions (tobacco and underage drinking prevention, etc.).
5. Hygienic support of design, construction and equipment of children's educational, out-of-school and recreational facilities.
6. Development and implementation of regulatory and procedural documents on sanitary-epidemiological, biological, and chemical safety and hygienic requirements for resources, methods, conditions of education, as well as children's goods.

Thus, hygiene for children and adolescents as a preventive medicine that studies the impact of living conditions and education of children on their health and develops scientific bases and practical measures to ensure optimal function level and favorable development of child's organism, is an important component of hygienic education of doctors of all specialties and should occupy its rightful place in the training of health personnel in the 21st century.

21.2. Main laws of growth and development of the child's organism

The health of children is a certain guarantee of the health and well-being of coming generations. Disease prevention as well as child and adolescent health preservation and promotion have always been and remain a priority for any society.

This problem is of particular significance for Ukraine, since the Chornobyl accident and many other objective factors have created unfavorable environmental conditions that require a large focus regarding the prevention of various diseases in children and adolescents.

Age peculiarities of growth, development and formation of child's health have specific laws. They are characterized by unevenness and morphofunctional features. A distinctive manifestation of this unevenness are the differences between periods of intensive growth and periods of differentiation of specific organs and tissues of the body.

Unevenness and morphofunctional features of development are inherent to almost all child's organs and systems: CNS, respiratory system, lymphatic tissue, etc. There are some differences in the development of boys and girls. Within the climatic conditions of Ukraine, prepubertal period of girls begins at the age of 10–12, boys — 13–14 years. This leads to the presence of two "intersections" of the main morphological indicators compared to the dynamics of their increase. However, functional indicators such as muscle strength, vital lung capacity and some others in boys exceed those in girls throughout their growth and development.

Growth disorders

Rapid growth is a time of increased health risk. Firstly, the development of blood vessels does not keep up with the development of tissues, which impairs the blood supply of tissues. Secondly, different parts of the same organs develop unevenly creating structural defects and dysfunctions; thirdly, the soft bones are deformed during this period due to the alternation of weakness and tension of different muscle groups that press on them. All of this leads to what is known as adolescent diseases. Their dangerous peculiarity lies in the fact that the seemingly "commonplace" problem unattended during intensive growth can make a person disabled for term of life in a matter of six months. Major growth disorders:

Spinal curvature. Growing bones, including the spine bones, easily take on the shape forced by muscles and the load on the upper shoulder girdle. In a case of excessive load, a child may develop scoliosis.

Mitral valve prolapse. It occurs in approximately every 10th child/adolescent aged 12 to 15 years. The cause is that the mitral valve grows faster than the heart tissue. The result is a condition similar to heart disease (valve insufficiency). There are symptoms onset of mild heart

failure (or cardiac insufficiency) — cyanosis (blue skin) of the nose tip, nails, fingers, shortness of breath, rapid fatigability. There may be chest pain associated with emotional stress.

Visual impairment in adolescents. This problem is a direct result of improper position at a table while reading, as well as insufficient lighting of the workplace.

There is a number of classifications (periodizations) of child's organism development. The following periods are basically outlined according to the scheme of age periodization:

- newbornness (1 day — 10 days);
- infancy (10 days — 1 year);
- early childhood (1 year — 3 years);
- first childhood (4–7 years);
- second childhood (boys — 8–12 years, girls — 8–11 years);
- adolescence (girls — 12–15 years, boys — 13–16 years);
- youthhood (girls –16–20 years, boys — 17–21 years).

The following periodization is simplified to some extent, but is more commonly used in the practice of pediatricians, hygienists, and teachers:

- toddler age (up to 3 years);
- preschool age (3–7 years);
- elementary-school age (7–10 years);
- middle-school age (11–14 years);
- senior-school age (15–18 years).

Each of the age periods has its own morphofunctional features:

Toddler age (up to 3 years) is characterized by intensive growth and development of the body and the organs. Body weight increases, and the musculoskeletal system is formed. There is a particularly intensive growth of neurocranium (braincase). During the first year of life, its volume increases 2.5 times, and a three years old child has neurocranium with 80% volume of the adult's one. At the age of 1.5–2 months, a child tries to hold his head, the high muscle tone of the arm muscles (arm bending) disappears, and, at the age of 5–6 months, a child develops sitting skills. By the age of 3, the ability of free walking and running is fully formed. The relatively large mass of the heart and its high vascularization determine the possibility of ensuring the necessary blood circulation and a gradual decrease in heart rate (from 120–140 in the first months of life to 100–110 in 3–4 years).

The surface of the air vesicles in a newborn child is 5.5–6 m^2. Toddlers mostly have shallow breathing, although the lungs volume during the first years of life increases 4.5 times. The required lung ventilation is provided by the increased frequency of respiratory movements (in newborn it makes 40–60, in children aged 2–3 years — 25–30 per 1 minute).

The secretory function of the stomach is still relatively weak, but the absorption capacity is quite large. With the appearance of milk teeth and the gradual transition from breast feeding to mixed, the thickness of the muscular layer of the stomach increases along with the intensive growth of the intestinal tract.

Significant morphofunctional changes are observed in the CNS. From the 2–3rd week, there is the formation of the first acquired reflex regarding the feeding position. Acquired reflexes to visual and auditory stimuli are formed during the 2–3rd month of life.

The smaller a child, the more irradiation processes in the cerebral cortex prevail over concentration processes. This leads to poor coordination of movements and sometimes to the occurrence of inadequate responses to various external influences.

The child's vocabulary gradually increases, and by the age of 3 it already has 800–1000 words. The development of language is facilitated by active communication with others, clear speech of adults, acquaintance with other children, fascination with images, etc. Visual function is improved. At the end of the first month of life, a child is able to fix eyes on something, and during the first year child acquires the color-distinguish ability. The perception response to acoustic influences also develops. The response to sound stimuli appears at the end of the second — beginning of the third month of life.

Morphologically the endocrine system at birth is already formed. As a child grows, his/her activity increases and improves.

Thus, during the toddler age there are very important morphological and functional changes, the result of which is the formation of the ability to move freely, acquirement of the basics of speech, age-appropriate perception and assessment of the outward things.

In preschool age (3–7 years) a child continues to grow and develop relatively evenly. Intensive formation of the musculoskeletal system is under way; the ossification of the cartilaginous tissue of the epiphyses of the tubular bones and skeletal system is almost over; the child's propensity towards manual exercises (drawing, modeling, etc.) develops. The need in various complexly coordinated physical exercising determines the intensive development of the nervous system of the muscles. The formation of lung tissue is almost complete; the vital ca-

pacity of the lungs increases; the frequency of respiratory movements decreases to 22–24 per 1 minute. The secretory and motor functions of the stomach and intestines are not dissimilar to those in adults.

The functional capabilities of the CNS are significantly improved. The harmonization of irradiation and concentration processes is improved, and the form of communication between a child and adults and the environment acquires a much higher level.

The organism of a child of **elementary-school age (7–10 years)** continues the physical growth and development (body weight increases by an average of 2–3 kg each year, chest circumference — by 1.5–2 cm, body length — by 4–5 cm). The processes of ossification and skeletal system development proceed also continue. Muscle strength increases. The general resistance to adverse environmental influences slightly increases. However, despite the positive changes that have occurred in the previous period, the processes of excitation still prevail over the inhibitory, and both of them — over the processes of concentration, which leads to minor exhaustion and rapid fatigability of the CNS.

Middle-school age (11–14 years) is very responsible for the further holistic and balanced development and becoming of a child and adolescent. This period is characterized by continued intense growth, increase in muscle and body size, skeletal formation. The vital capacity of the lungs in 14-year-old girls increases to 2700 cm^3, in boys — to 3200 cm^3. Along with this, there is the initiation of enhanced development of the genital glands and development of secondary sexual characteristics. Due to the increased excitability of the CNS and its subcortical parts, the processes of internal inhibition are significantly weakened. The autonomic regulation of the cardiovascular and respiratory systems is impaired (especially in girls), and emotional excitability and fatigue (tiredness) is increased.

Senior-school age (15–18 years) is distinguished by the completion of sexual maturation accompanied by a further increase in body length and weight, and completion (mainly) of growth and ossification of tubular bones, skeleton, feet and hands (these processes end only at the age of 20–25 years). The morphofunctional development of all organs and systems of an organism almost comes to the end (at a later stage this process mainly is driven by intense activity and training). It should be noted that during this period, adolescents often have mental instability, susceptibility to inadequate reactions, manifestations of negativism, etc. All this must be taken into account when organizing the educational process and communication with adolescents.

The ongoing processes of CNS development make it possible to identify the main types of higher nervous activity, without which it is impossible to effectively and rationally organize the daily activities of children and adolescents. These types are the following:

Type I — optimally excitable, balanced, fast (responses are adequate to the strength of stimuli, the cerebral cortex is in a state of optimal performance; conditioned reflexes are stable, formed easily and quickly; children are companionable, "self starter", disciplined, Fig. 21.1)

Type II — optimally excitable, balanced, atonic, slow: conditioned reflexes are formed slowly but steadily; children have sufficient lexical stock, and they are calm, persistent, disciplined (Fig. 21.2).

Type III — strong, highly excitable, unbalanced: regulatory function of the cerebral cortex is reduced;



Fig. 21.1. Children with higher nervous activity of type I. Source: *network.org.ua*



Fig. 21.2. A child with higher nervous activity of type II. Source: *vk.com*

excitation processes significantly predominate over inhibition processes; reactions are often inadequate; there is increased emotionality, sometimes even aggression (Fig. 21.3).

Type IV — weak, less excitable (conditioned reflexes are formed slowly; the processes of internal inhibition are weakened; strong stimuli cause fatigue (tiredness); there is a tendency to nervous disorders, Fig. 21.4).

The type of higher nervous activity can change with age both naturally and (which should be noted separately) through appropriate educational and training work, lifestyle, compliance with the rules of personal hygiene, etc.



Fig. 21.3. Children with higher nervous activity of type III. Source: *censor.net.ua*



Fig. 21.4. A child with higher nervous activity of type IV. Source: *twitter.com*

21.3. Health status of children and adolescents. Health assessment criteria

It is recognized that the health of children and adolescents is characterized not only by the presence or absence of disease, but also by the age-appropriate harmonious development of an organism, the adequate level of development of many functions, qualities, and so on. Therefore, the main initial criteria for Health assessment are:

- presence or absence of chronic diseases at the time of examination;
- level of functional state of the main systems of the body;
- degree of body resistance to the influence of adverse environmental factors;
- level of achieved physical and neuropsychological development and level of its balanced state.

The analysis and taking into account the defined criteria allow singling out **5 health status groups of children and adolescents**:

- First group. Practically healthy children with normal development and functioning of all systems and organs (Fig. 21.5).



Fig. 21.5. The first group of children's and adolescents' health status. Source: *pomoho.net*

- Second group. Practically healthy children, but with some morphological or functional abnormalities, as well as reduced resistance to acute and chronic diseases.
- Third group. Children with chronic diseases in a state of stable compensation while maintaining the functional capabilities of the body.
- Fourth group. Children with chronic diseases in a state of subcompensation with reduced functionality of the body.
- Fifth group. Children with chronic diseases in a state of persistent decompensation with a significant reduction in the functional capabilities of the body (in most cases, these children need constant assistance and care).

21.4. Methods of hygienic assessment of child's physical development

In order to determine the affiliation of a child to a particular health status group (this is of great importance when addressing many issues related to the organization of educational activities, physical and labor education, career guidance, etc.), objective indicators of the functional state of the body, the level of its adaptive resources, physical development and biological age are used and evaluated.

Assessing the functionality of higher nervous activity, analytical systems, attention, memory, thinking, personality characteristics should be considered as extremely important methods (Table 21.1).

There are certain age patterns of the children's morbidity structure.

In the neonatal period, the leading place is occupied by diseases and conditions mainly related to the influence of fetal development factors. Toddler age is characterized by domination of respiratory and infectious diseases. Auditory system diseases, nervous system disorders, digestive diseases, allergic manifestations, etc. have some relevance at this age as well. At the age of up to 7 years, respiratory diseases are in the first place. In elementary-school children (7–10 years), morbidity structure is mostly expressed by infectious and digestive diseases, injuries; in children of middle-school age (11–14 years) — injuries, infectious, skin and digestive diseases; in children of senior-school age (15–17 years) — injuries, digestive system, skin and infectious diseases. In addi-

Table 21.1. Methods of studying the functional state of the body of children and adolescents (G. N. Serdiukovska, 1984)

Studied function	Studied characteristics	Method	Equipment
Individual-typological features of higher nervous activity	Strength of the nervous system. Mobility and balance of nervous processes. Lability of the nervous system	Chronoreflexometry. Critical flicker-fusion frequency (CFF)	Chronoreflexometer. Device for CFF study
Visual analyzer	Linear eye estimation. Lability of the visual analyzer	Determining of the line segment length. Determining of CFF	F. Galton's scale. Device for CFF study
Sensorimotor (motor) analyzer	Accuracy of reproduction of the prescribed movement. Accuracy of maintaining muscular effort. Motion coordination. Muscle strength	Kinematometry. Dynamometry Coordynamometry, thermometry. Dynamometry	Zhukovskiy kinematometer. Rosenblatt's dynamomete. Coordynamometer, thermometer. Dynamometer
Tactile analyzer	Threshold of tactile sensation	McWorthy's method	McWorthy's scale
Attentiveness	Stability of attention. Attention switch	Correction task. Finding numbers	Anfimov's table. Schulte – Platonov table
Memory	Mechanical memory. Image memory	Nechaev's method. Buehler's test	Cards, stop-watch timer. Cards, stop-watch timer

tion, disorders of the cardiovascular system, vision (visual impairment), auditory system, nervous system, musculoskeletal system (skeletal deformities), as well as the level of physical development balance are no less important focus among the health problems of school-age children.

Physical development clearly and adequately reflects the morphofunctional state of a child over time and the level of its compliance with biological age. Its features, as well as the balance (harmonicity) level are evaluated on the basis of somatoscopic (anthroposcopic), somatometric (anthropometric) and physiometric indices with the subsequent assessment using the sigma deviation method, regression scales, complex and centile methods.

Somatoscopic indices include the state of the skin and mucous membranes, the degree of fat deposition, characteristics of the musculoskeletal system (skeleton, shape of the chest, spine, legs and feet), signs of sexual maturation (growth of pubic and armpit hair, development of the mammary glands in girls, facial hair growth, thyroid cartilage development, heterophonia or voice break in young men). The key ***somatometric indices*** are body length and weight, chest circumference and other circumferences (head, shoulder, hip, etc.). ***Physiometric indices*** include muscle strength of the hands, vital capacity of the lungs, back strength, etc.

Assessment of physical development is carried out on the basis of comparison of individual data with average normative values (standards of physical development) for each age and sex group. Such average values reflect the level of physical development of children and adolescents living in similar geographical, ethnic, national and social conditions.

Methods for assessing the physical development of children and adolescents and the level of its balance state:

1. The method of sigmal deviations with a graphical representation of the physical development profile.
2. Evaluation on regression scales (evaluation tables take into account the correlation dependence between length, body weight and chest circumference).
3. Complex method of physical development assessment (with account for both the features of the morphofunctional state of the organism and the correspondence of the level of its biological development to the chronological age).
4. Centile method for assessment of physical development.

Assessment of physical development by **the method of sigmal deviations** with a graphical representation of the profile of physical development involves comparing each individual feature with the weighted arithmetic mean value for this feature at a certain age, which allows to determine its actual deviation from normative values (Table 21.2).

Table 21.2. Indices of physical development of school-age children

Age	Body length, cm		Body weight, kg		Chest circumference, cm	
	M	*σ*	*M*	*σ*	*M*	*σ*
Boys						
7	121.6	5.8	24.3	3.98	61.0	3.68
8	128.1	5.56	27.9	4.94	62.5	4.92
9	132.6	5.4	30.2	5.3	65.4	4.74
10	137.3	5.6	33.4	6.0	67.5	4.80
11	142.5	6.26	37.0	6.82	69.9	5.20
12	147.0	6.96	39.9	6.7	71.6	4.46
13	153.5	8.22	45.1	8.74	75.0	5.48
14	161.1	8.74	50.8	8.70	78.7	6.14
15	166.9	8.16	57.2	10.12	82.0	6.0

Table 21.2. Indices of physical development of school-age children

Age	Body length, cm		Body weight, kg		Chest circumference, cm	
	M	*σ*	*M*	*σ*	*M*	*σ*
16	173.1	7.02	62.98	8.24	85.3	4.52
17	178.4	7.6	65.6	7.8	87.0	4.0
Girls						
7	121.5	5.54	23.3	3.65	59.0	2.4
8	127.0	5.26	26.8	4.74	59.0	3.2
9	131.5	5.74	29.0	4.52	61.9	2.7
10	137.4	6.15	33.3	7.0	63.4	2.4
11	142.8	7.1	37.0	7.30	66.8	4.0
12	149.3	6.8	40.4	7.08	70.4	4.8
13	156.2	6.2	48.5	7.74	73.2	5.6
14	157.2	5.42	51.8	8.78	79.4	5.1
15	158.0	5.54	23.3	3.65	82.1	5.1
16	159.2	5.2	54.6	6.6	83.4	4.5
17	159.5	4.9	55.9	7.0	84.8	4.2

Then, via dividing the actual deviation by the value of the standard deviation, the *sigmal deviation* (*σ*) is found. It gives information on the size of sigma value (upward or downward deviation) that differ the child's indicators from the average for a certain age-sex period.

Deviations in the range from *–1σ* to *+1σ* are considered to be the *average* development of the indicator under study, from *–1σ* to *–2σ* — development is *below average*, from *–2σ* and below — development is *low (underdevelopment)*, from *+1σ* to *+2σ* — *above average*, from *+2σ* and above — *high*.

For the purpose to build a *profile of physical development*, horizontal lines are drawn at the same distance from each other, the number of which is determined by the number of features (indicators) to be evaluated. The values of the obtained deviations are put on each of them, which are connected by straight lines. The method of sigmal deviations allows to determine the level of development of each individual indicex of physical development and its proportionality, information about which is provided by the profile. If the values of deviations fit into one sigma deviation — the development is considered as proportional, if they do not fit — *disproportional*.

The conclusion on the physical development of a child when using the method of sigma deviations should be as follows (example): "*Physical development of the 10-year-old child, in terms of body length — average (above average, high, below average, low), in terms of body weight — average (above average, high, below average, low), in terms of chest circumference — average (above average, high, below average, low), proportional (disproportional)*".

The use of **regression scales** as the method of assessment of physical development (Table 21.3) overcomes the main disadvantage of the sigma deviation method, namely — the separate assessment of each somatometric feature. For the present purpose, evaluation tables take into account the correlation dependence between body length, weight, and chest circumference and, thus, allow a more thorough assessment of the physical development level on a set of interrelated features.

The first stage of individual assessment of physical development according to the evaluation tables of regression scales is aimed at finding a group (medium, below average, above average, low, or high development), which should include the length of a child's body. At the

Table 21.3. Assessment of physical development of 11-year-old schoolchildren (regression scale by body length)

Values of sigmal deviations	Body length, cm	Body weight, kg	Chest circumference, cm	Body length, cm	Body weight, kg	Chest circumference, cm
	11-year-old boys			*11-year-old girls*		
Low (from M –2σ and below)	123	20.9	59.8	123	22.1	58.0
	124	216	60.2	124	22.9	58.5
	125	22.7	60.6	125	23.6	59.0
	126	23.1	61.0	126	24.3	59.5
	127	23.7	61.4	127	25.1	60.0
	128	24.5	61.8	128	25.8	60.5
	129	25.2	66.2	129	26.5	61.0
Below average (from M –1σ to M –2σ)	130	25.9	62.7	130	27.2	61.6
	131	22.6	63.1	131	28.0	62.1
	132	27.3	63.5	132	28.7	62.6
	133	28.1	63.9	133	29.4	63.1
	134	28.8	64.3	134	30.2	64.1
	135	29.5	64.7	135	30.9	64.6
	136	30.2	65.1	136	31.6	65.1
Average (M ±1σ)	137	30.9	65.5	137	32.4	65.6
	138	31.7	65.9	138	33.1	66.1
	139	32.4	66.3	139	33.8	66.7
	140	33.1	66.8	140	34.6	67.2
	141	33.8	67.2	141	35.3	67.7
	142	34.5	67.6	142	36.0	68.2
	143	35.3	68.0	143	36.7	68.7
	144	36.0	68.4	144	37.5	69.2
	145	36.7	68.8	145	38.2	69.7
	146	37.4	69.2	146	38.9	70.2
	147	38.1	69.6	147	39.7	70.7
	148	38.9	70.0	148	40.4	71.2
	149	39.6	70.4	149	41.1	71.8
	159	40.3	70.8	159	41.8	72.3
	151	41.0	71.3	151	42.6	72.8

Table 21.3. Assessment of physical development of 11-year-old schoolchildren (regression scale by body length)

Values of sigmal deviations	Body length, cm	Body weight, kg	Chest circumference, cm	Body length, cm	Body weight, kg	Chest circumference, cm
	11-year-old boys			*11-year-old girls*		
Above average (from M + 1σ to M + 2σ)	152	41.7	71.7	152	43.3	73.3
	153	42.5	72.1	153	44.0	73.8
	154	432	72.5	154	44.8	74.3
	155	43.9	72.9	155	45.5	74.8
	156	44.6	73.3	156	46.2	75.3
	157	45.3	73.7	157	47.0	75.8
	158	46.1	74.1	158	47.7	76.3
	159	46.8	74.5	159	48.4	76.9
High (from M + 2σ and above)	160	47.5	75.0	160	49.2	77.4
	161	48.2	75.4	161	49.9	77.9
	162	48.9	74.8	162	50.6	78.4
	163	49.7	76.2	163	51.3	78.9
High (from M + 2σ and above)	164	50.4	76.6	164	52.1	79.4
	165	51.1	77.0	165	52.8	79.9
M ± σ Ry / x ± σR	144.5 7.01	36.4 7.01 0.72 4.89	68.6 5.46 0.41 4.63	143.9 7.54	37.4 7.72 0.73 5.37	68.6 6.22 0.51 4.92

next stage, the indicators of body weight and chest circumference are found. They should correspond to the actual growth. Then these indicators are compared with them the actual indicators of the indicators under study. To do this, standard value should be subtracted from the actual development value of the indicator; the subtraction result should be divided by the regression sigma (σ_R) for each studied indicator. The evaluation criteria are similar to the previous ones.

The conducted study allows to refer a child to one of the physical development groups: *normal physical development* — body weight in the range from M – $1\sigma_R$ to M + $1\sigma_R$; *body weight deficit* — body weight less than M $-1\sigma_R$; *excess body weight* — body weight more than M + $2\sigma_R$; *low height* — body length less than M – 2σ.

A **complex method** of assessing physical development allows to take into account both the features (indicators) of the morphofunctional state of the organism and the correspondence of the level of its biological development to the chronological age. Initially, according to the following data — body length, its annual increase, the number of permanent teeth, the degree of secondary sexual characteristics development, the period of hand bones ossification — the biological age of a child is determined and compared with the chronological one.

Depending on the values of the obtained indices, it can correspond to the chronological age, ahead of it or lag behind it (Table 21.4).

The next stage of the complex method is to assess ***the morphofunctional state of the organism*** using regression scales and age-sex standards of the development of functional indicators. Physical development is considered as:

- harmonious, if the values of body weight and chest circumference differ from the normative values in the range from $-1\sigma_R$ to $+1\sigma_R$, and functional indicators are characterized by deviations from –1σ and above;

Table 21.4. Indices of the biological development level of school-age boys

Age	Body length ($M \pm \sigma$)	Annual body length velocity, cm	Signs of ossification of the hand bones	Number of permanent teeth ($M \pm \sigma$)	The degree of sexual maturation
7	$M_7 \pm \sigma$	4–6	Presence of ossification centres of all carpal bone (except postulnar bone), the appearance of the ulnar bone epiphysis	7 ± 3	P_0, Ax_0
8	$M_8 \pm \sigma$	4–6	Presence of the ulnar bone epiphysis	12 ± 2	P_0, Ax_0
9	$M_9 \pm \sigma$	4–6	Presence of the well-marked ulnar bone epiphysis	14 ± 2	P_0, Ax_0
10	$M_{10} \pm \sigma$	4–6	Appearance and formation of the styloid process of ulna	18 ± 3	P_0, Ax_0
11	$M_{11} \pm \sigma$	4–6	Presence of the well-marked styloid process of ulna	20 ± 4	P_0, Ax_0
12	$M_{12} \pm \sigma$	4–6	Appearance of postulnar bone	24 ± 3	$P_{0.1}$, Ax_0, V_1
13	$M_{13} \pm \sigma$	7–10	Appearance of sesamoid bone in the I metacarpophalangeal articulation	27 ± 1	P_1, Ax_0, V_1, $L_{0.1}$
14	$M_{14} \pm \sigma$	7–10	Presence of sesamoid bone	28	P_2, Ax_1, $V_{1.2}$, $L_{0.1}$, $F_{0.1}$
15	$M_{15} \pm \sigma$	4–7	Beginning of ossification of the I metacarpal bone	28	P_3, Ax_2, V_2, $L_{1.2}$, F_1
16	$M_{16} \pm \sigma$	3–4	Ossification of the I metacarpal bone and phalangette	28	$P_{3.4}$, Ax_3, V_2 L_2, $F_{1.2}$
17	–	1–2	Ossification of the II–V metacarpal bones	28	P_4, Ax_3, V_2, L_2, $F_{2.3}$

Note: *Ax — armpit hair; P — pubic hair; F — facial hair; L — development of laryngeal prominence; V — heterophonia (voice break)*

- disharmonious, if the values of body weight and chest circumference lag behind or ahead of standard values due to excessive fat deposition by $\pm 1\sigma_R$ — $\pm 2\sigma_R$, and functional values are in the range from -1σ to -2σ;
- sharply disharmonious, if the values of body weight and chest circumference lag behind or ahead of the normative indicators due to excessive fat deposition by more than $\pm 2\sigma_R$, and functional indicators are characterized by deviations from -2σ and below

The conclusion on the physical development of a child when using the complex method should be as follows (Table 21.5): "Physical development of the 10-year-old child is average (above average, high, below average, low), harmonious (disharmonious, sharply disharmonious), biological age corresponds to *the chronological age (ahead of the chronological age, lags behind the chronological age)*".

The centile method of physical development assessment, in contrast to traditional methods focused on the assessment of physical development indices, which vary according to the normal distribution law, is an effective nonparametric method of brief description of the indicators distribution with right- or left-handed asymmetry (body weight, chest circumference etc.).

The principle of the centile method is to compare the actual indicators of development of a particular characteristic of physical development with an ordered series, which include the entire range of fluctuations of the studied index. The range is divided into 100 intervals, falling into which has the same probability, but the sizes of these centile intervals in absolute units are different. To determine the degree of physical development, seven

Table 21.5. Complex assessment of physical development of children and adolescents

Biological level	Morphofunctional state	Body weight, chest circumference	Functional indices
Corresponds to age	Harmonious	M ± $1\sigma_R$ and more due to muscle development	M ± $1\sigma_R$ and above
Ahead of age	Disharmonious	From M – $1\sigma_R$ to M – $2\sigma_R$; from M + $1\sigma_R$ to M + $2\sigma_R$	From M – $1\sigma_R$ to M – $2\sigma_R$
Lags behind the age	Sharply disharmonious	From M – $2\sigma_R$ and below, from M + $2\sigma_R$ and above	From M – $2\sigma_R$ and below

Note: *M — weighted arithmetic mean; σ_R — regression sigma*

fixed centiles are used: 3, 10, 25, 50, 75, 90 and 97 and respectively 8 centile intervals:

- 1st interval (below 3 %) — very low indices;
- 2nd interval (from 3 to 10 %) — low indices;
- 3rd interval (from 10 to 25 %) — decreased indices;
- 4th and 5th intervals (respectively from 25 to 50 % and from 50 to 75 %) — average indices;
- 6th interval (from 75 to 90 %) — increased indices;
- 7th interval (from 90 to 97 %) — high indices;
- 8th interval (higher than 97 %) — very high indices.

Individual assessment of morphofunctional indices is performed using one-dimensional assessment scales, which include the amplitude (maximum and minimum value), the central tendency (median of the ordered series) and 8 centile intervals. These scales allow to determine both individual characteristics of somatometric features and its balance (harmonicity) level, given the fact that the 4th and 5th intervals of the nomogram characterize the harmonious physical development, the 3rd and 6th intervals — disharmonious, the 1st and 2nd, and 7th and 8th — sharply disharmonious (deficit or excess body weight).

21.5. Hygienic assessment of the organization of physical and labor education in children's institutions

Medical control over the physical education of children and adolescents involves medical monitoring of the state and dynamics of their health and the peculiarities of the body's responses to physical activity, sanitary supervision of the premises and conditions of physical education and sports.

Preschool age. Based on the possibilities of involving preschool children in physical education, exercise, etc., it is commonly to divide them into three groups. *The first group* includes children who on medical grounds belong to the first and second health status groups, i.e. those whose health state allows involvement in all types of physical education in accordance with their age and functional development. *The second group* includes children with various diseases in the stage of compensation and delayed physical development, as well as sickly children. Children in this group need a cautious approach to exercises related to muscular effort, "soft" type of cold water treatment (developing resistance to the cold), and so on. Finally, *the third group* includes children with congenital malformations, chronic diseases accompanied by long-term (persistent) sub- and decompensation and acute inflammatory diseases of any location, and so on. Depending on the health state and functional capabilities, children in this group can be completely exempted from sports. They need an individual regimen of therapeutic exercise.

School-age children, depending on their health and level of functional capabilities, are also divided into 3 physical education groups: main (full exercise load), preparatory (reduced exercise load) and special.

The main group includes healthy children and adolescents, as well as those with minor functional abnormalities if they do not impair the general well-being of a child and allow physical exercises under the general school curriculum.

If there are functional health disorders, some chronic diseases, increased excitability of the cardiovascular and nervous systems, rapid fatigue (tiredness), after acute diseases, etc., schoolchildren should be included in the preparatory group. In this group, classes should be conducted with less exercise load and individual selection of exercises.

The special group includes schoolchildren with chronic diseases in the stage of decompensation and subcompensation, with myopia over 5 diopters, significant de-

fects of the musculoskeletal system, etc. Children in this group are exempted from classes in the main group and, as a rule, in the preparatory group. They should be engaged in an individual regimen of therapeutic exercise. There are special guidelines with detailed recommendations for indications for physical activity in a particular group of children with a certain form and stage of various diseases.

Approximate terms of the beginning of physical education classes and admission to sports competitions after the past diseases are established and showed in the table below (Table 21.6). However, in each case, this issue is resolved individually after an in-depth medical examination.

All questions concerning the admission of a child of any age to a specific group of physical education, the transition from one group to another, etc. are handled by the doctor and based on the results of the primary and, then, regular periodic medical examination. Objective criteria for such an assessment may be indicators of the level of physical activity, body condition and performance capability of children and adolescents. The doctor should prohibit physical education classes only in "complicated" individual cases, if he doubts their benefits for the child.

Table 21.6. The main terms for the continuation of physical education after acute diseases

Diseases	The term for the continuation of classes after disease
Sore throat	2–4 weeks
Bronchitis, ARVI	1–3 weeks
Acute otitis	2–4 weeks
Pneumonia	1–2 weeks
Pleurisy	1–2 weeks
Influenza virus infection (Flu)	2–4 weeks
Acute infectious diseases	1–2 weeks
Acute nephritis	2 weeks
Infectious hepatitis	8–12 weeks
Appendicitis (after surgery)	1–2 weeks
Fractures of the bones of the extremities	1–3 weeks
Concussion (brain commotion)	3–12 months or more

The criteria for a complex assessment of motor activity of children and adolescents are *the number of locomotions, the amount of energy consumption and the duration of the dynamic component* both in the daily cycle and during a certain period of time, for example, during school or non-school hours.

The number of locomotions (in steps) is determined with the help of a pedometer (step counter), which is attached to the clothes of the study subject in a vertical position near the center of gravity of his/her body.

The amount of energy consumption (in kJ or kcal) is calculated by the timing-table method taking into account the fact that the body's energy consumption consists of components such as basal metabolism; energy expenditure for growth, development, etc. (15 % of the basal metabolism); energy expenditures associated with the specific-dynamic action of food (10 % of the basal metabolism); energy expenditure due to the performance of certain activities and motor activity.

The duration of the motor dynamic component (in minutes or in %) is determined on the basis of timing observations, questionnaires or interviews with students.

Hygienic assessment of physical education class involves conducting timing observations (introductory, preparatory, main and final part), determining the general and motor density of the lesson and external signs of tiredness, plotting of physiological curves of physical load, use of functional tests, study of motor activity level and physical state level, control over the air-thermal conditions of the intraschool environment and assessing the correctness of medical support of the lesson.

In the course of *timing observations*, it should be taken into account that the introductory part (3–4 minutes) involves the preparation of the children group for the lesson, the preparatory part (12–15 minutes) determines the general physical training, the main part (20–25 minutes), which actually is the topic of the lesson, is divided into 2 periods, namely: the periods of formation of motor skills and physical games, and the final part (3–5 minutes) should ensure that the body is brought to its original state.

The total density of a physical education lesson is the ratio of useful time, i.e. the time spent on performing various movements, showing physical exercises and their explanation by the teacher, line-up (or count off) and reline-up, cleaning of sports equipment — to the total duration of the lesson. According to hygienic requirements, its value must be at least 80 %. The *motor density of a physical education lesson* is the ratio of the time spent on performing various movements to the total duration

of the lesson. According to hygienic standards, its value should not be less than 60 %.

The physiological curve of physical load is a graphical representation of the reactions of the key indicators of the body's functional state (heart rate, blood pressure, respiratory rate, etc.) in response to physical activity. In the conditions of correct structure of a lesson the physiological curve should have a two-vertex parabola-shaped form, and after the introductory part of a lesson the level of physiological indicators, as a rule, should increase by 15–20 %, after the period of formation of motor skills of the main part — by 50–60 %, after the physical games — by 70–90 %, after the final part — by 5–10 %, which indicates the presence of a training effect, and in 2–3 minutes after the end of the lesson should return to the level of the initial values.

The main *external signs* of tiredness that are taken into account are a change in the skin color, changes in the characteristics of respiration, attention, well-being, sweating and the peculiarities of the necessary movements.

Functional tests, widely used for the moment, are as follows:

- orthostatic test (change the child's position from lying to standing followed by determination of cardiovascular and respiratory reactions);
- Martine — Kushelevsky test (20 squats for 15 seconds);
- modified Letunov's test (10 push-ups for 10 seconds);
- running on the spot at maximum speed for 10 seconds and running on the spot for 1 minute (girls) and 1.5 minutes (boys) at a pace of 180 steps per minute;
- step-test (PWC_{170}) etc.

21.6. Daily routine and hygiene of learning and cognitive activity

The daily routine of children and adolescents and the organization of the educational process in school and cognitive activity should be formed taking into account the state of health, age, physical and mental capacity of a child and the level of development achieved.

In a point of fact, the daily routine is the distribution of time to perform various activities and recreation during the day. It is based on conditioned reflex activity, namely — the processes of forming a certain dynamic stereotype about the implementation of its individual types.

The daily routine is considered correct if it provides sufficient time for a child to perform all the necessary elements of life and provides a high level of efficiency.

For the purpose of hygienic assessment of the daily routine of children and adolescents, methods of questionnaires, interviews and timing observations are used.

In the course of research it is necessary to obtain information about the presence and duration of the daily routine of the main regimen elements (sleep, school activities, nutrition regimen, outdoor recreation, homework, household duties, free time), correctness and appropriateness of their interposition, correspondence to the state of health, age-sex, anatomical-physiological and functional features of an organism and personal habits of a child.

It should be emphasized that the weekly study load should usually be limited to 24 hours for schoolchildren of the 1st–3rd classes, 27 hours — for schoolchildren of 4th class, 29 hours — for schoolchildren of 5–7th classes, 30 hours — for schoolchildren of 8th class, and 32 hours — for schoolchildren of 9–11th classes.

Due to the peculiarities of the biorhythmological structure of the personality and the patterns of changes in performance during the day, the schedule should be formed so that lessons on the most difficult subjects were held after a period of active mental process and before the onset of mental tiredness.

Hygienic assessment of the organization of the educational process at school involves the study of educational schedules, class schedules and lesson organization.

The control over the educational schedule is connected with the determination of the time of lessons at school, the duration of lessons, the breaks between lessons and shifts, the correspondence of the number of lessons during the year and week to the curriculum.

The main elements of *sanitary and hygienic supervision over the lessons schedule* are the following:

- the determination of correspondence between distribution/alternation of subjects during the school day/week and of health and morphofunctional capabilities of children and adolescents;
- taking into account the physiological curve of schoolchildren;
- studying the complexity of subjects and the nature of their arrangement (the presence of double lessons, placement next to lessons on subjects similar in content or type of activity, for example, native language and foreign language, algebra and geometry, etc.).

To determine the degree of complexity of lessons, the following methods are used:

Methods of grouping subjects by difficulty:

- group 1 — mathematics, foreign language;
- group 2 — chemistry, physics;

- group 3 — native language, history, geography;
- group 4 — natural science, literature;
- group 5 — physical culture, music, arts and crafts lesson.

Method of rank scale of complexity of school subjects:

- mathematics — 11 points;
- foreign language — 10;
- physics, chemistry — 9;
- history — 8;
- native language — 7;
- literature — 7;
- natural science, geography — 6;
- physical culture — 5;
- arts and crafts lesson — 4;
- technical drawing — 3;
- drawing — 2;
- music — 1 point.

Hygienic assessment of the lesson involves the study of the conditions of its conduct, the presentation of educational material, methods and visual expression in teaching, the degree of tiredness of schoolchildren during the learning process, timing observations of the duration of the main structural elements of the lesson (organizational part, homework check, main part, consolidation of new knowledge, final part).

There are breaks between lessons, which last from 10 to 30 minutes. It is advisable to take a long break (30 minutes) after the 2nd or after the 3rd lesson. One of the possible and common options for the distribution of breaks is as follows: 20 minutes after the 2nd and 3rd lessons, which allows to use the first long break for breakfast of junior and middle school children, and the second break — for breakfast of high school students.

During the exams, the daily routine should be changed so that the total duration of self-training classes does not exceed 8–9 hours with a mandatory two-, three-hour stay at the fresh air during the day and before the bedtime.

An important element of the daily routine is the hygienic regulation of extracurricular activities of children and adolescents both in out-of-school institutions and in their free time.

22

CHAPTER

HYGIENE OF CHILDREN'S INSTITUTIONS. REQUIREMENTS FOR PLANNING, IMPROVEMENT AND EQUIPMENT OF CHILDREN'S INSTITUTIONS

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22.1. Features of the main factors and conditions of the teaching and educational process affecting the health of children and adolescents

Children's institutions include children's preschool institutions (nurseries, kindergartens, etc.), children's educational (general and specialized) schools (lyceums, gymnasiums) of various types and out-of-school institutions (cultural centers, youth clubs, summer camps, etc.).

A child's health, social and psychological adaptation, normal growth and development are largely determined by the child's environment.

For a child aged 6–17, this environment is a school, as he/she spends about 70 % of his/her time there.

It is no coincidence that hygienists, physiologists, pediatricians, teachers/educators, psychologists try to identify the full range of factors that can impair the child's growth and development, worsen child's health.

The main factors of the school environment that can affect the child's health:

1. Microclimate of classrooms.
2. Indoor air conditions.
3. Natural and artificial lighting of classrooms and other premises.
4. Inappropriate juvenile furniture.
5. Hypodynamia.
6. Improper diet.
7. Psycho-emotional load.

According to the data of special medical epidemiological observations, children's health is significantly deteriorated during the schooling period. The frequency of detection of visual impairment increases four times, digestive disorders — two times, disorders of nervous and endocrine systems and functional problems in the cardiovascular system — 3.5 times.

On average, only 10.0 % of school leavers in Ukraine can be considered healthy, 52.6 % have serious morphofunctional disorders, and 36.0–40.0 % suffer from chronic diseases. In recent years, there has also been an increase in neuropsychiatric disorders in schoolchildren. Only 23 % of children can be considered as thriving, 77 % of children are at risk group, and, moreover, 28 % of them have dysfunctional state that are out of the norm (M. M. Korenev, etc.).

Without taking into account the negative consequences of the impact on the growing organism, the hygienic principles of the organization of the educational process are violated. The term of schooling increases (up to 12 years); the age of children attending schools decreases; the study load increases; the number of classes and groups in general educational institutions and vocational technical schools decreases, but the maximum number per class increases. New school curriculums and textbooks, including computer ones, are being changed and introduced, which should have a hygienic assessment of their safety for the physical and mental health of schoolchildren.

The single design inspection of all general educational institutions conducted in 2001–2002 in Ukraine revealed that the material and technical condition of physical facilities of schools and their equipment do not meet the hygienic requirements for the conditions for healthy and harmonious development of children: 68 % of gym halls of the surveyed 13 620 facilities have satisfactory conditions, among all assembly halls — 45 %, dining halls — 70 %, premises for after-school child-care — only 9 %.

Computer classrooms are equipped in 30 % of educational institutions, and these computer classrooms have equipment that meets hygienic requirements in 75 % of cases, and only 31 % of classrooms have specialized computer furniture. 77 % of educational institutions are fully provided with school furniture.

According to functional-planning and lighting indicators, educational premises do not meet hygienic requirements in more than 20 % of schools. The actual maximum number per class exceeds the intended by project by 28 % in urban schools and by 5.3 % — in village schools.

14 % of schools (33 % of urban and 7 % of village schools) work in 2–2.5 shifts, and school starts earlier than at 8:30 a.m. in 23 % of cases. This leads to a systematic violation of chronobiological regimes in children.

The analysis of the organization of medical care showed:

- only 18.0 % of general educational institutions in Ukraine have medical rooms that meet the requirements of DSanPiN 5.5.2.008–01 "State sanitary regulations and norms of arrangement, maintenance of general education institutions and organization of educational process";
- medical workers shortages (in general, only 8.9 % of schools have pediatricians: 24.7 % of urban schools — and 1.4 % of village schools);
- medical examinations of the 2002–2003 school year covered 86.7 % of schoolchildren in urban areas and only 51 % — in rural areas;
- within the educational institutions, only 20.5 % of schools carry out preventive and health-improving measures for the rehabilitation of schoolchildren with health disorders.

22.2. Hygienic requirements for planning and improvement of children's institutions

School building plots should be located in settlement areas in compliance with sanitary norms regarding the distance from sources of harmful emissions, noise, vibration, electromagnetic and ionizing radiation. That is, they should be placed in the most environmentally friendly places at a certain distance from sources of air pollution, noise and major highways. It is reasonable to accommodate these facilities within a square (block).

The location of children's institutions should be close to the places of residence of the relevant contingents of children and adolescents. For preschools, the service radius should be 0.3–0.5 km, for elementary grade — up to 0.5 km, for middle grade — up to 1 km, for senior grade — up to 1.5 km, in rural areas (providing organized transportation of children by specially designated and suitable transport) — up to 3 km.

The sizes of land plots for location of facilities for children and adolescents must comply with hygienic standards.

When the relevant facilities are located, the need of continuous insolation of the main premises and outdoor playgrounds and other areas at least three hours should be taken into account.

The internal planning of children's preschool facilities should provide the creation of necessary conditions to adhere to the principle of group isolation, to ensure the possibility of physical activity of children, to create a favorable air and thermal environment, sufficient lighting, etc. The landscaping area (green area) of land plot should be not less than 15–17 m^2 per place, i.e. more than 50 % of their total area. Reduction of this standard is possible only when the area of the children's facility directly borders on forest or park areas.

On the territory of the children's preschool land plot, provisions should be made to provide the presence of group playgrounds for children of different ages, a common sports ground, berry garden, utility zone and footpaths.

When planning plots for educational facilities for school-age children, the starting point is to ensure rational functional zoning of the territory and a sufficient area of the respective zones. The area of the land plot of educational facilities (schools) must correspond to the standard values given in the Table 22.1.

Modern types of general education schools include: elementary, secondary and middle schools, gymnasiums and lyceums.

Table 22.1. Area of the land plot of general education school (without boarding school)

Number of pupils	Plot area, ha	Number of pupils	Plot area, ha
40	0.3	627	2.0
80	0.5	784	2.2
129	1.2	1176	2.8
320	1.7	1568	3.0
464	2.0	1960	4.0

The buildings of general education schools are accommodated not closer than 2.5 m from the red line of the land plot, along the perimeter of which there is a protective green belt (trees, shrubs) not less than 1.5 m wide and on the street side — not less than 3 m.

The following **functional zones** should be located on the land plots of the educational institution: educational, educational-research (educational-production), sport, utility (economical), residential (in the presence of dormitories, bedroom buildings, etc.) and recreation area. It is desirable to place the sports area in such a way that it is not visible from the windows of classrooms (especially primary).

The height of buildings of general education schools should not exceed three or four-storey; the height of storey (from floor to floor of above storey) should be not less than 3.6 m; the height of lecture halls (50 seats or more), assembly halls (auditoriums), sports buildings — not less than 4.2 m.

The building system for educational institutions includes three main types: **compact (centralized) — A, block (section) — B and pavilion (decentralized) — C** (Fig. 22.1). The type, number and layout of rooms/premises depend on the type of institution.

However, modern secondary schools are built mainly on a block (section) system. This system provides for the possibility for occupancy of children of different ages in separate blocks; concurrently, the school-wide premises are combined into a separate block.

22.3. Hygienic requirements for the equipment of children's institutions

The school buildings should include three groups of rooms/premises: main (training rooms, classrooms, laboratories, training workshops, gym hall), auxiliary (library, recreation rooms/play rooms, canteen, lunch room, assembly hall, utility rooms, storage rooms, toilets/ washrooms, etc.) and office premises (administration offices, teachers' common rooms, medical offices, etc.).

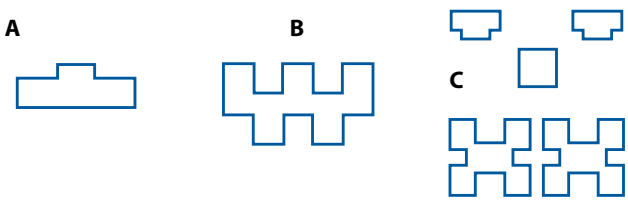


Fig. 22.1. Main building systems for children's facilities (an explanation further in the text)

Most of the time schoolchildren are inside classrooms and training rooms which must meet certain hygienic requirements (Table 22.2).

The area of the classroom should be not less than 60 m^2, the training room — 50–60 m^2, the minimum area per pupil in these rooms is 2.0 m^2. The best shape of the classroom is rectangular with a ratio of depth to width 3:4. The distance from the first row of desks to the blackboard should be 1.6–2 m, ceiling height — 3–3.5 m. Placement of windows — left side, viewing angle (angle between the line of sight and the plane of the blackboard in the horizontal plane) must be not less than 30–35°. The area of the teacher's room is determined at the rate of 1.5–2.5 m^2 per one class.

At gyms there should be two change rooms with an area size of 16 m^2 per each room, two showers — 3 m^2 each, and two toilets — 2 m^2 each.

Schools that contain more than 20 classes should have two gyms, including one (144 m^2) — for lessons with elementary grade students.

The assembly hall is designed for a simultaneous stay of at least 25 % of students from the total number with an area of 0.6 m^2 per person present.

The seat capacity in the dining halls of general education schools is fixed on the basis of one seat for three students. The area size of the dining hall in these establishments is calculated as 1.4 m^2 per seat.

Each educational institution should have medical care facilities, which include: therapeutic room (at least 16 m^2 size), treatment (procedure) room (10 m^2), physiotherapeutic room (18 m^2), dentist's room (16 m^2), psychophysiological decompression room (18 m^2). The

Table 22.2. The list of the main educational premises of school buildings and their area size

Room, group rooms	Minimum area per student (m^2)
Classrooms, training rooms	1.25–2.4
Laboratories of natural sciences, drawing rooms	2.8
Laboratories of professional-technical and special profile	4
Informatics and computer rooms (per workplace near the display)	6
Auditoriums (depending on the number of seats, equipment)	From 1 to 3

therapeutic room can be used as an ophthalmological. This requires that the length of one of its walls be not less than 5.8 m.

Sanitary equipment of buildings and individual premises of children's institutions must provide a microclimate and air environment that meets hygienic requirements.

Ensuring the required level of illumination of the premises and ultraviolet radiation is achieved by taking appropriate measures both during the construction of children's institutions and during their operation. One such measure is the optimal orientation of the windows.

Building specifications set the following values of daylight factor (DF): in classrooms not less than 1.5 %, in drawing and technical drawing rooms not less than 2 %. According to the results of hygienic research, it is believed that the DF values should be even higher and reach 2.5–5 %.

In the main premises of children's facilities intended for lesson that require the increased visual load, the light factor should be 1 : 4 or more. In other rooms it can be 1 : 5–1 : 6. The distance between the windows (width of the part of the wall) should not exceed 0.5 m.

With one-sided arrangement of windows, the depth coefficient (the ratio of room depth to the distance from the floor to the upper edge of the window) should not exceed 2. If the depth of the room is more than 6–6.5 meters, there is a need for two-sided natural light. In order to provide the free light penetration into the premises, the opposite buildings should be located at a distance of at least 2.5–3 of their height from the building of the children's institution.

The colors of the surrounding surfaces and the equipment on which the reflection coefficient depends are important. White reflects 80–90 % of light rays, yellow and light blue — 70–80 %, green — 60 %, light brown, dark pink — 30–45 %, dark green — 22–25 % of light rays. There must be a certain contrast ratio of the brightness of the surfaces: 1 : 7 (copybook — window), 1 : 12 (blackboard — window), 4 : 1 (copybook — desk) (Table 22.3).

In the premises of children's preschool institutions, the lamps with reflected or diffused light should be used. Their brightness should not exceed 200 cd/m^2.

In the case of combined lighting (natural and artificial), the optimal ratio between light fluxes from the window and from the source of artificial lighting is 2 : 1.

22.4. Methods for survey of school environment conditions in educational institutions and hygienic estimation of educational furniture

Anatomical and physiological age features of the child's body, as well as the need for an effective educational process, recreation and educational work with children necessitate the use of preschool and school equipment that would meet certain hygienic requirements. These requirements take into account, first of all, the peculiarities of the processes of visual analyzer and musculoskeletal system formation, maintenance of the working body position, etc.

It should be noted that with children's age, there are changes in body tilt value. Thus, the head of elementary school student has an average inclination relative to the horizontal plane of 45°, and the thoracic spine — 55°, and in senior school students these figures are 33° and 48°, respectively. Normal position is considered to be a position in which a stable balance of the body, normal activity of the cardiovascular, respiratory and digestive systems, visual and auditory analyzers are provided.

Table 22.3. Standards for artificial lighting

Premises/rooms	Illumination, lux	
	incandescent lamps	*luminescent lamps*
Group rooms, play rooms, rooms for music lessons, reception, change-rooms in a preschool institution	150	200
Bedrooms in a preschool institution	50	75
Training rooms, classrooms, auditoriums, laboratories, workshops of schools and vocational schools	200	300
Drawing and technical drawing rooms	300	500
Gym halls and assembly halls	150	200
Recreational premises	100	150

Therefore, the dimensions of preschool and school furniture should be standard and meet the regulatory requirements listed in Table 22.4.

Tables, chairs and desks should have color markings that correspond to a certain group and that could be seen from the side of the passage between them. Marking is made in the form of a circle with a diameter of 25 mm or a horizontal strip 20 mm wide. On the desks (on the lower surface of the top and chairs — seats) a mark in the form of a fraction is made: in the numerator — the letter that defines the group of furniture, and in the denominator — the body length range of children for whom the furniture is intended (example, B/130–145).

It is necessary to maintain the correct ratio between tables and chairs which is regulated by the values of the distance of the seat, distance of the back and differentia (Fig. 22.2).

The best way to observe the basic hygienic requirements for school furniture is to use the classic school desk (Erismann's desk, Fig. 22.3).

There are the following criteria for hygienic evaluation of school furniture: seat depth which should be from 2/3 to 3/4 of the thigh length; differentia (vertical distance from the rear edge of the table top from the seat to the elbow of the freely lowered hand plus 5–6 cm); seat distance (horizontal distance between the front edge of the seat and the projection of the rear edge of the table top on the seat plane) between the seat and the rear edge of the table), that can be negative (when the edge of the seat goes beyond the edge of the table) and zero (when the edges coincide). The optimum distance is negative and should be 4–7 cm. The distance of the seat back (distance from the chair back to the rear edge of the table top) should exceed the anterior-posterior size of the student's chest by 5–6 cm. The angle of the table top is optimal in the range from 12 to 15". At mismatch of



Fig. 22.2. Modern desk



Fig. 22.3. Erismann's desk

Table 22.4. The main sizes of desks, tables and chairs for schoolchildren

Furniture group	Body length, cm	Height of the rear edge of the table top above the floor, mm	Seat height above the floor, mm	Marking color
A	Up to 130	540	320	Yellow
B	130–145	600	360	Red
C	145–160	660	400	Blue
D	160–175	720	440	Green
E	More than 175	780	480	White

the sizes of school furniture and students height, there is development of postural disorder.

The seat distance (distance from the rear edge of the table to the front edge of the seat in the horizontal plane) must be negative, i.e. the seat of the chair should go beyond the edges of the table by 3–4 cm for group A, 5–6 cm for groups B and C, and 7–8 cm for groups D and E (Fig. 22.4).

The seat back distance (distance from the rear edge of the table to the back of the chair in the horizontal plane) should exceed the anterior-posterior diameter of the chest by 3–5 cm.

The differentiation (distance from the rear edge of the table to the seat in the vertical plane) should exceed by 5–6 cm the distance from the seat plane to the elbow of the freely lowered arm of a sitting student.

When allocating desks and chairs for students in classrooms and training rooms, the smaller tables should be in the first three rows, in the last row — the largest furniture for this class.

Requirements for individual parameters of furniture allocation in the classroom are as follows: the distance from the first row of desks to the blackboard should be 2.4–2.6 m, the space between the rows of desks — 0.6–0.8 m, between the first row of desks and the outer wall — 0.6–0.7 m, between the third row and the inner wall — 0.5–0.6 m, between the rear wall and the last row of desks — 0.4–0.5 m.

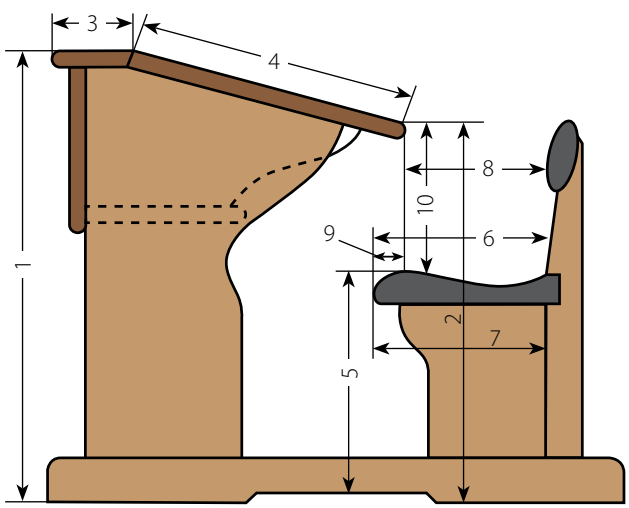


Fig. 22.4. The main sizes of the school desk: 1 — the height of the front edge of the table; 2 — the height of the rear edge of the table; 3 — the width of the horizontal part of the top; 4 — the width of the inclined part of the top; 5 — seat height; 6 — seat depth; 7 — seat width; 8 — seat back distance; 9 — seat distance; 10 — differentiation

If the classrooms are not rectangular but square in configuration, and the furniture is placed in 4 rows, the distance from the blackboard to the first desks (tables) should be not less than 3 m, the space from the desks of the first row to the outer wall should be 0.8–1 m, between rows of desks — 0.6 m.

The lower edge of the blackboard should be at a distance of 75–80 cm from the floor for elementary grade children and 80–90 cm — for middle and high school students.

To prevent postural disorders, students are moved from the first desk row to the third and vice versa at least 2 times a year without violating the conformity of the furniture group to their height and taking into account vision and hearing. According to the current sanitary and hygienic standards, the area per student should not be less than 1.25 m^2 in classrooms, and 1.4–1.65 m^2 — in training rooms or laboratories (depending on the profile of the laboratory), 3.3 m^2 — in workshops. Classroom length should be 9 m, width — from 5.7 to 6.2 m, height — not less than 3 m. Summary data on the indicators highlighted above in terms of comfort, allowable and unacceptable zones are reported for head masters of general education schools, who are directly responsible for sanitary and hygienic conditions in school premises.

The basic requirements for occupational hygiene have been transformed in relation to teachers and students as the main subjects of the educational process, i.e. their mental work at a lesson. Following the long or hard work, there is an objective body state of fatigue and reduced efficiency. The dynamics of the child's ability to work is largely determined by age and properties of nervous system. Younger schoolchildren become mentally tired quite quickly, so the study load for them is limited at school and at home. In middle grade students, the period of optimal working capacity of full compensation is prolonged, and in senior students, this period is stabilized and approached to the work norms of an adult.

Among the external factors that contribute to the improvement of mental performance of the subjects of the educational process, there are requirements for their seating at a table or desk. The workplace must be permanent. The height of the chair should be such that the legs rest with the full foot on the floor forming right or slightly obtuse angles in the hip and knee joints. Thighs 2/3–3/4 of the length should be on the seat. When seating at a desk, the chair is pushed 3–5 cm behind the table top. When reading and writing, the most appropriate position is to lean forward slightly. When listening to the

teacher's explanation, a "back" position is possible when the student is sitting back on a chair.

Proper sitting position of students, leaning back in their chairs, conditions for the functioning of the organs of vision, blood circulation, respiration, digestion prevent early fatigue, help to maintain correct posture. Especially teachers should monitor the working posture of students to prevent spinal curvature and vision deficiency.

School textbooks and children's toys must meet certain hygienic requirements (Fig. 22.5).

Regarding textbooks, these requirements are applied to the size and shape of the font, quality of the paper, text-pictures, size and weight of the books, and book covers. For preschool children and first-graders who learn to read, the height of the letters in textbooks should be 6–8 mm. The font height for pupils of 2–4 classes should be from 2 to 2.5 mm, and starting from the 5th class — 1.75 mm. The minimum thickness of the main strokes should be 0.25–0.3 mm, and the distance between them in the letter — not less than 0.5–0.6 mm.

In common textbooks, it is not recommended to structure the text on the page in two columns, because such format significantly complicates the functioning of the visual analyzer (increases the number of eye movements, makes it difficult to find the beginning of the lines). In textbooks for 1st–2nd classes, the distance between the lines should be not less than 2.8 mm (between words — not less than 4 mm), for 3rd–4th classes — not less than 3 mm, starting from 5th class — not less than 2 mm. The paper used for printing textbooks should be white or light yellow with a reflection coefficient of 0.7–0.8, which provides a good contrast between the background and the printed material (letters, drawings). When reading, the optimal distance between the head and text is considered to be 25 cm for children aged 8–9 years and 30–35 cm — for children from 11–12 years. The optimal angle of the book to the table surface should be 40–45°.

Based on the researches of a functional condition of the musculoskeletal system, and, mainly, the indicators defining stability of an upright position, the following admissible weights of a daily educational set (i.e. weights of textbooks, writing implements and a school backpack or bag) of schoolchildren are established: for 1st–2nd classes — 1.2 kg; for 3rd–4th classes — 2.2 kg; for middle classes — 2.2–3.2 kg; for senior pupils — 3.2–3.7 kg. However, it should be noted that the weight of each textbook for primary graders should not exceed 300 g.



Fig. 22.5. Textbooks of modern design. Source: *osvita.ua*

Special mention should go to the following basic hygienic requirements for toys: materials for their manufacture should not contain toxic substances. The use of waste materials is not allowed. The design of the toys and materials from which they are made must not pose a risk of injury. The surface coating of the toys must be safe and not washed off with hot (60 °C) water with 2 % chlorinated lime detergents or other disinfectant, and it should be resistant to saliva, sweat, and fire.

23 CHAPTER NUTRITION AS A FACTOR OF HEALTH, SCIENTIFIC FUNDAMENTALS OF RATIONAL NUTRITION

A. M. Antonenko, A. M. Hrynzovskyi, P. V. Stavnichenko, M. V. Kondratiuk

23.1. Nutrition hygiene as a science: definition of the concept, tasks

Nutrition hygiene, or trophology, is a branch of hygiene that studies and develops the issues of rational nutrition of healthy and sick people, substantiates measures for food safety and prevention of foodborne diseases.

The main task of nutrition hygiene is to improve health by maximizing the benefits of the biological effects of food on the body as an environmental factor.

In the field of nutrition hygiene, the doctor must:

1. Be able to give a hygienic assessment of the nutrition of a healthy, sick person or group of people and recommendations for its improvement.
2. Know the hygienic characteristics of basic food products used for human nutrition (chemical composition, biological value, and digestibility).
3. Be able to diagnose nutritional diseases, know the correct tactics for these diseases treatment, and most importantly — their prevention.
4. Carry out current sanitary supervision at public catering establishments (hospital, sanatorium food unit).
5. Be able to conduct sanitary and educational work on the use of nutrition for the prevention and treatment of diseases.

23.2. Scientific theories and concepts of nutrition

1. Ancient hematopoetic theory of nutrition (Aristotle, Galen).
2. Classical theory of balanced nutrition (Yu. Liebig, late 19th century.).
3. The theory of adequate nutrition (A. M. Ugolev).
4. The theory of balanced nutrition (A. A. Pokrovsky).
5. The theory of rational nutrition.
6. The concept of differentiated nutrition.
7. The concept of directed (targeted) nutrition.
8. The concept of individual nutrition.
9. The concept of natural nutrition.
10. The concept of a vegetarian diet.
11. The concept of separate nutrition according to G. Shelton.
12. The concept of raw food.
13. The concept of macrobiotic nutrition.

23.2.1. Classical theories and concepts of nutrition

The history of science considers three main theories of nutrition:

- antique;
- balanced nutrition;
- adequate nutrition.

Ancient theory of nutrition

The ancient theory was formed in the days of the ancient Greek thinker Aristotle and lasted until the time of the ancient Roman physician Galen. According to this theory, the nutrition of all body structures is due to blood, which is continuously formed in the digestive system from nutrients as a result of a complex process of unknown nature, to some extent similar to fermentation. This blood is purified in the liver, after which it is used for all organs and tissues nutrition. Numerous therapeutic diets of ancient people were built based on this theory. It served as one of the justifications for cleansing the body of harmful substances through bloodletting.

Theory of balanced nutrition (Fig. 23.1)

This theory originated more than 200 years ago and until recently had an advantage in dietology. It was de-

veloped on the basis of the achievements of natural science and was directly based on the research of Hermann Helmholtz and Robert Mayer, who formulated the law of conservation of energy in a living organism. The works of I. Sechenov were important for the development of this theory.

The essence of the theory of balanced nutrition:

1. An ideal diet is one in which the intake of nutrients in the body corresponds to their expenditure.
2. Food consists of several components that differ in physiological significance: useful, ballast and harmful, or toxic. It also contains essential substances that cannot be formed in the body, but are necessary for its vital functions.
3. Metabolism in humans is determined by the level of concentration of amino acids, monosaccharaides, fatty acids, vitamins and minerals, which allows creating the so-called "elemental" (monomeric) diets.
4. Food is disposed of by the body itself.

The theory of balanced nutrition has been re-evaluated. The crisis of this theory stimulated new research in the field of digestive physiology, food biochemistry, and microbiology. New digestive mechanisms were discovered. It turned out that digestion occurs not only in the intestinal cavity, but also largely directly on its wall, on the membranes of its cells. A previously unknown intestinal hormonal system was discovered. New information on the role of microorganisms that live permanently in the intestine and their relationship with the human body was received.

Theory of adequate nutrition

According to this theory, the necessary components of food are not only useful but also ballast substances (dietary fiber). The idea of the internal ecology (endoecology) of human, which exists due to the interaction of the organism and its microflora, was formed.

Normal nutrition is caused not by one flow of nutrients from the gastrointestinal tract into the internal environment of the body, but by several flows of nutrients and regulatory substances (Fig. 23.1).

The main nutrient flow is amino acids, monosaccharaides (glucose, fructose), fatty acids, vitamins, minerals, which are formed during the enzymatic breakdown of food. In addition to this main stream, five other streams of various substances enter the internal environment from the gastrointestinal tract.

Among them is the flow of hormonal and physiologically active substances produced by cells of the gastrointestinal tract. These cells secrete about 30 hormones and hormone-like substances that control not only the functions of the digestive system, but also the most important functions of the body.

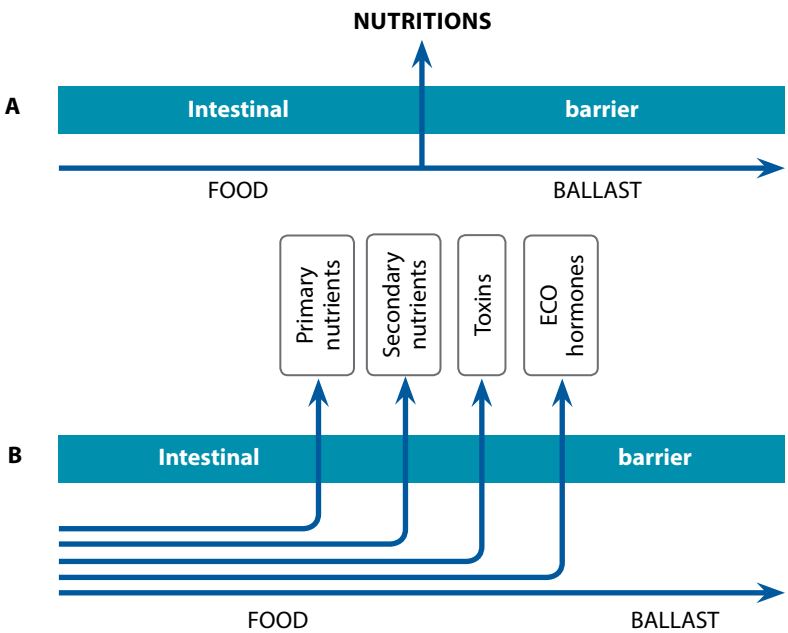


Fig. 23.1. Nutrient flows from the digestive tract according to the theory: A — balanced nutrition. B — adequate nutrition

Three more streams are formed in the intestine, associated with intestinal microorganisms (bacterial products modified ballast substances and modified nutrients). Conditionally, substances that come with contaminated food are released into a separate stream.

Thus, nutrition should be not only balanced but also adequate, i.e. meet the capabilities of the body. In the development of the theory of adequate nutrition is important the work of academician O. Ugolev, head of the laboratory of nutrition physiology of the I. Pavlov Institute of Physiology in St. Petersburg. The practical implementation of the postulates of the theory of adequate nutrition is the laws of rational nutrition.

Nutrition concept

Based on the theory of adequate nutrition, various scientific concepts of nutrition have been developed.

Concept of differentiated nutrition

This concept is based on the latest information on the composition of food and the biological constitution (genotype) of a human.

Concept of directed (targeted) nutrition

Nutrition standards used by various nutritionists are designed for an average person. However, such a person does not exist in nature. It is proved that any formula of a balanced diet cannot be equally adequate at once for all processes of vital activity of an organism of a certain person. It is impossible to choose a diet that protects against all xenobiotics at once. To justify nutrition, it is important to take into account the individual characteristics of metabolism in people within one region.

Concept of individual nutrition

According to this concept, a person includes a variety of foods in his diet. It is noticed: if a person prepares food independently, his taste needs, and accordingly, the supply of necessary substances are more fully satisfied. In some cases, choosing the right dishes, you can cause purposeful changes in your body. As individual food, it is possible to consider selection according to the taste and purposefulness of standard and independent diets.

23.2.2. Alternative theories and concepts of nutrition

In recent decades, many new original theories of nutrition have emerged that do not fit into traditional notions with deep historical roots. However, each of these theories has a rational grain. To choose your diet, it is important to know the strengths and weaknesses of alternative nutrition theories. Consider the main ones.

Vegetarianism (Fig. 23.2)

Vegetarianism is one of the oldest alternative theories of nutrition. This is the general name for food systems that exclude or limit the consumption of animal products.

Advantages of vegetarianism:

- reducing the risk of atherosclerosis;
- normalization of blood pressure;
- decreasing of blood viscosity;
- reducing the risk of tumor diseases of the intestine;
- improving bile flow and liver function.

Disadvantages:

- great difficulties in sufficient supply of the body with complete proteins, saturated fatty acids, iron, some vitamins when eating only plant foods, as most plant products contain relatively few of these substances;
- while following the principles of strict vegetarianism, it is necessary to consume excessive amounts of plant foods that would meet the body's energy needs. Hence, the overload of the digestive system with a large amount of food, which causes a high probability of dysbacteriosis, hypovitaminosis and protein deficiency;
- for people affected by serious diseases, such as malignant tumors, diseases of the blood system, such food can be fatal; over time, under conditions of strict vegetarianism, a person may develop a deficiency of iron, zinc, calcium, vitamins B_2, B_{12}, D, essential amino acids — lysine and threonine.

Therapeutic fasting

The period of complete abstinence from food can be short (1–3 days), of medium duration (7–10 days) or long (up to 40–50 days). The latter should be performed only under strict medical supervision. The course of medical fasting is a serious burden on the body, a kind of stressful situation.

Currently, dosed fasting and unloading diet therapy are among the methods of treatment of many acute and

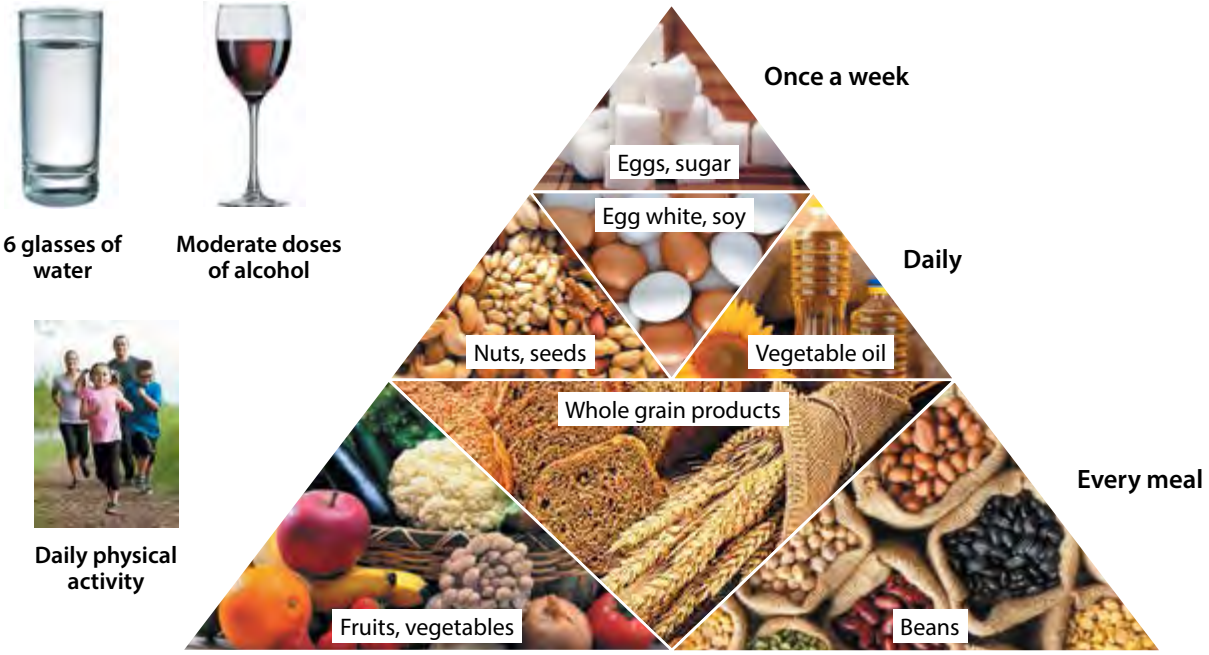


Fig. 23.2. Vegetarian food pyramid. Source: *https://www.vectorstock.com/royalty-free-vector/vegetarian-food-pyramid-vector-23317592*

chronic diseases: cardiovascular, gastrointestinal, allergic, respiratory, joint, obesity, a number of mental disorders.

Ancestor nutrition theory

This theory is based on the assumption that modern human inherited from his distant ancestors an adaptation only to a certain diet from products that have not been subjected to heat treatment. Supporters of two directions — raw food and dry eating, preach the theory of ancestral nutrition; however, these directions, despite the general concept, are antagonistic to each other.

Theory of separate food (Fig. 23.3)

The main provisions of G. Shelton's theory:

1. Do not eat protein and starch at the same time — meat, fish, eggs, cheese, milk, cottage cheese are incompatible with bread, flour products and cereals. This is due to the fact that proteins are digested in an acidic environment in the lower part of the stomach, and starch — in its upper parts under the action of salivare enzymes and requires an alkaline environment. In the acidic environment of the stomach, the activity of salivary enzymes is inhibited, and the digestion of starch is stopped.
2. Acidic foods should not be combined with protein and starchy foods because they destroy pepsin in the stomach. As a result, protein food rots, and starchy food is not digested.
3. Sugar and sweet fruits are recommended to eat separately from everything else.



Fig. 23.3. Separate food. Source: *peda.net*

Theory of the main food factor (macrobiotics) (Fig. 23.4)

Macrobiotics is based on a bipolar picture of the world, which is reflected in nutrition. According to it, each food product contains the polar elements yin and yang. To calculate the ratio between yin and yang, for example, the method of growth (underground, above ground), growth time, color, shape, structure, mineral and water content are taken into account. The method of preparation can increase the content of yin or yang in the product.

Macrobiotics evaluates a dish in terms of the ratio of yin and yang in it. The desired ratio is 5:1. For example, whole grains meet this condition. That is why the basis of the macrobiotic diet is whole grains.

Concept of nutritional value indices

The essence of the concept is that the value of food or diet for the body is the sum of quantitative values that characterize the chemical components of the product. However, such attempts lead to the fact that qualitatively ambiguous components of the diet appear in the index as interchangeable. This creates the danger of the formation of defective rations, because it is not based on a balanced diet of basic nutrients, and the number of accrued indices.

Concept of "living" energy (Fig. 23.5)

The concept of "living" energy has been known since the beginning of the 19th century. Its supporters are convinced that there is a special energy in the environment, peculiar only to a living being — "living". It is transmitted through certain substances, structures, which cannot be "materialized". Perhaps such a material substrate is adenosine triphosphate (ATP). However, calculations have shown that macroergic phosphorus compounds can give only one hundred thousandths of a percent of the energy of proteins, fats and carbohydrates. In addition, no systems capable of absorbing phosphate energy have been identified in the digestive tract. The tragic experience of the last world war showed that a diet with an energy value of about 4.2 mJ (1000 kcal) causes dystrophic disorders in the body.

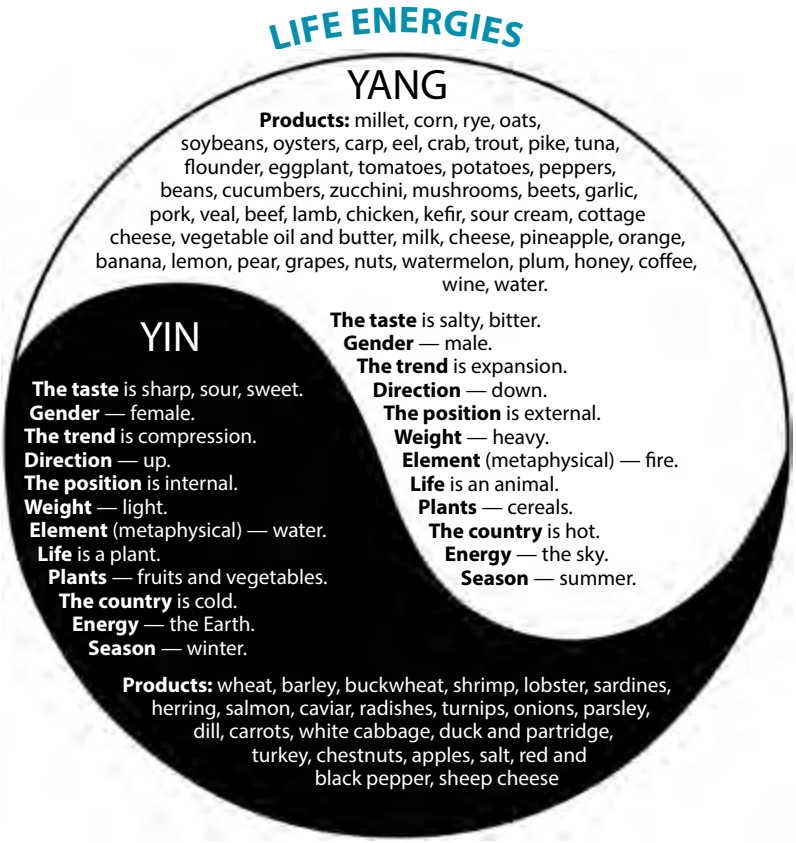


Fig. 23.4. Theory of the main food factor — macrobiotics

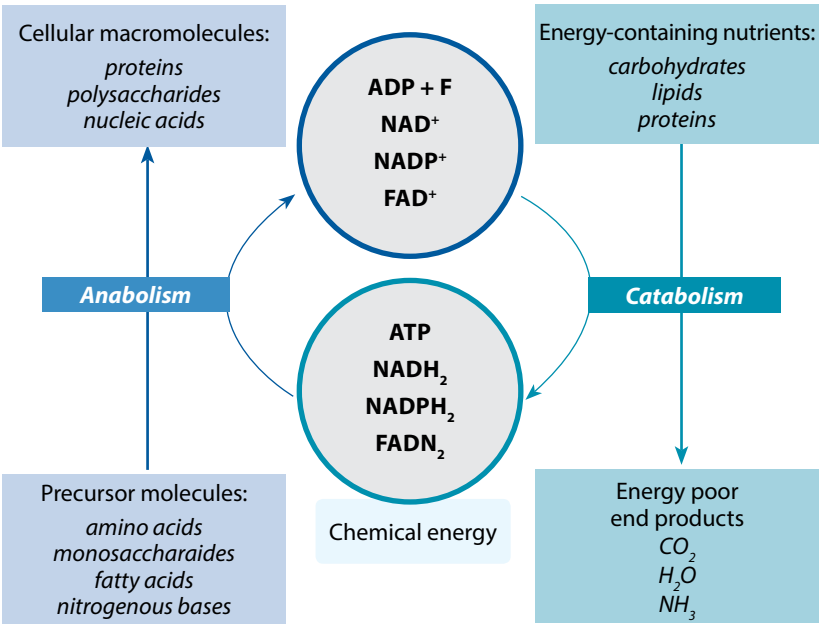


Fig. 23.5. Functioning of "living energy". Source: *svitppt.com.ua*

According to many modern researchers, the concept of "living" energy is unscientific and cannot be recommended for use in nutrition.

23.3. The importance of nutrition for the health and physical development of the population

In the body, two opposite processes occur simultaneously. The first is catabolism, or dissimilation, which involves reactions involving the breakdown of substances, their oxidation, and the excretion of breakdown products. The second — anabolism or assimilation — combines all the reactions associated with the synthesis of essential substances, their assimilation and use for growth, development and vital functions of the organism. These two processes are the basis of metabolism and are the main sign of life (Fig. 23.6).

Due to metabolism and the inseparable interrelation of the processes of dissimilation and assimilation, the organism interacts with the environment. The combination of catabolic and anabolic processes provides a constant renewal of body composition, which is therefore in a dynamic state of continuous adjustment and renewal. The processes of dissimilation and assimilation, their mutual relation and interrelation constitute the essence of life

23.4. Basic functions and biological action of food

Food functions

1. Energy — proteins, fats, carbohydrates, organic acids (pasta, cereals, confectionery, potatoes, sugar, fats).
2. Plastic — proteins, minerals, lipoids. Assimilation — processes that depend on food intake; dissimilation — a constant, independent process (meat, fish, dairy and egg products).
3. Bioregulatory — amino acids, vitamins, microelements, polyunsaturated fatty acids (vegetables, fruits, berries, and bird eggs).
4. Adaptive-regulatory — dietary fibers, water (wheat, rye bread from wholemeal flour, cereals, potatoes, vegetables, fruits).
5. Immune-regulatory — essential omega-3 fatty acids, zinc, iron, iodine, proteins, vitamins (effects on immunocompetent cells).
6. Rehabilitation — changing of the properties and chemical diet (regulation of functions and trophism of tissues, organs and systems of the body as a whole in the direction of their weakening or strengthening). Acceleration of recovery, prevention of recurrence.
7. Signal-motivational — flavoring and extractive substances (regulation of food motivation). Seasonings (vinegar, salt, sugar), onions, garlic, dill, celery, essential oils, mustard, vitamins.

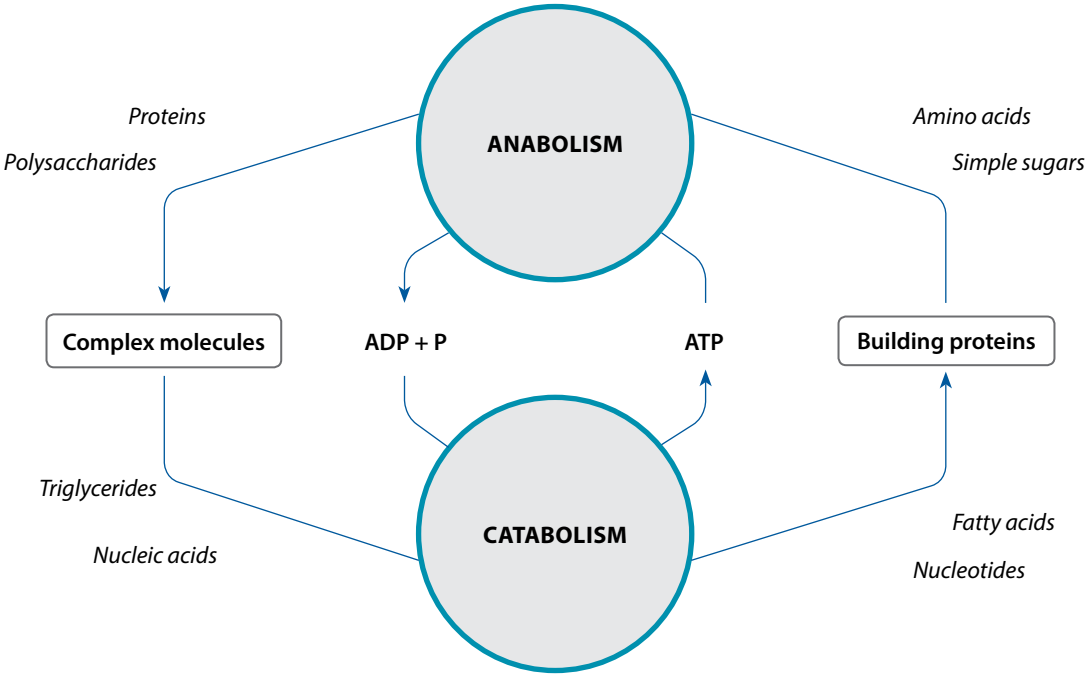


Fig. 23.6. Metabolism in human body. Source: *http://krebbing.blogspot.com/2007/12/anabolism-and-catabolism.html*

Biological effect of food

1. Specific effect that prevents the emergence and development of the syndrome of malnutrition and overeating (nutritional diseases).
2. Nonspecific effect that prevents the development and progression of non-infectious (non-specific) diseases.
3. Protective effect that increases the body's resistance to the adverse effects of the production environment.
4. Pharmacological effect that restores homeostasis disturbed by the disease and the activity of functional systems of the body.

23.5. Types of food

Types of food:

1. *Preventive* — a balanced diet, adjusted for risk factors for non-contagious diseases, taking into account the presence of human inherent biochemical and physiological characteristics, which appeared due to adverse environmental influences.
2. *Therapeutic and prophylactic* — to prevent the development of occupational diseases (milk, dairy products, vitamins, pectin).
3. *Ecological and protective* — to increase the resilience of the body of the population living in environmentally hazardous areas.
4. *Dietary (therapeutic)* — to restore the homeostasis disturbed by a disease and the activity of functional systems of the body.

Therapeutic — the use for therapeutic purposes of special diets for sick people with acute diseases and chronic diseases in the acute stage (exacerbation).

Dietary — the use for preventive purposes of special diets and foods for people with chronic diseases in remission.

23.6. Scientific bases and conditions of rational nutrition

Rational nutrition is full in quantity and balanced in quality nutrition pattern for normal height, physical and psychophysiological organism development, its high work capacity, active longevity and adverse environmental natural, man-caused, social environment factors resistance.

Functions of nutrition

1. Rational nutrition provides the optimal ratio between the processes of assimilation (anabolism) and

dissimilation (catabolism) of the human body at different periods of his life.
2. Rational nutrition determines a high and stable physical and mental performance of the body, compensates for energy expenditure that occurs in all types of work.
3. Rational nutrition provides high specific and nonspecific resistance, endurance and wide adaptive capacity of the organism to the action of adverse environmental factors.
4. Rational nutrition ensures the normal functioning of the organs of the gastrointestinal tract.
5. Nutrition determines the effective primary, secondary and tertiary prevention and treatment of diseases of the gastrointestinal tract (gastritis, colitis, enteritis, pancreatitis, peptic ulcer disease), cardiovascular system (coronary heart disease, hypertension), endocrine system (diabetes) and other diseases.

Rational nutrition provides active human longevity, i.e. a significant life expectancy while maintaining high efficiency, because it avoids metabolic disorders caused by insufficient or excessive in quantitative or qualitative terms nutrition.

The rational nutrition has to follow such basic principles

1. To be full in quantity. The dietary intake food calorific value must correspond to the organism energy consumption including the undigested part of the dietary intake.
2. To supply the dietary intake quality (balance) which means that all nutrients, proteins, fats (including animal), carbohydrates (including polysaccharides, celluloses, dietary fibers), vitamins, macro- and microelements, flavoring substances must be contained in optimal quantities and ratios.
3. The rational dietary pattern must be followed: food intake hours must correspond to the organism biological rhythms: adults must have 3–4 meals a day and children of different ages — 5–6 meals a day. Intervals between food intakes must be 5–6 hours for adults and 3–4 hours for children. The daily intake distribution must correspond to the organism physiological needs: the breakfast and dinner (the organism physical activity period) must contain 30–35 % and 45–50 % of the daily intake, the supper (after finishing the active daily period) — 20–25 %.
4. Food must be cooked in accordance to the digestive system enzyme abilities. The perfect taste, good nutrition value, easy gastrointestinal digestion and high level of food absorbency must be reached during the food preparation.
5. Food must not be toxic. Products and ready meals must not contain the toxic substances in concentrations harmful to the human organism.
6. Food must be harmless in epidemiological aspect. Products and ready meals must not contain the etiological agents of infectious foodborne diseases — bacteria, viruses, fungi, protozoa, geo- and biohelminth embryos.

23.7. Tasks of hygienic science and sanitary practice in solving modern problems of nutrition

1. To determine the optimal hygienic requirements for the quality and range of traditional and new products enriched with proteins, vitamins and other useful components, to develop criteria for enrichment of products with biologically active substances that ensure the optimal usefulness of these products for the population.
2. To scientifically substantiate the provision of high quality and biological value of a wide range and production of baby, preventive and dietary foods.
3. To strengthen control over residual chemical plant protection products or increase food production efficiency

23.8. Expert evaluation of food products. Indicators and degrees of food quality

The safety of livestock and plant products and food raw materials is one of the crucial components of economic security of each state. The ability to guarantee such security determines a country's ability to effectively control the production and import of safe and quality food. Intensive industrial development and widespread urbanization of agriculture lead to the entry of foreign substances into food raw materials and food, which adversely affect the health of the population. In addition, a certain danger may be the uncontrolled use of food additives, which are provided by many new technologies for food production. In this regard, food safety and qual-

ity are one of the main factors determining the health of the population of Ukraine.

Prior to Ukraine's accession to the WTO, all responsibility for food safety and quality rested with producers, who often developed and approved their own technical conditions without any restrictions other than formal compliance with general sanitary requirements. Development of their own technical specifications (TS) allowed manufacturers to apply at production of foodstuff various food additives for the purpose of improvement of taste qualities, color, appearance, giving of necessary consistence, optimum humidity. This made it possible to replace natural raw materials with soy, high-grade meat — with low-grade meat, and in some cases with organic or even chemical substitutes, which can be harmful to human health.

The task of hygienic examination of food products is to determine the properties that characterize the nutritional value and safety of products for human health (professor Sokolovskaya I. A.) (Fig. 23.7).

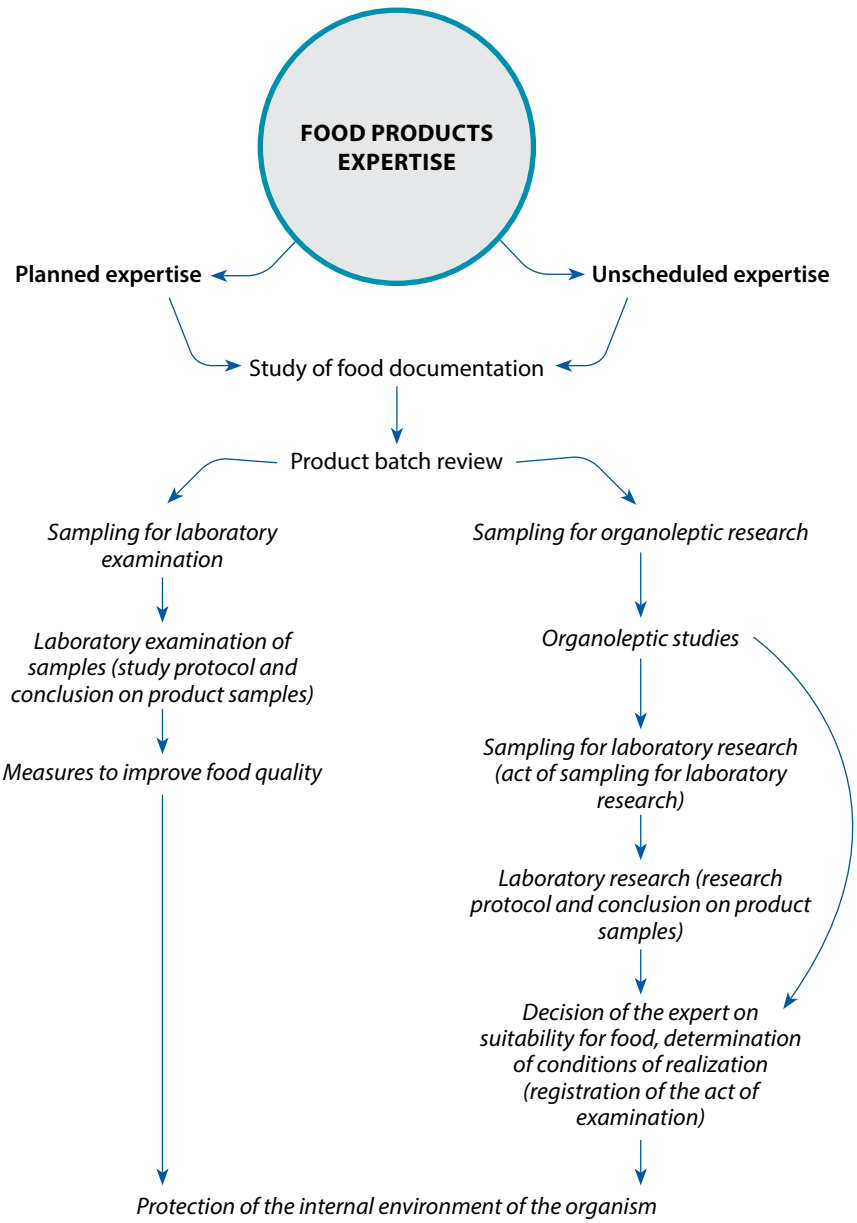


Fig. 23.7. Organization and procedure for examination of food products (MD, professor Smolyar V. I. Modern problems of identification and falsification of food products)

Degrees of food quality

A good quality product is a product that fully meets the requirements of the State Standard.

A low-quality product is a product that has certain deviations from the State Standard, but they cannot cause complaints or changes in the health of a consumer.

A conditionally suitable product is a product that has certain deviations from the requirements of the State Standard, which may cause complaints or changes in the health of the consumer, but can also be eliminated through the use of special cooking measures (additional heat treatment, addition of spices, etc.).

A substandard product is a product that has certain deviations from the requirements of current standards and quality standards, which can cause complaints or changes in the health of the consumer and cannot be eliminated by special culinary processing. Such a product should not be used in human nutrition and, therefore, is intended for destruction or processing, followed by use for animal feed, technical purposes and the like.

Counterfeit (falsified) products are products with altered properties, produced to deceive the consumer.

Refined products are products released from ballast substances by means of special processing means.

Surrogate products (or ersatz products) are products made to replace natural ones.

24 CHAPTER FUNCTIONS OF FOOD SUBSTANCES. HYGIENIC PROBLEMS OF UNDERNUTRITION AND OVERNUTRITION

A. M. Antonenko, M. M. Korshun, O. O. Novokhatska, I. V. Tkachenko

24.1. Classification and physiological functions of essential nutrients

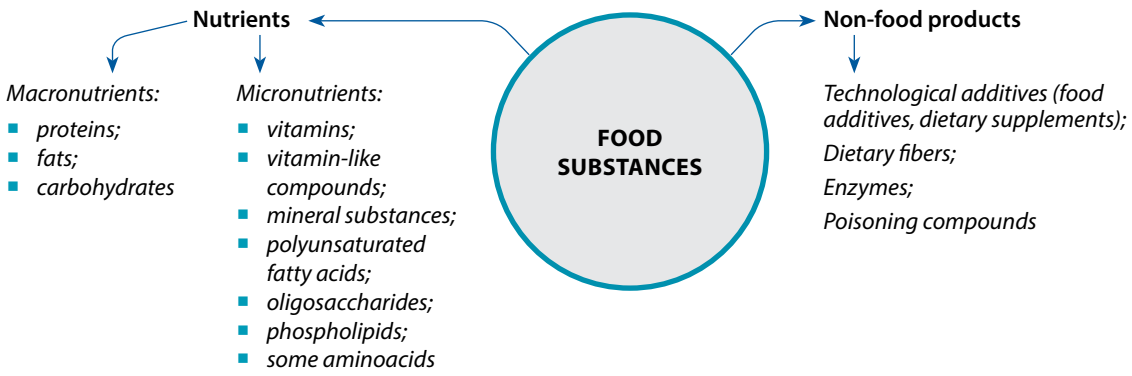


Fig. 24.1. Classification of nutrients (Humeniuk O. L. Food chemistry. Texts of lectures)

Table 24.1. Physiological functions of proteins

Function name	Function description
Structure	Proteins are the structural basis of all tissue and organ cells (collagen) and make up 22 % of human body weight
Plastic	Proteins are the main material for the processes of growth and development of the body, cell and tissue regeneration, a source of essential amino acids
Motor	Proteins (actin, myosin) provide muscle contraction, blood circulation, the work of all internal organs, human movement in space
Regulatory	Proteins ensure the normal functioning of the central and peripheral nervous system, conditioned reflex activity and internal inhibition. Humoral regulation of metabolism is carried out mainly by enzymes (biocatalysts), which are proteins, or hormones of polypeptide (protein) nature
Transport	Proteins are carriers of oxygen, carbon dioxide (hemoglobin, carboxyhemoglobin), hormones, metals, vitamins
Buffer	Proteins are involved in maintaining a constant reaction of the environment (pH) in blood plasma, cerebrospinal fluid, intestinal secretions
Protective	Proteins provide the body with resistance to infectious diseases, toxins, the formation of natural and acquired immunity (g-globulins, properdin)
Energy	Proteins determine 11–13 % of the body's daily energy needs. Energy expenditure of 1 gram of protein — 4 kcal, or 17 kJ

Table 24.2. Physiological functions of fats

Function name	Function description
Structure	Fats are part of the protoplasm and cell membranes of various tissues; form fat depots. Fats make up 12 % of a person's body weight
Protective	Adipose tissue in fat depots (subcutaneous tissue, adipose tissue around internal organs, intermuscular layers of fat) protect internal organs and tissues from bruises and concussions
Heat protection	Fat depots prevent heat transfer to the environment, insulate the body and participate in thermoregulation
Regulatory	Fats provide permeability of cell membranes and protoplasm for metabolic products, regulate the enzymatic activity of proteins by forming biologically active forms, promote the formation of proteins, carbohydrates, mineral salts and vitamins
Transport	Fats deliver biologically active substances to the body — polyunsaturated fatty acids (linoleic, linolenic, arachidonic and lupanodonic), lipids, phosphatides (lecithin) and sterols of animal (zoosterols — cholesterol) or plant origin (phytosterols — sitosterol), fatty acids A, D, E, K
Digestive	Fats provide favorable taste properties of food, increase the duration of food persistence in the stomach, create a feeling of satiety, promote the absorption of proteins, carbohydrates, minerals and vitamins
Energy	Fats determine 33 % of the body's daily energy needs. Energy expenditure of 1 g of fat — 9 kcal or 38 kJ

Physiological functions of polyunsaturated fatty acids

1. Plastic.
2. Ensuring the functions of the cell membrane.
3. Reducing the synthesis, conversion and excretion of cholesterol.
4. Synthesis of prostaglandins.
5. Normalization of the vascular wall (increased elasticity, decreased permeability).

Main functions of vitamins

1. Biosynthesis of heme, cytochrome P450, mercapturic acids, etc.
2. Coenzyme role.
3. Functioning of the antioxidant system, maintenance of the structure and functions of the endoplasmic reticulum (E, A, C).

Main functions of minerals

1. Maintaining the acid-base status.
2. Prevention of accumulation of acidic products of metabolism.
3. Substrates for the synthesis of heme, cytochrome P450, hemoglobin, porphyrins, glutathione peroxidase.

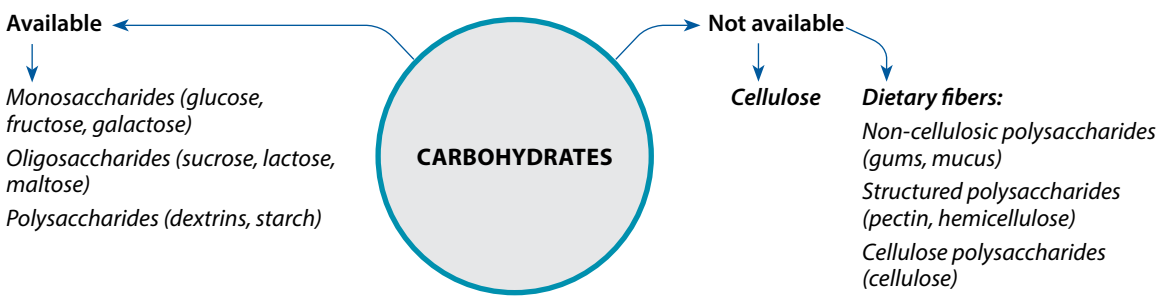


Fig. 24.2. Carbohydrates classification

Table 24.3. Physiological functions of carbohydrates

Function name	Function description
Structure	Carbohydrates are part of the cells of all tissues, forming stores (glycogen) in the liver, muscles, myocardium and brain tissue. Carbohydrates make up 2 % of a person's body weight
Energy	Carbohydrates are the main source of energy. Energy expenditure of 1 g of carbohydrates — 4 kcal, or 17 kJ
Plastic	Carbohydrates are involved in the synthesis of nucleic acids, BUN, glucoproteins, mucopolysaccharides, coenzymes. With excessive intake of carbohydrates, fatty acids are formed from them
Buffer	Oxidized to CO_2 and H_2O and reduce acidosis, ie help maintain a constant reaction of the environment (pH) in blood plasma
Disposal	Carbohydrates limit the body's use of fats and proteins for other purposes
Protective	Carbohydrates prevent the penetration of microorganisms through cell membranes (hyaluronic acid), normalize the intestinal microflora (fiber, pectin), delay the development of intestinal bacteria (breast milk oligosaccharides), inhibit the development of putrefactive microorganisms (lactose, lactose, pectin) and weak disinfectant action (pectins), determine the human blood group (heteropolysaccharides)
Digestive	Low-digestible carbohydrates (fibers) stimulate the secretory activity and peristalsis of the gastrointestinal tract, bind water and thus increase the volume of food lumps, promote the influence of food enzymes and maximum digestion, form fecal masses, prevent constipation, provide daily bowel movements
Regulatory	The content of carbohydrates in tissues determines the intensity of redox processes
Preventive	Carbohydrates play an important role in the prevention of caries, diabetes, atherosclerosis, thrombosis, myocardial infarction, stroke

24.2. Assessment of food adequacy. Nutritional status of the organism, its types, indicators and methods of study

Assessment of food adequacy is carried out by:

1. Determination of indicators that characterize the diet, dietary habits and eating conditions. To do this, use the following methods:
   - social and hygienic:
     - questionnaire method;
     - interrogative-weight;
     - weight;
     - statistical method (according to reports and menu layouts).
   - socio-economic bases of nutrition:
     - budget method;
     - balance method.
2. Nutrition health research. To do this, determine the nutritional status.

Nutritional status — the physiological state of the organism due to its nutrition.

Dietary status — the actual state of nutrition of the population or a person.

The study of the nutritional status of a person or an organized group of persons with the same physical, emotional load and general nutrition allows you to objectively assess this diet and timely identify nutritional disorders and diseases (energy-protein, vitamin, macro-, micronutrient deficiency, etc.). Therefore, along with determining the energy expenditure and completeness of the daily diet, the assessment of nutritional status is one of the first and main methods of medical control over the nutrition of different sexes, age and socio-professional groups.

There are several categories in the classification of nutrition status:

1. *Optimal*, when physiological condition and body weight correspond to height, age, sex, severity, intensity and strenuousness of work performed.
2. *Excess*, due to hereditary predisposition, overeating, insufficiency of exercises; accompanied by weight

gain, obesity, which occurs in four stages: I — fat deposits 15–20 % more than normal body weight; II — by 30–49 %; III — by 50–99 %; IV — 100 % or more.

3. ***Insufficient*** when body weight lags behind age, height — due to malnutrition (quantitative and qualitative), heavy and intense physical labor, psycho-emotional stress and so on.

In addition to the above, professor P. E. Kalmykov identifies the following categories of nutritional status:

Pre-disease (premorbid), caused (in addition to the abovementioned) by the different physiological disorders of the organism or the most evident intake defects (energy, protein, fat, vitamin, macro- and microelement deficiency).

Morbid (unhealthy) — weight loss caused by the disease, starvation (strong intake defects both quantitative and qualitative). The starvation may take two forms — alimentary cachexia (severe weight loss, marasmus), edematous which may be caused mostly by the protein lack at the intake. The vitamin deficiency — in avitaminosis (scurvy, beri-beri, rickets and others), other nutrient deficiencies show themselves in corresponding pathology forms.

The study of the nutritional status of a person or a homogeneous in mode of work and nutrition collective is carried out on a set of indices — subjective (questionnaires, surveys) and objective (Table 24.4).

Methods of assessing nutritional status

1. **Socio-economic** (used by the State):
   - budget (food costs);
   - balance (consumption of basic products).
2. **Socio-hygienic:**

Questionnaire data should include information on:

- passport data, gender, age, profession;
- bad habits (smoking, alcohol, drugs);
- working conditions (type of work, severity and intensity of work, the nature and severity of occupational hazards — physical, chemical, biological, overstrain of individual organs and systems);
- living conditions, degree and quality of public services, physical culture, sports (type, regularity), economic opportunities of the family or organized team;
- the nature of food for 1–3 days: the number of meals, hours and place of reception, the list of dishes, products, their weight, the quality of cooking, etc.

Among the objective indicators of nutritional status, the most informative and important are:

1. *Somatoscopic:* examination of the human body or (selectively) a group of people in the study group allows to identify the number of signs that quantitatively and qualitatively characterize their nutrition.
2. *Somatometric:* measurement of length, body weight, chest, shoulder, waist, pelvis, thighs circumference, thickness of skin and fat folds (at the lower angle of the shoulder blade, on the back of the middle of the shoulder, on the lateral surface of the chest, abdomen).

   Based on these measurements, calculate the mass growth indices:

   2.1. Broca Index — normal body weight (BW) in kg is equal to body height (BH) in centimeters minus 100 (105 or 110):

   for men:
   - at a height of 155–165 cm BW = BH – 100;
   - at a height of 166–175 cm BW = BH – 105;
   - at a height of more than 175 cm BW = BH – 110.

   In all cases, women's body weight should be 5 % less than men's one.

   2.2. Kettle mass growth index — body mass index (BMI) is calculated by the formula:

$$BMI = \frac{BW}{BH^2},$$

where BW — body weight, kg; BH — body height, m.

3. *Physiometric indices of nutritional status*. Energy and plastic value of nutrition is assessed by determining muscle strength (manual, dynamometer, ergometry), restitution of pulse and respiration after exercise,

Table 24.4. Main indices of nutritional status

Functions of nutrition	Nutritional adequacy	Morbidity
1. External nutrition (digestion and absorption) 2. Internal nutrition (intermediate exchange and assimilation)	1. Nutritional deficiency 2. Food redundancy 3. Imbalanced diet	1. Specific alimentary-associated morbidity 2. Nonspecific morbidity 3. Infectious morbidity

indicators that characterize fatigue — tremometry, chronoreflexometry, number search and more.

4. *Clinical indices* — determination of alimentary origin diseases symptoms (gastritis, gastric and duodenal ulcers, liver and gallbladder diseases, gout, hypo-, avitaminoses, etc.).
5. *Biochemical indices* — hematological, urological and other indicators of nutritional status.

24.3. Main types and methods of determining the body's energy expenditure

Energy expenditures:

1. *Not regulated* by the human:
   - energy expenditure for basic metabolism (work of the heart, lungs, kidneys, maintenance of temperature, muscle tone);
   - energy expenditure due to the specific dynamic action of food — the strengthening of oxidative processes for the conversion of nutrients in the body of basic metabolism); are approximately 10% of the value of the basal metabolism.
2. *Regulated* (work, household behavior, housework, sports).

Energy expenditure also depends on climate weather conditions, workplace microclimate, nature and quality of clothing, skills and abilities in the labor process.

Methods for determining the body's energy expenditures

1. *Laboratory* — methods of direct and indirect calorimetry.
2. *Calculation:*
   - according to anthropometric and chronometric data;
   - by specific energy expenditure and types of energy expenditure;
   - by nomograms.
3. *Laboratory-calculation* — the method of "alimentary calorimetry" (according to the dynamics of body weight and caloric content of the diet).

The most accurate, but cumbersome methods of determining energy expenditures are the following methods:

- direct calorimetry (according to the release of heat from the body in a special calorimetric chamber);
- indirect calorimetry — by gas exchange (the amount of oxygen and carbon dioxide consumed per unit time), which is determined at rest and when performing a particular job. Exhaled air for analysis of O_2 and CO_2 content is accumulated in special Douglas bags;
- pulsometry method, in which with the help of a special device — pulsotachometer — the frequency and filling of the pulse are measured when performing various types of work and other loads, the results of which in the device are automatically translated into kilojoules;
- method of alimentary energymetry — laboratory determination of caloric content of the daily diet, taking into account the undigested part of food;
- calculation methods: separately determine the basal metabolism using special tables of Harris and Benedict on the basis of sex and body weight (first number), as well as sex, age and height (second number). The sum of these numbers is the value of the basal metabolism. To the basic metabolism are added energy expenditure for the specific-dynamic action of food, which is 10% of the value of the basic metabolism, and energy expenditure for all types of stress performed by a person during the active part of the day (physical and mental work, rest, eating, etc.). These energy costs are calculated using special tables, which set out the energy (in calories) for different types of load for 1 hour, based on daily time — the number of hours or minutes spent by a person during the day for each type of load.

Specialists of the World Health Organization (WHO) have developed a method for determining energy expenditure, according to which the basal metabolism (BM) and the specific dynamic effect of food are calculated by special equations based on age, sex, height, body weight (Table 24.5), and energy expenditure — by multiplying the BM by the physical activity ratio (PAR), the values of which are designed for different activities.

The average values of BM were also developed taking into account gender, age, body weight and specific-dynamic action of food and PAR in accordance with the professional affiliation of the person.

The sum of the basal metabolism with specific-dynamic action of food and energy expenditure for all types of activity will be daily energy expenditure.

Table 24.5. Equation for calculating basal metabolism (based on body weight and height)

Age range (years)		Basal metabolism (BM), kcal
Men	10–18	16.6 × BW + 77 × BH + 572
	18–30	15.4 × BW – 27 × BH + 717
	30–60	11,3 × BW + 16 × BH + 901
	over 60	8.8 × BW + 1128 × BH – 1071
Women	10–18	7.4 × BW + 82 × BH + 217
	18–30	13.3 × BW + 334 × BH + 35
	30–60	8.7 × BW – 25 × BH + 865
	over 60	9.2 × BW + 637 × BHP – 302

where BW — body weight, kg; BH — body height, m.

24.4. Quantitative and qualitative completeness of nutrition. Physiological norms of nutrition

The breakdown of nutrients coming from the environment occurs in the body as a result of dissimilation, accompanied by the release of energy, which is the energy of metabolism. The body spends a lot of energy on work. All the body's energy expenditure can be determined.

The energy expended on the basic metabolism (BM) Is spent on maintaining the necessary level of life support systems — the constancy of the heart, respiratory function, excretory function, maintaining a constant body temperature and so on. The energy of the basal metabolism for each person is individual and at the same time is a fairly constant value. Approximately in average conditions it is possible to accept the size of energy of the basal metabolism for 1 kcal on 1 kg of body weight for an hour. The value of the basal metabolism can be determined by special studies, as well as by calculation using special formulas and tables (for example, tables of Harris and Benedict).

The loss of energy for basal metabolism depends on many factors, which are determined by both the state of the organism and environmental conditions. In women, the basal metabolism is 5–10 % lower than in men. In children, the basal metabolism is higher than in adults. In this case, the younger the child, the greater the rates of basal metabolism. Exceeding the basic metabolism in children can reach 15 % or more compared to adults. In the elderly, on the contrary, the basic metabolism is reduced by 10–15 % compared to the young.

The value of the basal metabolism is influenced by the state of the central nervous system, stress, infectious diseases, hormones. Thyroid hormones increase metabolism, sex hormones and pituitary hormones reduce basal metabolism.

In people living in areas with an average annual temperature of about 0 °C, the basal metabolism is increased by 5 % compared to those living in areas with an average annual temperature of +10 °C. In people living in areas where the average annual temperature is above +20 °C the basal metabolism is reduced by 5 %.

The energy needs of people living in the far north are 10–15 % higher, and in the south — 5 % lower than in temperate climates.

Due to the less intensive metabolic processes and lower body weight, women's energy needs can be accepted on average 15 % less than men in the relevant groups.

The energy value of the diet of pregnant women should be 2900 kcal, and nursing mothers — 3200 kcal. The energy intensity of children's diet depends on age, intensity of plastic and energy processes.

It should be noted that the required relative caloric intake of children per unit body weight is 1.5–2.0 times higher than in adults, and is 80–100 kcal/kg for children under 5 years, 70–79 kcal/kg for 6–13 years, 60–69 kcal/kg for 14–17 years and 53 kcal/kg for adults.

The total energy expenditure can also be calculated by the specific energy expenditure per 1 kg of body weight: for persons of group I it is 40 kcal, for group II — 43 kcal, for group III — 46 kcal, for group IV — 53 kcal and more.

In the scientific literature, you can find data expressing human energy expenditure in both calories and kilojoules. Today we must express all scientific data in the SI system, ie energy — in kJ. Keep in mind that 1 kcal corresponds to 4.2 kJ and 1 kJ corresponds to 0.24 kcal.

Knowing a person's daily energy expenditure, i.e. energy needs, it is easy to calculate the need for dynamic nutrients.

As mentioned above, the percentage of daily energy expenditure, which is covered by proteins, is on average 11–13 %, due to fats — 30–33 %, due to carbohydrates — 56–59 %.

The values of caloric coefficients are: for proteins — 4 kcal/g, for fats — 9 kcal/g, for carbohydrates — 4 kcal/g.

24.5. Problems of general starvation and overeating. Their social essence, impact on health, prevention

It is known that 1/4 of the Earth's population, or more than 2 billion 100 million people, overeat (Fig. 24.3–24.5). According to recent studies, people in the Middle East and North Africa most often encounter this problem. In these countries, 60 % of men and 65 % of women are overweight. On second place — India, followed by China and the United States (15 %). Moreover, we are talking about the population, which violates the balance of the diet in the direction of increasing both in quantity and in quality.

If the weight is 5 % greater or less than the average, it fits into the concept of norm. If the weight is higher than the average by 6–14 %, it is an overweight person. If the weight exceeds the average by 15 % or more, this is already a phenomenon of obesity. There are four degrees of obesity: degree I — excess weight 15–29 %; degree II — 30–49 %; degree III — 50–99 % and degree IV — 100 % and more.

The largest proportion of overweight people live in the dwarf island nations of the Pacific Ocean. Overweight figures make up more than 90 % of the total population: in Nauru it is a record — 92.8 % and on the Cook Island — 90.6 %. Developed Gulf countries have a high level of overweight: Kuwait 79.3 %, Qatar — 72.1 %, the UAE — 72.0 %, Saudi Arabia — 71.3 %.

The geography of obesity among the countries of the world is almost the same as the geography of the share of overweight people. The leaders are also the island nations of the Pacific region with rates of 60–70 %, and residents of Kuwait, 42.8 % of whom are obese suffer from this disease the most among the developed countries of the world.

Excess body weight is a significant risk factor for a large number of diseases; it increases morbidity, disability, mortality. This thesis is especially illustrative of the example of mortality. In general, if we take the mortality of people with normal weight for 100 %, then for people with significant obesity it is up to 179 %. Obese children are more likely to have diseases of the upper respiratory tract. Obesity in pregnant women leads to complicated childbirth, more frequent fetal asphyxia, higher infant mortality during childbirth.

At the same time, the issue of hunger remains relevant in many countries.

The data provided by The Food and Agriculture Organization of the United Nations (FAO) is impressive. The daily caloric content of the diet of the majority of the population in India and Latin America is about 2000 kcal (instead of 3000–4000), in Kenya — 2020 kcal.



Fig. 24.3. Overeating. Photo source: *thesun.ie*

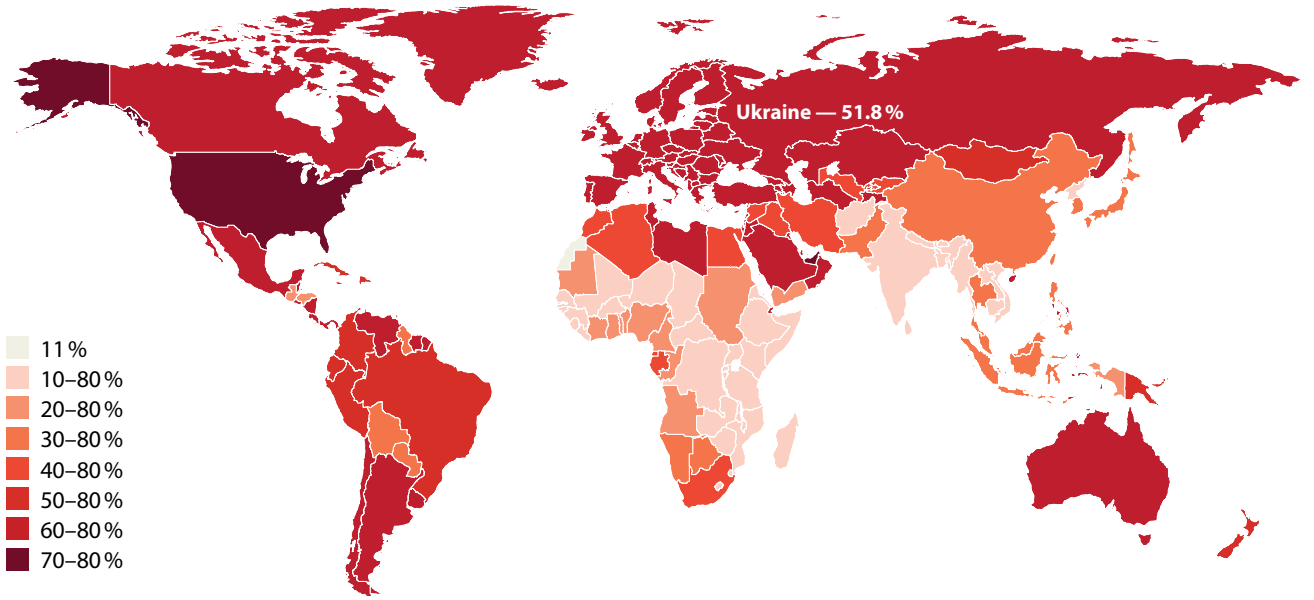


Fig. 24.4. Number of overweight people *(World Obesity Federation)*

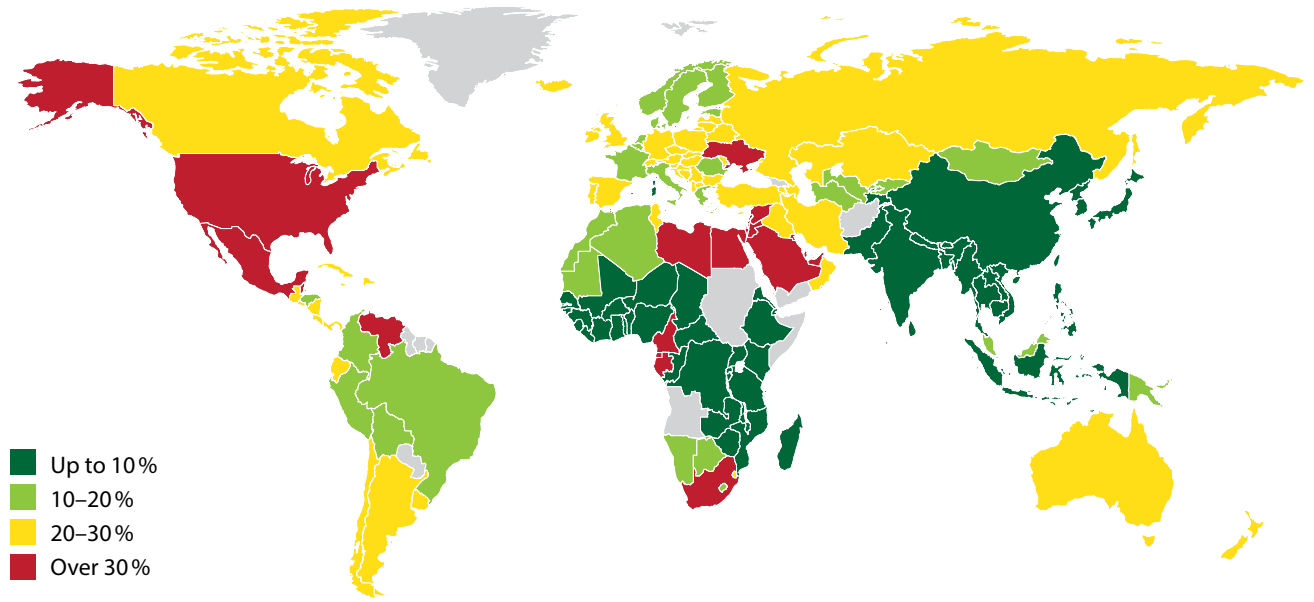


Fig. 24.5. Number of obese people *(World Health Organization)*

Of particular importance is protein starvation, which is observed against the background of quantitative inferiority of the daily diet and leads to disastrous consequences.

According to WHO (FAO), the population of most developing countries has 1/3 fewer calories in their daily diet, almost twice less protein and 5 times less animal protein than people in developed countries (Fig. 24.6).

Such systematic malnutrition, especially low content in the daily diet of the most biologically valuable proteins of animal origin, leads to:

1. Deterioration of physical and psychological development of entire nations.
2. Extinction of individual tribes and nationalities.

In total, 40.000 people die of hunger every day on Earth.

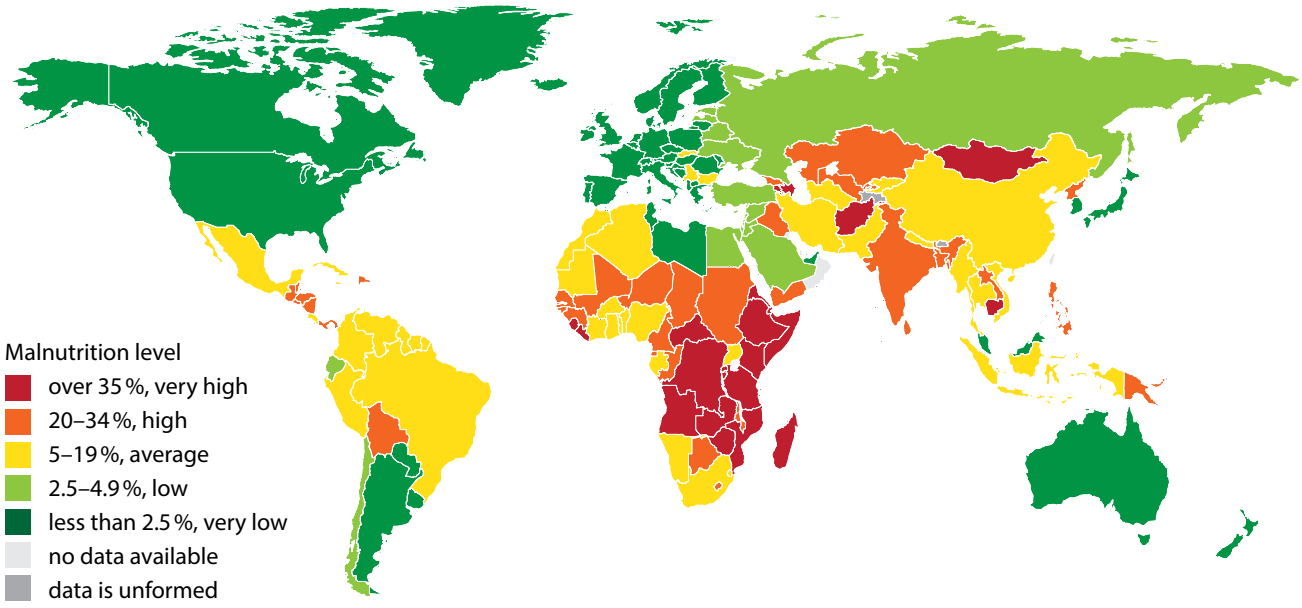


Fig. 24.6. World Hunger Index. Source: *propelsteps.wordpress.com*

Pathological conditions and diseases associated with a lack or excess of protein in the human diet are singled out.

Protein deficiency (kwashiorkor — a disease of children weaned). No animal products. Symptoms:

- blood albumin (edema);
- lipoproteins (fatty liver disease);
- hemoglobin synthesis (anemia);
- enzymatic activity of pancreas (secondary ↓ utilization of proteins).

Protein-energy malnutrition, alimentary insanity (weakness, ↓ efficiency, feeling of chills and hunger, senile face, dull, brittle hair).

Excess protein: more than 3 g/kg — gout; 3–5 g/kg — androgenization of the body (early sexual maturity), ↓ growth rate, acid-base state shifts to the acidic side, the level of CNS excitation increases.

24.6. New methods of obtaining and sources of nutrients

1. Genetically modified products.
2. Vegetarian days.
3. The diet of cavemen.
4. National cuisine.
5. The use of insects.
6. Maximum use of ocean resources.
7. Balancing what is grown and consumed.

25 CHAPTER DISEASES RELATED TO VIOLATION OF THE BASICS OF RATIONAL NUTRITION AND CONSUMPTION OF SUBSTANDARD PRODUCTS

A. M. Antonenko

25.1. Definition and classification of diseases associated with violation of the basics of rational nutrition and consumption of substandard products

Nutritional (alimentary) diseases are pathological conditions associated with a violation of the basics of rational nutrition and the consumption of poor quality products.

Classification of nutritional diseases

Group 1 — diseases directly related to nutrition (primary syndromes of excess or malnutrition):

- diseases associated with starvation, quantitative and qualitative malnutrition (alimentary insanity, kwashiorkor);
- diseases associated with overeating (obesity, gout, androgenization of the child's body);
- diseases and pathological conditions associated with impaired supply of vitamins and microelements:
  - hypovitaminosis, hypervitaminosis, avitaminosis;
  - hypo- and hyper- micro- and macroelementosis.

Group 2 — secondary diseases:

- diseases associated with nutrition regimen disorders (gastritis, gastric ulcer, duodenal ulcer, coprostasis, etc.);
- diseases associated with disorders of culinary processing of products (also gastritis, peptic ulcer disease, etc.).

Group 3 — diseases that have a multifactorial etiology, often on the background of genetic predisposition:

- atherosclerosis, hypertension, urolithiasis, diabetes mellitus.

Group 4 — nutritional factors of transmission of infectious and parasitic diseases that are transmitted only through food, food poisoning, xenobiotic poisoning:

- food poisoning;
- intestinal bacterial, viral, zoonotic infections (typhoid fever, paratyphoid A, B, dysentery; hepatitis A, polio, enteroviruses; brucellosis, foot and mouth disease, tuberculosis and others); geo- and biohelminthiasis (roundworms, hairworms, bovine, porcine tapeworms, Trichinella, fish tapeworms, flukes, etc.);
- damage by products contaminated by means of mass destruction in the modern war — radioactive products of nuclear explosions, war poisons, especially dangerous bacterial agents (radioactive, toxic, bacterial substances).

Group 5 — food intolerance (set of clinical reactions to food):

- food allergy (immunological mechanism);
- pseudoallergy (nonspecific individual reactions, enzymopathy).

25.2. Food poisonings: definition, classification (Table. 25.1)

Food poisoning **is an acute (rarely — chronic) non-contagious disease caused by the consumption of food that contains a large number of certain types of semipathogen microorganisms or contains toxic substances of microbial or non-microbial etiology.**

Food poisoning does not include:

1. Alcohol poisoning (it is not a food product of rational nutrition).
2. Poisoning by food in which poison has been introduced for the purpose of murder or suicide (domestic criminal cases).
3. Poisoning by poisonous substances accidentally taken as edible.
4. Digestive disorders caused by the consumption of unripe fruits, berries, gross violations of the

Table 25.1. Classification of food poisoning

Group	Subgroup		Etiological factor
Microbial	Toxicoinfections		Conditionally pathogenic strains of Escherichia coli, Proteus, Streptococci, Bacillus cereus, Clostridium perfringens, etc.
	Toxicoses	Bacterial toxicoses	Toxins of enterotoxigenic staphylococci. Botulinum toxin
		Mycotoxicoses	Toxins of fungi of the Aspergillus, Fusarium, Claviceps purpura group
Non microbial	Poisoning by products that are toxic in nature	Plant origin	Seeds of poisonous weeds (heliotrope, trichodesma, sophora); wild and cultivated plants: blackthorn, datura, hemlock, belladonna, elderberry)
		Animal origin	Caviar of some fish (Schizothorax, Barbels, Tetraodontidae); endocrine glands (adrenal glands, pancreas)
		Mushrooms	Amanita phalloides, morels
	Poisoning by foods that may be poisonous under certain conditions	Plant origin	Bitter kernels of stone fruits (peach, apricot, cherry), beech seeds, raw beans, sprouted potatoes
		Animal origin	Liver of pike, burbot, beluga, mackerel; mussels, honey
	Poisoning by impurities to good quality food		Impurities that pass into food from utensils, equipment, inventory, packaging materials: salts of heavy metals (lead, zinc, copper, etc.); pesticides, polymer degradation products, food additives (not allowed or used in unauthorized doses)
Unknown	The etiology is not fully understood (assumed to be the presence of toxic fungi in combination with some macro- and micronutrients). Toxic properties of some non-toxic fish		Endemic osteoarthritis (Kashin — Bek disease), or strontium-induced rickets. Haff disease (Alimentary-toxic paroxymal myoglobinuria)

principles of nutrition (wrong combination of foods).
5. Nausea and vomiting in a mental reaction to certain properties of food.
6. Toxicosis of pregnant women.
7. Allergic and anaphylactic reactions on food.
8. Acute hypervitaminosis (A, D).
9. Intestinal infections.

25.3. Food toxicoinfections: definition, types, etiology, characteristic signs, prevention

Food toxicoinfection is an acute, often massive disease that occurs when eating food that contains a large number of live pathogens and their toxins released during the death and reproduction of microorganisms (Table 25.1, Table 25.2).

Food toxicoinfections are characterized by:

1. Sudden outbreak and very short incubation period (6–24 hours).
2. Almost simultaneous disease of all those who consumed the same food, irradiated with opportunistic pathogens.
3. There is a strong connection between the disease and the consumption of certain foods prepared or sold with violation of sanitary norms.
4. Territorial limitation of the disease due to the area of sale of microbially contaminated product.
5. Absence of contact (contagious) cases of the disease.
6. General orientation of preventive measures.

Table 25.2. Conditions of occurrence and characteristic symptoms of major toxicoinfections

Products in which it is contained and conditions of reproduction	Factors that negatively affect	Incubation period, duration of the disease, main symptoms	Features
E. coli			
Dairy and meat products (heat-treated, not subject to repeated heat treatment) 35–45 °C	100 °C	4–10 hours 1–3 days Similar to the gastrointestinal form of salmonellosis	Source — human; outbreaks in the warm season
Pr. mirabilis, Pr. vulgaris			
Minced meat, blood sausage, fish, potato dishes 25–37 °C	Stable	4–6 hours (24–36 hours) 2–5 days 37.5–38.5 °C, cramp-like abdominal pain, repeated vomiting, diarrhea with blood. Weakness, cyanosis, convulsions, oliguria	Foods contaminated with Proteus, seemingly benign (if have undergone heat treatment before contamination with Proteus), although Proteus belongs to putrefactive proteolytic microbes. This is because Proteus unable to break down a protein molecule, it breaks down polypeptides
Enterococci			
Ready meals without repeated heat treatment (liver and blood sausage, sausages, cheese, meatballs and meatballs, jellies, mashed potatoes, creams	85 °C — 10 min	3–18 hours Few hours — 3 days Nausea, vomiting, abdominal pain, diarrhea	They make foods slimy and cause an unpleasant bitter taste
Cl. perfringens			
Meat and meat products in case of violation of the terms of sale		5–22 hours 1–2 hours Repeated stinking diarrhea, nausea, tenesmus and abdominal pain. Normal temperature.	Spore-forming anaerobes
Bac. cereus			
Vanilla and cream egg sauce, canned meat in gravy, freshly prepared meat powder, vanilla pudding, fried pork. 30–32 °C	Sodium chloride 10–15%, acidic environment, high fat and sugar content	4–16 hours 2 days Colic-like abdominal pain, nausea, diarrhea (liquid, watery stools with large amounts of mucus, 10–12 times a day)	Aerobic spore bacterium does not change the organoleptic properties of products

Main measures for the prevention of food poisoning:

1. Timely treatment of food workers.
2. Identification of E. coli carriers among employees of food units and their remediation.
3. Hygienic training of food workers, health education.
4. Interruption of distribution routes.
5. Veterinary and sanitary supervision of animals.
6. Strict observance of sanitary rules of technology of production of foodstuff and dishes which are not subject to repeated heat treatment.

7. Strict observance of the sanitary regime on the food object and the terms of realization of products.
8. Appropriate measures in case of use of conditionally suitable products.
9. Observance of terms and conditions of realization of perishable products.

25.4. Bacterial toxicosis: definition, types, etiology, characteristic signs, prevention

Bacterial toxicosis is an acute disease caused by eating food that contains a toxin that has accumulated due to the development of a specific pathogen (Table 25.3).

In this case, the pathogen itself may no longer be in the food or it is detected in small quantities.

The main clinical difference between toxicosis and toxicoinfection is the absence of fever.

Measures to prevent botulism:

1. Measures to free raw materials from spores — mechanical cleaning of products intended for canning, thorough heat treatment.
2. Measures to destroy and inactivate the toxin.

Measures to prevent staphylococcal toxicosis:

1. Do not allow to work persons with purulent diseases, persons with acute catarrhal phenomena of the upper respiratory tract.
2. Sanitize employees of food establishments — carriers of staphylococcus.

Table 25.3. Conditions of occurrence and characteristic symptoms of major bacterial toxicoses

Products in which it is contained and conditions of reproduction	Factors that negatively affect	Incubation period, duration of the disease, main symptoms	Features
Botulism, Cl. botulinum			
Canned food, smoked sausage. For a long time, anaerob increases its activity in the digestive tract under the action of trypsin and pancreatin	Vegetative forms — alkalis and high temperatures, spores are resistant to physical and chemical factors	4–72 hours, 4–8 days Forms: "botulinum" acute gastroenteritis, dyspeptic-paralytic, ophthalmoparalytic and asphyxia. Nonspecific symptoms (first few hours): general weakness, headache, heartburn, nausea, repeated vomiting, diarrhea. Specific symptoms: neuro-paralytic phenomena, as a result of dysfunction of bulbar centers: diplopia, ptosis, mydriasis. Paralysis of the soft palate, tongue, pharynx, larynx, aphonia, impaired chewing and swallowing, constipation, flatulence, dry mouth, throat. Death from respiratory failure with clear consciousness. Polyvalent serum is administered. In the absence of effect, re-enter the serum after 5 hours	**According to toxin formation, all canned food is divided into 3 groups:** 1. Animal origin, vegetable (green peas, beans, asparagus, cauliflower). The toxin appears in 3–4 days. 2. Stuffed peppers, stuffed tomatoes, eggplant. Toxin after 5–6 months. 3. Sauerkraut, compotes, vegetable and fruit juices, tomato products. The toxin is formed if there are molds in the can that have consumed oxygen
Staphylococcal toxicosis, St. aureus, St. epidermidis			
Milk and dairy products, meat and meat products, custard confectionery. Mashed potatoes, wheat porridge. Nutitive media with a sugar concentration of less than 50 %	At pH 3.0, the toxin is inactivated by slight heating. At t 4 °C the toxin is not formed. Lactic acid inhibits development	30 min — 6 hours, 1 day. t — normal or subfebrile, nausea, repeated incessant vomiting with convulsive urges, sharp, cramping pain in the epigastric region, headache, cold sweat. Treatment is nonspecific	The optimum temperature for food storage is 2–4 °C. They do not change the organoleptic properties of products

3. Prevention of colds, timely treatment of diseases of the teeth and pharynx, sanitation in the workplace.

25.5. Food mycotoxicosis: definition, types, etiology, characteristic signs, prevention

(Table 25.4)

Food mycotoxicosis is mainly a chronic non-contagious disease that occurs as a result of eating foods that contain toxic metabolites of microscopic fungi.

Prevention of mycotoxicosis:

1. Exclusion of conditions that create high humidity of vegetable raw materials.
2. Harvest in the fall.
3. Adhere to grain storage conditions.
4. Withdrawal of grain that overwintered in the field and providing the population with good quality grain.

Table 25.4. Conditions of occurrence and characteristic symptoms of major mycotoxicoses

Growth conditions, breeding environment	Signs and symptoms
Aspergillus flavus, Aspergillus parasiticus — aflatoxin — cirrhosis and primary liver cancer	
27–30 °C, at relative air humidity more than 85 %. Substrates rich in starch (wheat, rye, barley, oats, rice, corn, sorghum) at a humidity of more than 18 % and lipids (peanuts, sunflower, cottonseed, copra of various nuts) at a its humidity of more than 10 % and relative air humidity 95–97 %	Lethargy, loss of appetite, incoordination, convulsions, paresis, digestive disorders, weight loss and developmental delays. Coagulopathy, hemorrhage, edema, fluid accumulation in the cavities, jaundice
Fusarium Sporotrichioides — fusariotoxin — alimentary-toxic aleykiya, or septic sore throat	
24–30 °C. Bread from cereals overwintered in the field (poisoning by "drunk bread")	1st stage — acute symptoms of intoxication. Bitter taste in the mouth, woodiness of the tongue, fever (burning) in the mouth, tearing in the throat and pharynx, pain when swallowing, symptoms of general intoxication. 2nd stage — leukopenic. Inhibition of leuko-, erythro- and thrombocytopoiesis. 3rd stage — pronounced clinical phenomena. Rash, bleeding, necrotic sore throat, hyperthermia, tachycardia. 4th stage — recovery and possible complications
Penicillium expansum — patulin — malignant neoplasms	
Mostly in the rotten part of apples, pears, stone fruits, juices, purees	Mutagenic and carcinogenic effects. In the initial stages — general symptoms
Claviceps purpurea — ergot alkaloids — ergotism	
Resistant to heat. Wheatgrass, oatmeal, barley, oats, rye, wheat	Convulsive form — general weakness, loss of appetite, pain throughout the body, tingling sensation, cold, vomiting, dyspepsia, contracture of the flexors of the arms and legs (in the case of a single intake of cereals with a large number of horns. Gangrenous form — 10–20 days after repeated consumption of grain, which contains horns in small quantities; general weakness, drowsiness, necrosis in peripheral areas of the body, limbs turn black, cool, lose sensitivity

25.6. Poisoning by plant products, poisonous under certain conditions: types, etiology, characteristics, prevention

Poisoning by products of plant and animal origin, which are poisonous by nature are rare. This is mainly poisoning of children left unattended. However, be sure to pay attention to poisoning with substances of plant origin, poisonous under certain conditions (Table 25.5), and mushroom poisoning (Table 25.6).

25.7. Mushroom poisoning: characteristic signs, prevention, treatment

The main types of mushroom poisoning and their clinical picture are given in Table 25.6.

Prevention of mushroom poisoning:

- ban on the sale of dried lamellar mushrooms on the market;
- fresh mushrooms can be sold only whole (with a leg);
- cook for 7 minutes — conditionally edible. Remove the broth, rinse with cold water.

25.8. Main measures of the doctor who first diagnosed food poisoning

Among the main measures of the doctor who first diagnosed food poisoning, it is necessary to highlight the following:

- provide emergency care to patients;
- when providing assistance, take vomit (wash water), feces, urine, blood for laboratory tests and put it in the cold;
- hospitalize all patients;
- examine all healthy people who ate suspicious food;
- establish medical supervision over healthy people;
- visit the kitchen, check the implementation of sanitary hygienic requirements;
- remove suspicious food and product, prohibit their use, take a sample, put in the cold;
- find out where the suspicious product came from;
- write an emergency report.

Table 25.5. Conditions of occurrence and characteristic symptoms of major poisonings caused by plant products, poisonous under certain conditions

Product (source), poisoning conditions	Disposal method	Clinical signs, features
Fazin (toxalbumin — hemagglutinating substance)		
Bean. The use of bean flour and food concentrates in insufficient heat treatment	Intense heating	Dyspeptic phenomena
Amygdalin (glucoside that cleaves hydrocyanic acid during hydrolysis)		
Bitter almonds (2–8 %) and bitter kernels of stone fruits (4–6 %). 60–80 g of peeled apricot kernels — death. Pomace after production of peach oil	Heat treatment. Stone fruit jam is safe, because during cooking the enzyme loses activity and hydrocyanic acid is not formed, but it can be stored only 1 year after canning	Mild form: headache, nausea. Severe: cyanosis, convulsions, loss of consciousness
Fagin		
Gray beech nuts	In the confectionery industry, only heat-treated nuts are used (120–130 °C 30 min)	General weakness, headache, nausea, bowel dysfunction
Solanine (hemolytic poison)		
Green or sprouted potatoes. Potato storage outdoors. Dose for poisoning: 200–400 mg		Nausea, vomiting, intestinal dysfunction. Bitter taste and scratching in the throat when eaten

Table 25.6. Conditions of occurrence and characteristic symptoms of major poisonings caused by mushrooms

Toxin	Signs of a mushroom	Clinical symptoms
Green, yellow and white — pale toadstool		
Anatoxin — resistant to heat, not destroyed by digestive enzymes. Gray toadstools contain phallotoxin — the strongest cellular poison, but is inactivated when heated	In July — a yellow tuberous thickening and a "collar" at the bottom of the leg	12 hours of incubation period. It starts at night. Sharp abdominal pain, diarrhea, vomiting, thirst, headache, dizziness ■ 50 % die in 2–3 days with clear consciousness; ■ after a short-term improvement, colic, diarrhea, jaundice appear in some people; death — in 9–10 days; ■ with a favorable course — a gradual slow recovery
Morels		
Galvenic acid (0.2–0.4 %). Hyromitrin	April — May, early June. Shapeless hat with a wavy or tortuous surface, the edge only partially fused with a cylindrical, very short leg	Poisoning is possible only with fresh mushrooms. The incubation period is 8–10 hours. It develops slowly: a feeling of fullness and pressure in the stomach, pain and nausea and vomiting for 1–2 days. On day 2, jaundice (hepatotropic poison) appears, the temperature is subfebrile. ■ 25 % die in 3–4 days in a coma with heart failure; ■ recovery for 4–7 days (after 5th days no one dies)

26 CHAPTER HYGIENIC IMPORTANCE OF VITAMINS AND MICROELEMENTS

A. M. Antonenko

26.1. The concept of vitamins and vitamin-like compounds, their classification, main functions and factors that determine the human body's need for vitamins

Vitamins are low molecular weight organic compounds that are necessary for the mechanisms of enzymatic catalysis and act in very low concentrations.

All vitamins are divided into fat-soluble (A, D, E, K) and water-soluble (C, group B and others).

Vitamin-like compounds:

- essential nutrients with a predominantly plastic function (choline, inositol);
- biologically active substances synthesized in the human body (lipoic acid, orotic acid, carnitine);
- biologically active substances in food (bioflavonoids, methylmethionine sulfonium) (vitamin U);
- growth factors of microorganisms (paraaminobenzoic acid).

Factors that determine the body's need for vitamins:

1. Physiological factors: sex, age, physiological condition, individual characteristics of the organism.
2. Natural and social conditions: climate, latitude, nature of food, difficulty of work.

26.2. The concept of hypovitaminosis, avitaminosis, hypervitaminosis and main causes of their occurrence

Hypovitaminosis is a pathological condition caused by a lack of vitamins in the body.

Avitaminosis is a disease that occurs in the absence of vitamins in the body.

Hypervitaminosis is a pathological condition associated with the intake of large amounts of vitamins.

Hypo- and especially avitaminosis is more typical for water-soluble vitamins, because they are easily excreted from the body and do not accumulate in tissues. Hypervitaminosis in most cases occurs with an excess of fat-soluble vitamins (they have a depot in the body, easily accumulate).

Main causes of hypo- and avitaminoses:

1. Nutritional deficiency of vitamins:
   - reduction of the content in the daily diet;
   - destruction due to prolonged and improper storage of products;
   - action of antivitamin factors contained in products (ascorbate oxidase, myaminase, niacytin);
   - unbalanced amount of vitamins in the diet;
   - distortion of eating habits and religious prejudices about the consumption of certain foods;
   - anorexia.
2. Inhibition of normal intestinal microflora that produces vitamins:
   - diseases of the gastrointestinal tract;
   - irrational chemotherapy.
3. Violation of the assimilation of vitamins:
   - disorders of absorption in the gastrointestinal tract (diseases of the stomach, intestines, lesions of the hepatobiliary system, competition with other vitamins, genetic defects in the transport and absorption of vitamins);
   - utilization of vitamins by intestinal helminthes and pathogenic intestinal microorganisms;
   - violation of the formation of transport forms of vitamins;
   - antivitamin action of pharmaceuticals.

4. Increasing the need for vitamins:
   - features of the physiological state (pregnancy, lactation);
   - features of climatic conditions;
   - intense physical activity;
   - infectious diseases and intoxications.

26.3. Hypovitaminosis: specific and nonspecific symptoms, examples, prevention (Table 26.1, Table 26.2)

General symptoms: weakness, decreased ability to work, increased fatigue, dizziness, drowsiness or insomnia, dry skin and mucous membranes, dullness and fragility of hair, decreased immunity.

Specific symptoms (Table 26.2, Fig 26.1):

Example:

Vitamin E, B_{13} (orotic acid): atherosclerosis, ischemia, infertility (because their main function is antioxidant).

Vitamin K (phylloquinone): hemorrhage, nosebleeds.

Vitamin C, P: petechial hemorrhages.

The fundamental difference in hemorrhages in vitamin K and C deficiency is in the mechanism of their development. In the first case, the function of blood clotting is disrupted, so the hemorrhage is more massive, and in the second — collagen synthesis is disrupted and, accordingly, reduces the strength and elasticity of the vascular wall, which leads to its fragility and the formation of small hemorrhages.

Vitamin B_2 (riboflavin): cheilosis (cracks in the corners of the mouth); oily seborrhea of the face; glossitis (swollen tongue with cracks); photophobia, decreased visual acuity; angular stomatitis. In this case, the typical presence of all symptoms on the face.

26.4. Avitaminosis: symptoms, examples, prevention

Rickets is a lack of vitamin **D** in babies by age 1. Although this is a fat-soluble vitamin, 1-year-olds still do not accumulate it enough, and the skeleton grows very quickly and the function of vitamin D is actively realized — the absorption of calcium and phosphorus by the bones. Therefore, beriberi can occur. Typical symptoms of rickets are a towering skull, a wedge-shaped chest, and an O-shaped curvature of the legs. The first sign is pumping hair on the back of the head.

Scurvy is a lack of vitamin **C**. It is manifested by heavy bleeding of gums and tooth loss. For the first time scurvy was found in sailors who ate a monotonous diet while sailing. Once the causes of this disease have been established, sauerkraut must be added to their diet.

Bery-beri disease is a lack of vitamin **B_1** (thiamine). Manifested by characteristic symptoms: chills, pain in the legs when walking, fatigue.

Pellagra — lack of vitamin **PP** (nicotinic acid). Manifested by a characteristic triad of DD: dermatitis, diarrhea, dementia (memory loss, dementia, delirium).

The main measures for the prevention of hypo- and avitaminosis are a balanced diet that meets the physiological state and activity of the body, the right combination of foods, their proper heat treatment (Fig. 26.2).

26.5. Hypervitaminosis: causes, symptoms, examples, prevention

The main cause of hypervitaminosis is irrational vitamin prophylaxis — that is, the use of doses of vitamin preparations that significantly exceed the recommended. This is mainly due to the fact that the body absorbs only the amount of nutrients it needs from natural foods, and excretes the rest.

General symptoms of hypervitaminosis are symptoms of intoxication: nausea, vomiting, fever, headache.

There are only known cases of *hypervitaminosis of vitamin A* with the consumption of large amounts of carrots (children develop "carotene jaundice") and bear liver (in the far north). An early characteristic sign of hypervitaminosis A is very dense and tangled hair, like a sponge.

It is important to remember about the possibility of *vitamin D* hypervitaminosis, especially in children, which is manifested by convulsions.

Vitamin K hypervitaminosis is rare. Manifested by hypercoagulation and thrombus formation.

The main principles of prevention of hypervitaminosis are compliance with the recommended doses of vitamin preparations and their strict appointment according to the indications.

Table 26.1. Main functions of fat-soluble vitamins, symptoms of violation of their entry into the human body

Vitamin	Daily needs for adult person	Physiological function	Main sources	Hypovitaminosis	Avitaminosis	Hypervitaminosis
A (retinol)	1 mg	Needed for the synthesis of the visual pigment rhodopsin (twilight vision); affects the processes of proliferation and keratinization of the epithelium	Animal fats, meat, eggs, milk, red vegetables and fruits	Hemeralopia (twilight vision impairment), color perception disorders, thin, dull hair, peeling skin	—	Tight, tangled hair, pain in the legs when walking, swelling and soreness in the clavicle, elbow flexion
D (calciferol)	2.5 μ (100 IU)	Needed for absorption of calcium and phosphorus ions from the intestine	Mammalian liver and meat, fish liver, eggs. Synthesized in the subcutaneous fat under the action of UVR	Muscle weakness, osteoporosis, frequent bone fractures (typical of the elderly due to loss of vitamin D receptors)	Rickets (only in children 1 year of age)	In children — convulsions; in adults — calcifications in the internal organs
K (phylloquinone)	0.2–0.3 mg	Participates in the synthesis of coagulation factors, prothrombin, etc.	Green leaves of vegetables. Synthesized in the intestine	Hemorrhages subcutaneously and in internal organs, nosebleeds	—	Hypercoagulation, thrombus formation
E (tocopherol)	15 mg	Antioxidant (oxidation inhibitor), affects fertility	Nuts, meat, vegetable oil	Atherosclerosis, ischemia, infertility (male and female)	—	Infertility (male and female), miscarriage in early pregnancy

Table 26.2. Main functions of water-soluble vitamins, symptoms of violation of their entry into the human body

Vitamin	Daily needs for adult person	Physiological function	Main sources	Hypovitaminosis	Avitaminosis
C (ascorbic acid)	100 mg	Participates in the synthesis of collagen, the inclusion of iron in ferritin, increases the body's resistance to infections	Black and red berries (especially rose hips, black currants)	Swelling and bleeding gums, petechiae (spotting) on the skin, decreased immunity	Scurvy: bleeding and necrosis of the gums, tooth loss
B_1 (thiamine)	1.3–1.6 mg (depending on physical activity)	Participates in energy metabolism (carbohydrate decarboxylation processes), is a coenzyme of pyruvate carboxylase	Wholemeal bread, beans, bran, yeast	General symptoms: constipation, distraction, reduced efficiency, sleep disturbances	Beri-beri: chills, pain in the legs when walking, fatigue
B_2 (riboflavin)	2–3 mg	Part of flavin enzymes. Carries out transfer of hydrogen and electrons in a respiratory chain	Cereals, beans, liver, milk	Symptoms on the face: cheilosis (cracks in the corners of the mouth), oily seborrhea, glossitis	—

Table 26.2. Main functions of water-soluble vitamins, symptoms of violation of their entry into the human body

Vitamin	Daily needs for adult person	Physiological function	Main sources	Hypovitaminosis	Avitaminosis
				(swollen tongue with cracks), conjunctivitis, angular stomatitis (abscesses on the mucous membrane of the mouth)	—
B (pantothenic acid)	10 mg	Participates in the metabolism of carbohydrates and fats, acetylation reactions, catalyzes protein synthesis, regulates neurotrophic processes	Cereals, beans, potatoes, liver, eggs, fish	Trophic skin disorders, dermatitis, general symptoms (weakness, fatigue, etc.)	—
B_6 (pyridoxine)	2 mg	Vitamin resistance to harmful chemical factors	Meat, liver, milk	Increased irritability, convulsions	—
B_9 (folic acid)	200–250 mg	Antianemic factor involved in the synthesis of hemoglobin	Green leaves of vegetables, liver. Synthesized by intestinal microorganisms	Malignant hypochromic megaloblastic anemia	—
B_{12} (cyanocobalamin)	2–3 μg	Component of enzymes of nucleic acid metabolism and methylation. Needed for hematopoiesis	Green leaves of vegetables, liver, are synthesized by intestinal microorganisms	Malignant hypochromic megaloblastic anemia	—
B_{13} (orotic acid)		Stimulates protein metabolism, accelerates the regeneration of liver cells, "fertility vitamin"	Yeast	Impaired fertility, liver dysfunction	—
H (biotin)	150–200 μg	Coenzyme deaminase, carboxylase, transferase, carries CO_2	Milk, egg yolk, liver, legumes	Nervous system disorders	—
PP (nicotinic acid)	150 mg	Participates in the processes of cellular respiration (transfer of hydrogen and electrons); regulation of secretory and motor functions of the gastrointestinal tract	Meat, liver, kidneys, fish, yeast	General symptoms (weakness, fatigue, etc.)	Pellagra: dermatitis, diarrhea, dementia
P		Vitamin permeability of the vascular wall, a synergist of vitamin C	Black and red berries (especially rose hips, black currants)	Swelling and bleeding gums, petechiae (spotting) on the skin	—
N (lipoic acid)		Participates in the processes of biological oxidation of proteins, fats, carbohydrates, in the metabolism of heavy metals	Meat, liver, yeast	General symptoms (weakness, fatigue, etc.), decreased resistance to the negative effects of heavy metals	—

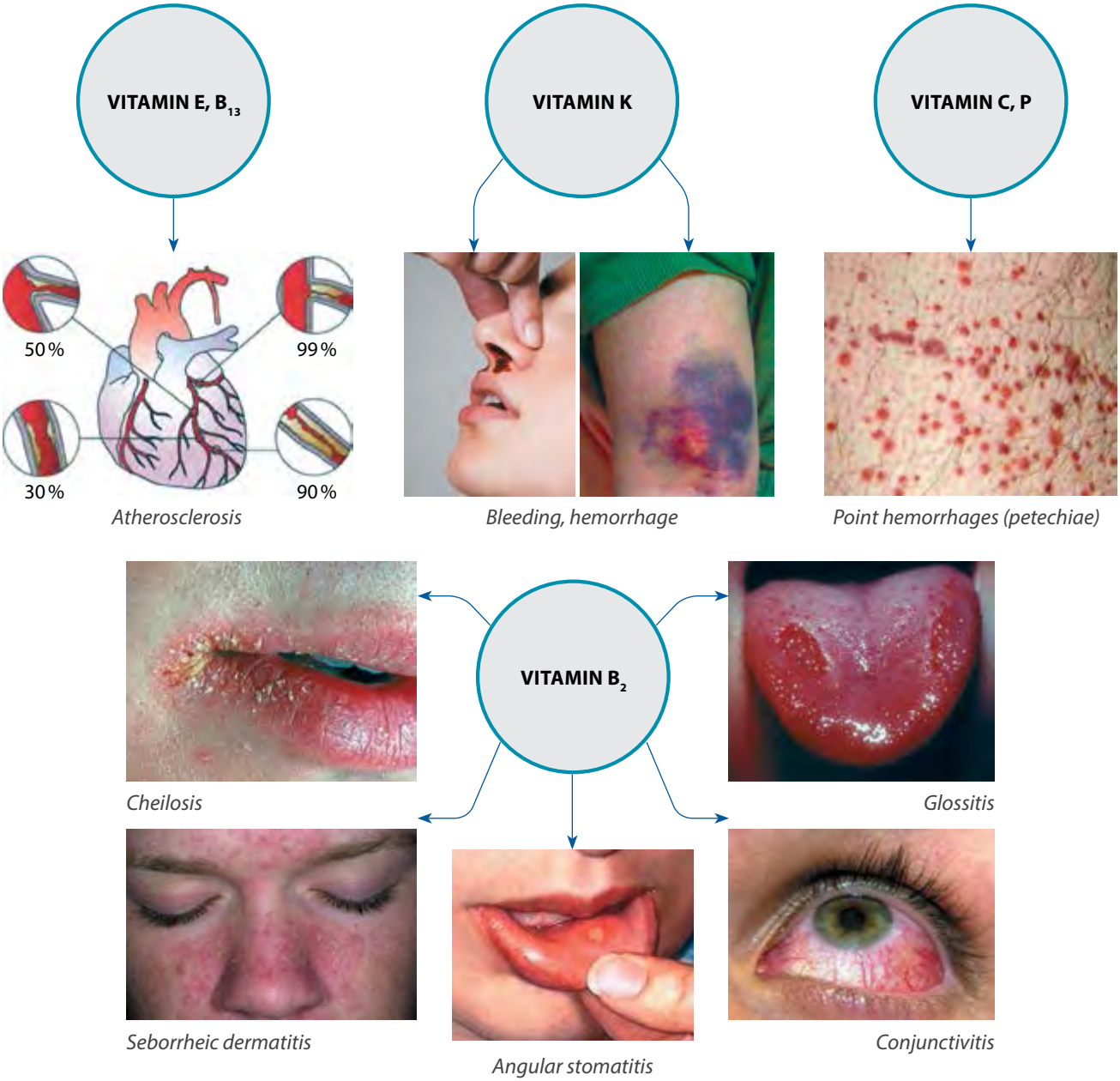


Fig. 26.1. Specific symptoms of hypovitaminosis

26.6. Main functions and factors that determine the body's need for microelements (Fig. 26.3)

26.7. Clinical signs of the main macro- and microelementosis and laboratory methods of their diagnosis (Table 26.3)

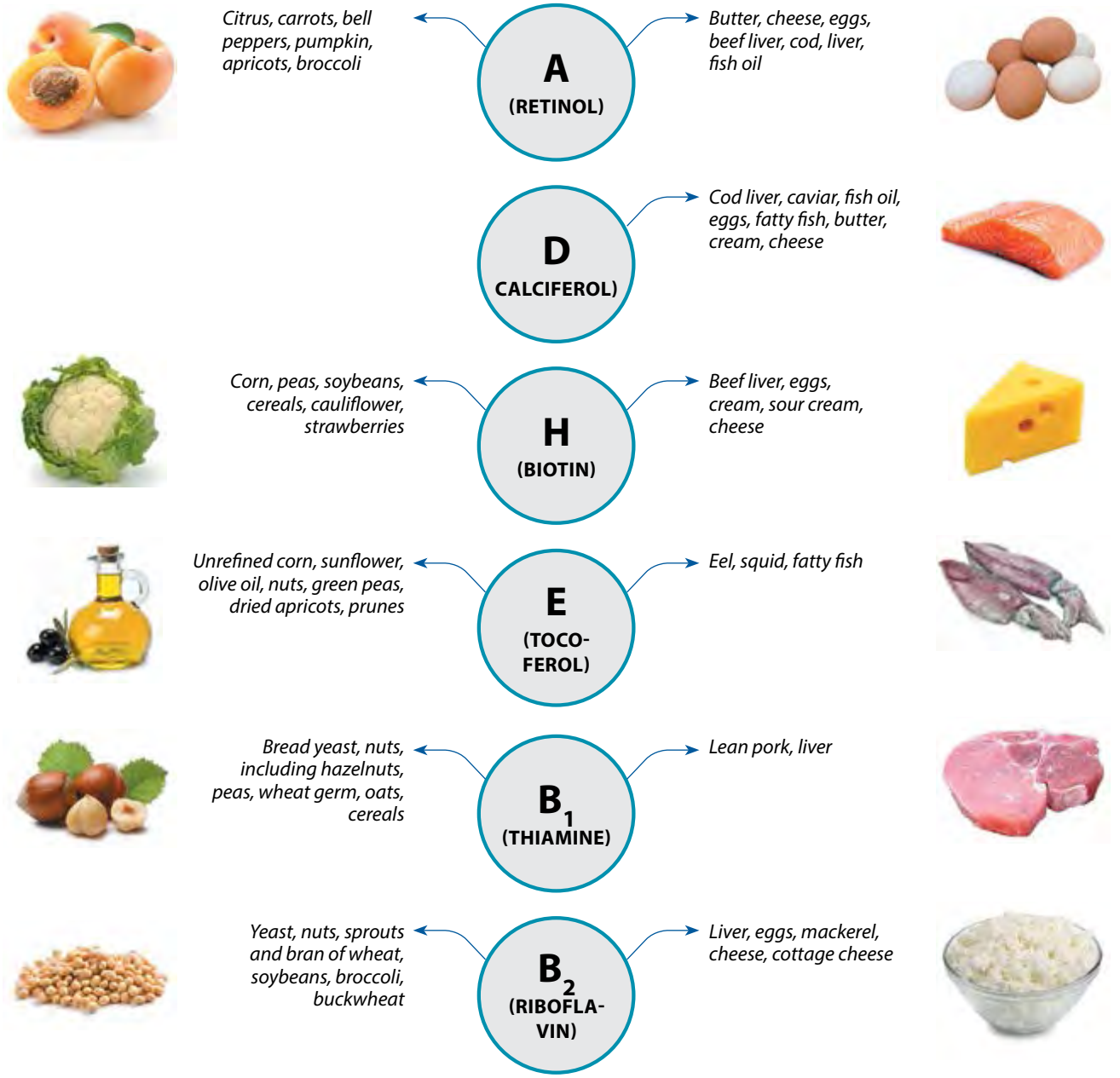


Fig. 26.2. Main sources of vitamins *(https://www.pedrada.com.ua/question/177-yak-zbalansuvati-ratson-ditini-doshklnogo-vku-vltku)*

26.8. Food additives

Food additives added to food for technological purposes:

1. Food additives that improve the consistency and organoleptic qualities of food (for taste and appearance).
2. Additives that increase the stability of products and increase their shelf life (preservatives).
3. Additives that improve food production technology.
4. Other food additives.

Classification of food additives (WHO)

Group I — stabilizers, food dyes, plasticizers, softeners, artificial sweet substances.

Group II — preservatives, benzoic acid, sulfur dioxide, some antibiotics, urotropin.

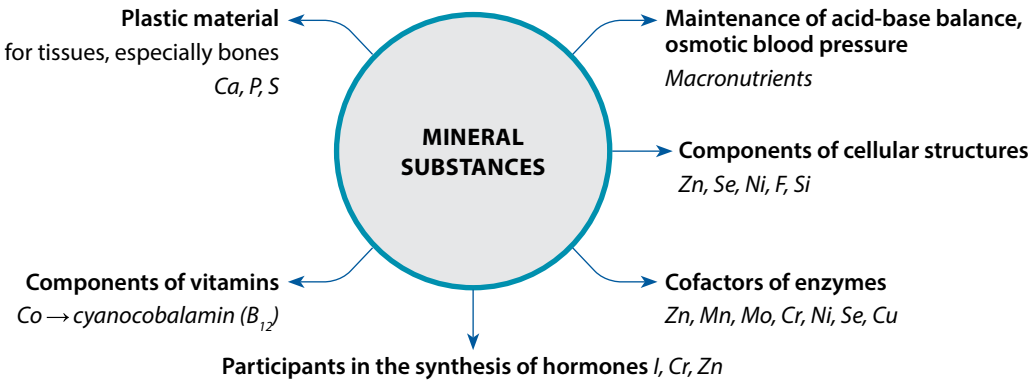


Fig. 26.3. The main functions of microelements *(dok.znaimo.com.ua)*

Table 26.3. Clinical signs of basic macro- and microelementosis and laboratory methods of their diagnosis

Element	Clinical signs	Laboratory tests
Iron (Fe)	Pale skin and mucous membranes, dizziness, shortness of breath, weakness, fatigue, decreased efficiency, drowsiness, headaches, numbness of the extremities, decreased resistance to exercise, decreased appetite, distortion of tastes (need to eat chalk, etc.), smoothness, dry mouth, burning sensation in the tongue, dryness, brittleness and hair loss, brittleness and transverse striation of nails, angular stomatitis	Iron content in blood and urine. The number of erythrocytes in the blood, hemoglobin, blood color
Copper (Cu)	Pale skin, irritability, swelling around the eyes, sometimes prolonged diarrhea. Hypochromic anemia, reticulocytosis, decreased activity of the enzyme ceruloplasmin. Growth retardation of children and adolescents	Copper content in blood and urine. The number of erythrocytes in the blood, hemoglobin, blood color, cerulopazmin activity
Zink (Zn)	Delayed sexual development, lack of secondary sexual characteristics (hypogonadism, sexual infantilism). Enlargement of the liver, spleen, anemia. Reduction of reparative processes. Growth retardation of children and adolescents	Zinc content in blood and urine
Calcium (Ca)	Thinning of tooth enamel, predisposition to dental caries, slowing of ossification, osteoporosis, osteomalacia, bone deformity, rickets in children	The content of calcium in the blood
Potassium (K)	Muscle weakness, apathy, drowsiness, loss of appetite, nausea, vomiting, decreased urination, constipation, bradycardia, arrhythmia, hypotension	Potassium content in the blood
Magnesium (Mg)	Emotional instability, irritability, agitation, fear, nervous tic (spontaneous muscle twitching), convulsions, arrhythmia, hypertensive crises, predisposition to cancer	Magnesium content in the blood
Fluorine (F)	Thinning of tooth enamel, predisposition to caries. Growth retardation of children and adolescents (fluoride deficiency). Enamel speckles, osteoporosis and skeletal osteosclerosis, restricted movement (excess fluoride)	Fluoride in blood and urine, activity of blood enzymes, skeletal radiography
Iodine (J)	Compensatory diffuse growth of the thyroid gland, exophthalmos, irritability, sweating, fatigue, decreased efficiency	The content of iodine and thyroid hormones in the blood (thyroxine)

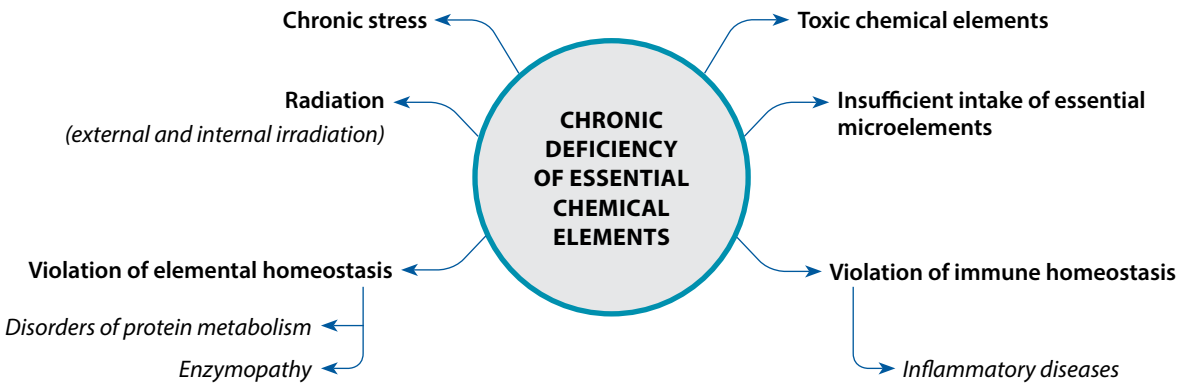


Fig. 26.4. Factors influencing the occurrence of chronic ME deficiency *(A. V. Skalny, 2000)*

Group III — process accelerators in food production, enzyme preparations, myoglobin fixatives, leavening agents, bleaches, foaming agents.

Group IV — other food additives: sodium hyposulfite as a stabilizer of iodine in table salt; calcium acetate — to prevent bread cravings (not more than 3000 mg/kg).

27 CHAPTER IONIZING RADIATION AS AN ENVIRONMENTAL FACTOR AND OCCUPATIONAL HAZARDS

S. T. Omelchuk, I. M. Pelo

Any human activity is potentially harmful. Over the last 70 years, humanity has created hundreds of artificial radionuclides and learned to harness the nuclear energy both for civilian purposes (for energy production, medicine, mineral exploration, etc.) and, unfortunately, for the manufacturing of mass destruction weapons. All this leads to an increase in the irradiation exposure to both individuals and the global population as a whole.

Therefore, scientific substantiation and practical application of effective measures for radiation safety assurance in a production environment and in places of human habitation are important and relevant issues.

27.1. History of radiation hygiene as a science, its purpose and tasks

The progress in physics in the late 19th and first half of the 20th centuries gave impetus to the emergence of radiation hygiene. At the time, Wilhelm Conrad Roentgen, Professor at the University of Würzburg (Germany, 1895), discovered X-rays that had unusual properties — they penetrated through wood, cardboard and other objects. These rays were later named after him — roentgen radiation (or X-radiation). French academician Henri Poincaré first demonstrated roentgenographic images taken with the help of rays discovered by W. C. Roentgen.

Advances in science and technology have led to the science integration that is characterized by the interpenetration of knowledge from the one branch of science to another.

The integration and differentiation of hygiene makes it possible to study more deeply the impact of the environment on humans, to scientifically substantiate and develop more effective means aimed at preserving and promoting human health.

The emergence of radiation hygiene is one of the examples of integration and differentiation of hygienic science.

Outstanding achievements in nuclear physics in the late 19th and in the first half of the 20th century:

- 1895 – W. C. Roentgen's discovery of X-rays.
- 1896 – A. H. Becquerel's discovery of natural radioactivity.
- 1898 – the discovery of polonium and radium (radioactive elements) by M. Sklodowska-Curie and P. Curie.
- 1900 – E. Rutherford's formulation of the radioactive decay law (the beginning of atomic era).
- 1932 – J. Chadwick's discovery of the neutron.
- 1934 – the discovery of artificial radioactivity by I. Joliot-Curie and F. Joliot.
- 1940 – the discovery of spontaneous fission of uranium nuclei by G. Flerov and K. Petrzhak. This brought an opportunity for E. Fermi to carry out a controlled chain reaction of uranium nuclei fission and create the world's first nuclear reactor in Chicago (USA), December 1942.
- 1954 – the world's first NPP (5 MWe), Obninsk, Kaluga region.

The following great events should be considered the beginning of an atomic era: the discovery of the phenomenon of radioactivity by the French scientist Antoine Henri Becquerel (1996), the discovery of the first radioactive elements — polonium and radium — by the French physicists M. Curie-Sklodowska (Polish origin) and P. Curie (1898), the discovery of α- and β-rays, the creation of the theory of decay and the discovery of the Basic Law of Radioactive Decay by E. Rutherford (Great Britain, 1900). The most significant discoveries of the first half of the

20th century were the discovery of the neutron by the English physicist J. Chadwick in 1932, as well as the proton-neutron theory of the nuclear structure proposed by the Soviet physicist D. D. Ivanenko. In 1934, I. Joliot-Curie and F. Joliot obtained other radioactive elements by bombardment of nuclei of elements by α-particles, thereby discovering the phenomenon of artificial radioactivity.

A few years later, the discovery of the induced (O. Hahn and F. Strassmann, Germany, 1939) and spontaneous uranium fission (G. Flerov and K. Petrzhak, 1940) enabled the Italian physicist Enrico Fermi to carry out a controlled chain reaction of uranium fission and to create the world's first nuclear reactor in Chicago (December, 1942). After some time, Fermi, under the direction of I. V. Kurchatov, created the world's first nuclear power plant with an uranium-graphite channel reactor with a capacity of 5 MWe in Obninsk, Kaluga region (1954).

Radiation hygiene is a separate branch of hygiene that studies the effect of ionizing radiation on a human in different conditions of life and activity, the dose forming patterns of irradiation of the population and personnel working on the sources of ionizing radiation and developing sanitary and hygienic measures that prevent radiation injuries and provide public health maintenance, i.e. reduce the risk of various negative effects of radiation.

Radiation hygiene is a branch of hygiene that studies the patterns of the ionizing radiation influence on human body and public health, scientifically substantiates and implements measures to ensure radiation safety in a production environment and in places of human habitation.

Radiation hygiene specialists in Ukraine use the Laws of Ukraine, Resolutions of the Cabinet of Ministers of Ukraine, Orders of the Ministry of Health of Ukraine, Norms of Radiation Safety of Ukraine, Sanitary Standards and Instructional guidelines approved by the Ministry of Health of Ukraine. The **main tasks** solved by radiation hygiene specialists are as follows:

- study of the impact of ionizing radiation sources used in various sectors of the economy and related levels of radiation exposure on humans;
- research of radiation factors of Chornobyl origin and development of anti-radiation measures aimed at preventing excessive exposure of the population of Ukraine;
- study of radiation levels from human-induced sources of ionizing radiation and their impact on public health;
- study of the radiation state of the environment caused by radioactive substances of Chornobyl origin and enterprises that generate radioactive waste during the technological process.

Along with practical tasks, radiation hygiene specialists address the issues of standardization and development of normative and methodological literature and implement the results of their scientific activity into the practical activity of sanitary-epidemiological service institutions.

The specific nature of ionizing radiation requires the use of special research methods, which include radiation-hygienic, nuclear-physical, radiobiological, radiation-chemical, dosimetric, radiometric, spectrometric, calculation, and statistical methods.

Thus, the widespread use of ionizing radiation sources in various fields of human activity necessitates qualified sanitary supervision over observance of the rules of radiation safety and environmental protection from the negative effects of ionizing radiation of human-induced and artificial sources. The reliable radiation safety system created in Ukraine promotes further extensive use of ionizing radiation sources in various sectors of economy.

27.2. Physical fundamentals of radiation hygiene

Ionizing radiation is electromagnetic or corpuscular radiation, which, when interacting with a substance, is able to directly or indirectly cause ionization and excitation of its atoms.

Radioactivity (from the Latin *radio* — radiate, *radius* — ray and *activus* — active) is a physical phenomenon, the essence of which is the spontaneous transformation of the nuclei of chemical elements, accompanied by a change in atomic number or mass number (structure or energy state) and the release of energy in the form of nuclear radiation.

Unstable (radioactive) atoms have the ability to transform from one to another. This process is called radioactive transformation or radioactive decay. There are several types of radioactive decay:

1. Alpha-decay is inherent in heavy nuclei with atomic number 83 and more, as well as in unstable atoms of rare-earth elements.
2. Beta-decay can be considered in two variants: beta-electron and beta-positron decay. For radionuclides with an excess of neutrons over protons, there is a conversion of a neutron into a proton **($n^o \rightarrow p$)** and 1 cell shift to the right; at the same time the electron and antineutrino (a particle with a negative charge

and zero rest mass) are released. The mass number remains the same, and an isobaric daughter nucleus is formed. A gamma quantum may be released. This variant of beta-decay is called electronic beta-decay (E. Fermi, 1934.). There are about 900 β-active radionuclides known today.

3. Gamma-decay (isomeric transition), discovered by I. V. Kurchatov and D. I. Rusinov (1935), involves the emission of gamma quanta during the transition of the nucleus from the excited state to the ground state. The nucleus is excited for several seconds, minutes and even hours. Such long-term excited states are called metastable, and radionuclides in this state are marked by a small Latin letter (m) along with the mass number of the radionuclide, which is characterized by such a metastable state. For example, ^{99}mTc; ^{137}mBa.
4. In 1937, L. Alvarez discovered another type of nuclear transformation — electron capture (EC), or K-capture (capture by the nucleus of an electron from the K-shell, (rarely — from the L-shell)). This nuclear transformation is inherent in radionuclides that have an excess of protons. As a result, the proton is converted into a neutron (the captured electron neutralizes the proton).
5. Spontaneous nuclear fission is peculiar to heavy elements. It occurs when nuclei capture neutrons or without such capture. O. Hahn and F. Strassmann discovered spontaneous fission, initiated by neutrons, in 1938, and G. N. Flerov and K. A. Petrzhak discovered spontaneous fission without bombardment by neutron flux in 1940. The fission reaction without neutron flux occurs much less frequently with a half-life of 10^{16} years.

The main types of nuclear radiation and its physical properties are reflected in Tables 27.1 and 27.2. The characteristic of the basic physical units of ionizing radiation is provided below (Table 27.3).

Exposure dose (X) is the first created measure of the effect of photon radiation on the environment. It is determined by the ratio of the total electric charge of all ions of the same polarity created in air with full inhibition of all secondary electrons formed by photons per unit mass or volume of atmospheric dry air. An off-system unit of photon radiation exposure dose is roentgen — 1, which forms 2.08×10^9 pairs of ions (one electrostatic unit) in 1 cm^3 (0.001 29 g) of dry air at a temperature of 0 °C and atmospheric pressure of 10^{13} MPa. The unit of exposure dose in the SI system is the coulomb per kilogram (C/kg). 1 R = 2.58×10^{-4} C/kg; 1 C/kg = 3876 R.

Equivalent dose (H) is dosimetric quantity equal to the product of the absorbed dose and the relevant radiation factor. The unit of equivalent dose in the SI system is the Sievert** (Sv). It is the unit of equivalent dose of any type of radiation in biological tissue of standard composition which creates the same biological effect as the absorbed dose of 1 Gy (J/kg) of exemplar X-ray radiation (with certain standard parameters).

For purposes of comparison of the biological effects of different types of radiation, there is the concept of *relative biological effectiveness* reflected in the value of the

Note. *** The unit is named after the Swedish physicist R. M. Sievert*

Table 27.1. Types of nuclear radiation

1. Corpuscular (particle)	2. Electromagnetic (quantum)
α (nuclei of helium atoms)	**γ** (gamma)
β (electron or positron)	
p (proton)	**X-rays** (or roentgen radiation)
n (neutron)	

Table 27.2. Physical properties of ionizing radiation

Type of radiation	Energy, MeV	Range in air	Range in biological tissues	Ionization density (number of ion pairs per 1 cm of range)
Alpha	Up to 10	≈ up to 10 cm	Up to 50 μm	1000–50000
Beta	Up to 3–4	≈ up to 15 m	Up to 2.5 cm	Up to 1000
Gamma	Up to 2–3	Up to 600 m	Dozens of cm	Up to 10
Neutrons	From almost zero to 20 and more	Up to 1.5 km (depending on energy)	Dozens of cm	Up to several thousand

radiation factor — W_R (quality factor) without a name of the term. Specifically, it determines the dependence of frequency of adverse biological effects occurrence as a result of irradiation of the human body in small doses. The values of radiation factors are shown in Table 27.4. *

Equivalent dose rate (н) is increase in equivalent dose per unit time. It is measured in Sv/sec.

$$н = dH / dt.$$

Table 27.3. Basic units of ionizing radiation

Term	Off-system units	In-system units	Proportion
Energy	E (erg)	J	1 J = 10^7 erg
X — exposure dose	R (roentgen)	C/kg	1 R = 2.58 10^{-4} C/kg 1 C/kg = 3876 R
x — exposure dose rate	R/s	ampere/kg	the same
D — absorbed dose	D = X rad; 100 erg/g	Gray J/kg	rad = 0.01 Gy 1 Gy = 100 rad
d — absorbed dose rate	rad/s	Gy/s W/kg	the same
K — air kerma	K = X × 0.873; rad	Gray	1 μrd = 8.73 nGy
H — equivalent dose	ber; 100 erg/g × κ (κ — radiation factor)	Sievert (Sv) J/kg × κ	ber = 0.01 Sv 1 Sv = 100 ber
н — dose equivalent rate	ber/s	Sv/s	the same
E — effective dose	E = ∑N × w, ber, w — tissue (weighting) factor	Sievert (Sv)	the same
e — effective dose rate*	e	nSv/h	1 μrd /h = 6.46 nSv/h
Collective effective dose	S; $S = \sum H_i N_i$	human × sievert	
Particle flux	Φ; c^{-1}	Φ; c^{-1}	
Particle flux density	φ; c^{-1} cm^{-2}	φ; c^{-1} m^{-2}	10^{-4}
Particle fluence	F; cm^{-2}	F; m^{-2}	10^{-4}

Note. ** Can be calculated only in the case of irradiation due to natural radiation background or long-term contamination, when the levels of radioactive contamination of the environment can be considered uniform.*

Table 27.4. Values of WR radiation factors for different types of ionizing radiation at long-term irradiation in small doses

Type of radiation	WR	Type of radiation	WR
X- and gamma-radiation	1	Neutrons with an energy of 10 keV	5
Electrons, positrons, beta particles	1	Neutrons with an energy of 10 keV — 100 keV	10
Protons with an energy of 2 MeV	5	Neutrons with an energy of 100 keV — 2 MeV	20
Alpha radiation with energy up to 10 MeV	20	Neutrons with an energy of 2 MeV — 20 MeV	10
Recoil nuclei	20	Neutrons with an energy of more than 20 MeV	5

The off-system unit of equivalent dose is ber (biological equivalent of rad). It corresponds to the absorbed dose of any type of radiation, which creates the same biological effect as the absorbed dose of 1 rad of photon radiation, for which the value of the radiation factor is equal to one, i.e. 100 erg of energy absorbed by 1 g of substance. Consequently, 1 Sv = 100 ber, 1 ber = 0.01 Sv. The old unit of measurement of the equivalent dose was "**rem**" (rem is the abbreviation of the words roentgen equivalent in man, or mammal).

To assess the harm to human health from uneven irradiation of the body, the concept of **effective dose** (H_E) was introduced. The abandonment of the concept of a critical organ and the recognition of the no-threshold concept according to ICRD publication No26 forced the use of the acceptable risk concept. This concept is the basis of the established dose limits in NRBU-97. The effective dose helps to determine the overall risk of long-term effects of radiation — disease or death from somatic and stochastic effects (malignant neoplasms, hematopoietic system diseases) or genetic effects (risk of hereditary diseases in offspring).

Thus, the effective dose reflects the contribution of irradiation of individual organs to the total radiation harm to the whole organism. In the case when one of the "other organs" list receives an equivalent dose that exceeds any of the main list, the tissue weighting factor of 0.025 is used for that organ. Values of tissue weighting factors, w_R (according to NRBU-97), are given in Tables 27.5 and 27.6.

Table 27.5. Values of tissue weighting factors, w_R (according to NRBU-97)

Gonads	0.20
RBM, large bowel, lungs, stomach	0.12
Urinary bladder, mammary gland, liver, oesophagus, thyroid gland	0.05
Skin, bone surface	0.01
Other organs*	0.05

Note. **Adrenal glands, brain, respiratory tract of the extraterrestrial areas, small intestine, kidneys, muscles, pancreas, spleen, thymus, uterus.*

Table 27.6. Values of tissue weighting factors, w_t (according to ICRD 103 publication)

Gonads	0.08
RBM, large intestine, lungs, stomach, mammary gland	0.12
Urinary bladder, liver, oesophagus, thyroid gland	0.04
Skin, bone surface, brain, salivary glands	0.01
Other tissues and organs (heart, kidneys, pancreas, small intestine)	0.12

27.3. Classification of ionizing radiation sources and their contribution to radiation exposure of humans

An **IR source** is any object that contains a radioactive substance or a technical device that generates or, under certain conditions, can generate ionizing radiation. Classification of ionizing radiation sources and their contribution to radiation exposure to humans are given in Table 27.7, Figures 27.1 and 27.2.

Table 27.7. Classification of IR sources

Identification of sources	Characteristics
By origin	Natural and anthropogenic
By nature	Radionuclide and non-radionuclide
By condition	Bare and sealed
By radionuclide composition	α-, β-, γ-irradiators
By radioactivity	Low-level and high-level radioactive
By application	Industrial, nuclear, energy, medical, scientific and technical, etc.

Information on the exposure of the Ukrainian population with various sources of natural origin is given in Table 27.8.

Industrial sources are ionizing radiation sources (IRS) of artificial origin, which are targeted in appropriate radiation technologies to obtain certain benefits. Human-made sources based on naturally occurring radioactive materials are also industrial. Fields of use of artificial IRS are as follows:

1. Medicine (diagnosis and treatment).
2. Nuclear energy (electricity generation).

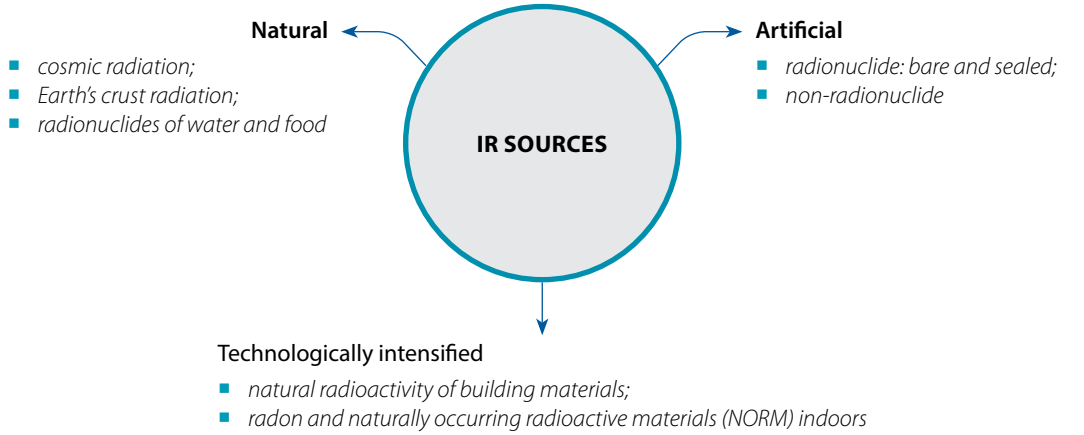


Fig. 27.1. Classification of IR sources

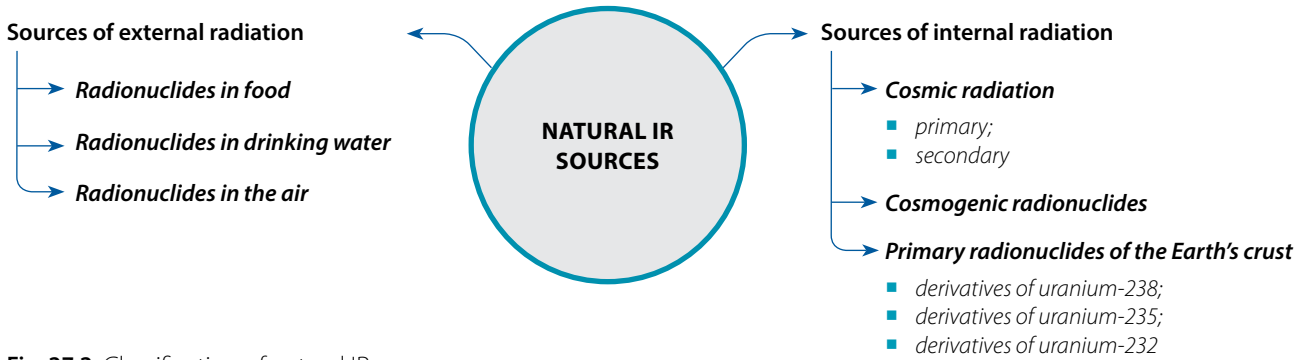


Fig. 27.2. Classification of natural IR sources

Table 27.8. Irradiation of the population of Ukraine with sources of natural origin

Radiation source	Dose (mSv/year)	% of the total dose	Component contribution (%)	
External (cosmic radiation, gamma background of the Earth)	1.0	13.5	Uncontrolled component	19.3
Internal (food, air, drinking water)	0.35	5.83		
Naturally occurring radioactive materials of drinking water	0.15	2.5	Controlled component	80.7
Naturally occurring radioactive materials of building materials	0.25	4.17		
Radon isotopes and products of radon decay indoors	3.25	74.0		
Total:	5.0	100		

3. Industry (defectoscopy and methods of technological control, irradiation of objects for their sterilization, radurization, etc.).
4. X-ray diffraction and X-ray spectrum analysis.
5. Geology (neutron well logging).
6. Scientific studies (radiobiology, physics, radiochemistry, etc.).
7. Military industrial facilities, space industry.

Powerful source of ionizing radiation is radioactive waste (RAW), which can be generated by any use of radionuclide IRS.

Artificial industrial sources by type are divided into non-radionuclide and radionuclide.

Non-radionuclide sources are devices that do not contain radioactive substances, but, in certain conditions, they are able to generate ionizing radiation. This occurs when braking or accelerating charged particles in a high voltage field. While powered off, they are completely safe and do not pose a threat to people around, as well as do not generate radioactive pollution.

Non-radionuclide sources include X-ray machines with different designs and different purposes. The most common are roentgenodiagnostic and roentgenotherapy apparatus used in medicine, devices for X-ray diffraction and X-ray spectrum analysis, devices for X-ray inspection (defectoscopes). Charged particle accelerators for medical and other purposes, which are also classified as non-radionuclide sources, are widely used.

Radionuclide sources of ionizing radiation are classified into sealed and bare.

A **sealed source** contains a radioactive substance enclosed in a hard protective cover made of non-radioactive material, which prevents the spread of the substance under regular conditions of use during the certain useful lifetime. Thus, in the normal operation of a closed source, it can create only external irradiation, except the special use when the internal organs are irradiated for radiation therapy (brachytherapy). There is a wide variety of sources by activity, type of radiation, design, purpose and basic operation requirements.

Bare sources of ionizing radiation include radionuclide sources, with the normal use of which, the entry of radioactive substances into work premises or the human body, radioactive contamination of work premises and the environment are possible. Open sources include:

1. Radiopharmaceuticals (RPh) are approved for medical usage substances that contain certain radionuclides.
2. Radioactive solutions used in calibration in scientific researches.
3. Radiochemicals used in radiochemical laboratories.
4. Nuclear fuel cycle (laboratories, fuel core, etc.).
5. Fission products formed as a result of the use of nuclear weapons.
6. RAW — emissions (into the air) and discharges (into water reservoirs) in case of radiation and nuclear accidents.
7. Radionuclides in the native state and their various compounds in the form of gas, aerosol, vapor, liquid, powder.

Radiation exposure of the population:

1. Radiation exposure is about 5 mSv per year:
   - natural radiation background sources — about 2 mSv per year (40 %);
   - human-made and artificial radiation background sources — about 3 mSv per year (60 %, 30 % each).
2. The portion of external radiation in the population exposure to radiation is about 43 %, internal radiation — about 57 %.
3. The main components of radiation exposure of human:
   - radionuclide radon — about 60 %;
   - medical roentgenological procedures — about 30 %.

27.4. Radiation protection as a hygienic issue

Radiation protection should be understood as a set of radiation and hygienic, drawing and designing, technical and organizational measures aimed at ensuring human radiation safety. Each of these measures cannot be carried out without knowledge of the physical properties of ionizing radiation, laws of formation of radiation loads, the peculiarities of the radiation and matter interaction. It is extremely important to inform the population and interested organizations about the state of radiological protection.

Radiation protection principles:

1. Hygienic regulation of irradiation levels.
2. State sanitary supervision (preventive and regular).
3. Radiation surveillance (state and department).
4. Medical supervision.
5. Professional education and sanitary education.
6. Use of collective and individual protective means.

There are several known physical basics of radiation protection. The most important are four:

1. Protection by reducing the activity of the used source.
2. Protection by reducing the time of exposure to the source (time protection).
3. Protection by increasing the distance between the person and the source (distance protection).
4. Shielding — a substance placed between the source and the person.

27.5. Biological effect of ionizing radiation

The biological effect of ionizing radiation should be understood as its ability to cause structural and functional changes in biological objects both at the molecular level and at the organism level. Of all the species on the planet, humans are the most sensitive to ionizing radiation.

Mechanisms of biological effect of ionizing radiation

The biological effect of ionizing radiation occurs in three phases (at three levels):

1. **"Physical" phase** (duration 1×10^{-1} sec) — irradiation causes the forming of ionized and excited atoms and molecules in cells and tissues of the biological substrate (up to 70 % of IR energy is spent on radiolysis of water).
2. **"Physical-chemical" phase** (duration 1–10 sec) — ionized and excited atoms and molecules undergo physical-chemical changes that resulted in the formation of free radicals (activation of lipid peroxidation and formation of free radicals; it is a nonspecific mechanism of biological effect of IR).
3. **"Biochemical" phase** — there are changes in metabolic processes in cells resulting in various biological effects.

The initial stage. There is a physical effect at the atomic and molecular levels — the absorption of energy by atoms and molecules of biological tissue resulting in the formation of excited and ionized atoms and molecules.

$$\gamma \rightarrow M \leftrightarrow M^+ + e^-;$$
$$e^- + M \rightarrow M^-; M^+; M^-; M.$$

Energy is also absorbed by water molecules resulting in the formation of H_2O^+; H_2O^-.

$$\gamma \rightarrow H_2O \leftrightarrow H_2O^+ + e^-;$$
$$e^- + H_2O \rightarrow H_2O^-; H_2O^+; H_2O^-; H_2O.$$

These processes occur at a very high speed — 10^{-12}... 10^{-16} seconds.

When considering physical-chemical (radiation-chemical) changes, effects of radiation are distinguished into direct and indirect.

Direct effect is understood as changes that occur as a result of the absorption of radiation energy by the most radiosensitive part of the cell — the "target". The highest radiosensitivity is inherent to the DNA of the nucleus and membranes, which act as a "target". When radiation interacts with biological tissue, ionization occurs — the formation of negatively and positively charged ions.

Indirect effect is understood as changes in the cell due to the effect of products of water radiolysis. It is believed that indirect effect accounts for about 90 %, so it is of paramount importance, because the biological cell contains up to 65–70 % water.

The second stage is driven by the effect of the primary stage products — oxidizing radicals, radiotoxins and others. There are redox-reactions, deamination, break of peptide bonds, oxidation of SH-groups.

At the cellular level, there are changes in the morphology of cells that provide heredity, — clumping and formation of conglomerates (agglomeration), enlargement and pyknosis of nuclei, single and double breaks of chromosomes. There are abnormalities of normal biochemical processes, primarily inhibition of the proteins and enzymes secretion, which is due to the effect of radiotoxins. Such physicochemical changes in cells, which cause dysfunction of membranes, viscosity and hydrophilicity of the cytoplasm, cause changes in the electrical conductivity and thermal conductivity of cells. The duration of cellular abnormalities is measured in seconds, minutes, hours.

Pecularities of the biological effect of ionizing radiation are as follows:

1. Absence of selective effect of radiation on various atoms and molecules resulting in damage to any type of biological tissue.
2. Instant absorption of radiation energy resulting in the destructuring of atoms and molecules, which causes a change in their physical and chemical properties.
3. Due to the high penetrating power of many types of radiation, there is an effect of short duration (instantaneous) on various tissues of the body; in particular, under the effect of gamma radiation, no tissue remains intact.

The third stage — damage at the organism level as a result of changes in the morphology and functions of individual organs and systems.

As early as 1906, French scientists J. Bergonie and L. Tribondeau determined a pattern regarding the radiosensitivity of the body's cells. Tissues with poorly differentiated cells, as well as those with high proliferative activity, such as red bone marrow, seminal glands,

intestinal epithelium, etc., have high radiosensitivity. The most radiosensitive cell structure is the nucleus. During the life cycle, the cell has the greatest radiosensitivity in the mitotic period.

These patterns took the form of the basic radiobiological law of Bergonie and Tribondeau: "The radiosensitivity of a biological tissue is directly proportional to the mitotic activity and inversely proportional to the degree of differentiation of its cells."

The **IR biological effect** depends on:

- type of IR;
- amount of absorbed dose of IR;
- distribution of absorbed IR energy in the body;
- radiosensitivity of the body and individual organs;
- method of irradiation (type of radiation exposure);
- individual peculiarities of the organism;
- environmental conditions.

Features of IR biological effect:

- insensitivity of effect;
- presence of a latent period;
- ability to accumulate.

Important issues of radiobiology, which can be considered as features of the IR biological effect, are:

- radiological adaptation;
- threshold of effect.

27.6. Main types of radiation damages of the body and the conditions of its occurrence

The clinical biological radiation effects that occur due to irradiation will be considered further. Depending on the dose as well as the irradiation regimen, deterministic (inevitable) and non-deterministic (stochastic) effects may occur.

Deterministic effects (harmful tissue reactions) can be early or late, but they all appear when exposed to certain doses. These effects have a dose threshold below which deterministic effects do not occur. The severity of deterministic effects increases with increasing radiation dose.

Types of radiation damage

Deterministic effects (non-stochastic) are the effects of radiation exposure, which occur only when a certain dose threshold is exceeded and the severity of the consequences depends on the dose (acute radiation disease (ARD), chronic radiation disease (CRD), radiation burns, etc.).

Stochastic effects are non-threshold effects of radiation exposure, the probability of which exists at any dose of IR and increases with increasing dose, while their relative severity does not depend on the dose.

Stochastic effects include malignant neoplasms (somatic effects) and genetic changes passed on to offspring (hereditary effects).

Stochastic (non-deterministic) effects

In the 1950s, animal experiments revealed the possibility of radiation-induced carcinogenic and genetic (non-deterministic) effects at doses below the threshold for deterministic effects (small doses). The probability of non-deterministic effects has stochastic nature and increases with increasing radiation exposure. It should be noted that the dose does not affect the severity of the pathology, but only increases the likelihood of its occurrence. Stochastic effects are somatic-stochastic, occurring in the somatic sphere (cancer, leukemia, reduced life expectancy, reduced immunobiological protection of the body), and genetic, which are manifested in the offspring in the form of hereditary diseases of a genetic nature (Down's syndrome, congenital cataracts, epilepsy, muscular dystrophy, various congenital abnormalities, Turner syndrome, etc.). Each type of pathology is characterized by certain periods of the highest frequency of their occurrence (Fig. 27.3).

In contrast to somatic disorders that occur directly in irradiated individuals, the genetic effects of radiation are manifested in the offspring of irradiated individuals. Genetic disorders can be divided into two main types:

- chromosome aberrations, that lead to changes in the number or structure of chromosomes;
- gene mutations — dominant (manifested in the first generation) and recessive (can occur in the presence of the same mutant gene in both parents). About 10 % of all newborns have genetic defects. Many embryos and fetuses with hereditary pathology do not survive to be born.

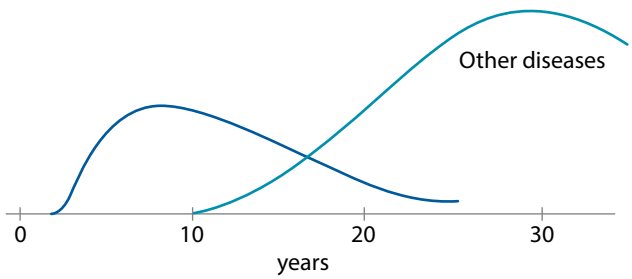


Fig. 27.3. Periods of the highest frequency of stochastic (non-deterministic) effects due to irradiation in small doses

28 CHAPTER FUNDAMENTALS OF HYGIENIC REGULATION OF IONIZING RADIATION

I. M. Pelo, S. T. Omelchuk

28.1. The importance of hygienic regulation of ionizing radiation, its history, methods, scientific concepts

Any type of human activity involves a certain danger to the individual health, health of other members of society and environmental damage. Unfortunately, it is impossible to develop a completely safe technique, and no human activity can provide an absolute safety. Therefore, the main task of hygiene is to reduce the negative impact of human activities on their health.

Hygienic regulation is an extremely important link in the system of measures for radiation protection of personnel and radiation safety of the population. Hygienic regulation allows to unify the requirements for the organization of work on facilities with radiation and nuclear technologies, radiation safety of the population in the places of residence and protection of the environment from radioactive contamination. Hygienic standard is the initial data for the calculations of radiation protection measures, which are based on the physical laws of attenuation of ionizing radiation. Hygienic regulation is the juridical base of the State Sanitary Supervision.

The necessity for regulation of the ionizing radiation effects on the human body became known in the early 20th century, because there was information about damage to health of workers who had direct contact with radioactive substances. At that time, radiation safety was based on the principle of the threshold effect of ionizing radiation, as only deterministic effects were known, which have a threshold value and occur at rather significant radiation exposure. In the middle of the 20th century, there was advent of artificial sources of ionizing radiation, and at the same time, the scientific evidence of the possibility of non-deterministic (carcinogenic) effects caused by low doses of radiation appeared.

At present, we have scientific information that indicates the possibility of stochastic effects at radiation doses much lower than the threshold of radiation injuries.

The evolution of dose limits for people working with sources of ionizing radiation is set out in the Recommendations of the International Commission on Radiation Protection (ICRP). This development begins from the early 30s of the 20th century, and it shows a significant reduction in allowable annual radiation doses: from 600 mSv to 20 mSv per year.

The first recommendations were based on the concept of "tolerance dose", i.e. such a dose of radiation that a person could tolerate (as previously believed) without health hazard. At that time, the appearance of radiation injuries, which were later called "deterministic" effects, was considered a health hazard.

The main principles of protection against ionizing radiation are set out in IAEA regulations (2001, 2002, etc.), ICRP Recommendations (1977, 1990, 2007), NRBU-97, OSPU-2005, as well as in industry-based sanitary rules for working with ionizing radiation sources.

The harmonization of the Ukrainian legal and regulatory framework in the field of radiological protection with international documents and recommendations is nowadays a pressing need.

The observance of hygienic regulations guarantees the prevention of deterministic effects in persons who have been exposed to radiation and limiting the probability of stochastic (non-deterministic) effects at an acceptable level.

In ICRP Publication 26 (1977), the concept of effective dose was introduced as an integral index, which can be used to determine the ionizing radiation damage to the whole body and compare it with the irradiation damage to various organs in others.

In ICRP Publication 60 (1990), the basics of radiation protection were divided in accordance with two different situations of human activity related to sources of ionizing radiation (SIR), the concepts of "practical activity" and

"intervention" were introduced. Approaches to limiting of irradiation in practice (in incident free operations of the facility) and intervention (in emergencies) are different. The ICRP Publication 60 represented the beginning of a new stage in radiation safety, radiation and hygienic regulations. The main provisions of this Publication provided the basis of Ukrainian legislation, in particular NRBU-97.

The information of ICRP Publication 103 (2007) are based on the analysis of the radiation exposure situation — for three radiation exposure scenarios: in an occupational environment, radiation exposure of a population and medical radiation exposure. The ICRP proposes to use the term "reference level" to limit the dose or risk. Irradiation planning above this level is not allowed, and if below — protection should be optimized.

A number of international organizations have been established for the purpose of international cooperation in the field of use of ionizing radiation sources and protection against its adverse effects on the population. The leading international governmental forum for scientific and technical cooperation relating to the peaceful uses of nuclear energy is the International Atomic Energy Agency (IAEA), headquartered in Vienna (Austria). The autonomous organization, which represents the international efforts translated into reality, was created within the United Nations (UN) in 1957. Today, the IARC provides a wide range of services, programs and activities in accordance with the needs of 130 member countries.

The UN Scientific Committee on the Effects of Atomic Radiation was established under the Resolution of the General Assembly (UNSCEAR) in 1955. It is aimed at preparation of scientific content on the level and effects of radiation on human health and the environment. The UNSCEAR reports are considered by the international community as a reliable and comprehensive source of information that can be used to assess risks and implement protective measures against radiation effects. In recent years, the UNSCEAR has been placing high emphasis on studying the consequences of the Chornobyl accident and the accident at the Fukushima Daiichi Nuclear Power Plant in Japan.

The Food and Agriculture Organization (FAO), an international organization under the auspices of the United Nations, is successfully operating in the sphere of development of agriculture, fishery, and forestry. The organization collects data and studies the state of foodstuff quality, including the presence of radioactive contamination.

The International Commission on Radiation Protection (ICRP), established in 1928, is an independent international organization that performs various functions related to the development of recommendations used by National Commissions on Radiation Protection (NCRP) in formation of laws and regulations for each country. The majority of countries takes into account the recommendations of the ICRP.

28.2. Sanitary legislation in the field of radiation hygiene

The National Commission for Radiation Protection of the Population of Ukraine (NCRPU) was established by the Resolution of the Verkhovna Rada of Ukraine No95-XII "On Immediate Measures for Protection of the Citizens of Ukraine from the Consequences of the Chornobyl Accident" on August 1, 1990. Dmytro Mykhailovych Hrodzynsky, Academician of the Academy of Sciences of the Ukrainian SSR, was appointed as the Head of the NCRPU. The NCRPU is developing documents intended to implementing protective measures for the population in general and for workers in the radiation and nuclear industry in particular, as well as documents regarding overcoming the consequences of the Chornobyl Accident, ecology and appropriate natural resource management.

The State Nuclear Regulatory Inspectorate of Ukraine (SNRIU), in accordance with the Provision approved by the Resolution No363 of the Cabinet of Ministers of Ukraine on August 20, 2014, is the central executive body that ensures the formation and implementation of state policy in the field of nuclear energy safety. The activity of the SNRIU is regulated by the Laws of Ukraine — "On the Use of Nuclear Energy and Radiation Safety", "On Permitting in the Sphere of Nuclear Energy Use".

The State Service of Ukraine on Food Safety and Consumer Protection, in accordance with the Regulation approved by the Resolution No667 of the Cabinet of Ministers of Ukraine on September 9, 2015, is a central executive body. Its activities are directed and coordinated by the Cabinet of Ministers of Ukraine through the Ministry of Economic Development, trade and agriculture, which implements state policy in the areas of safety and certain indicators of food quality, including the implementation of radiation control over the level of radioactive contamination of agricultural products and food.

The State Service on Food Safety and Consumer Protection carries out, within its competence, the following activities:

- control over the elimination of the causes and conditions of occurrence and spread of contagious, mass non-contagious diseases, poisonings and radiation injuries of people;
- engagement in sanitary and epidemiological investigations aimed at identifying the causes and conditions that lead to the emergence and spread of contagious diseases (including food route), group and individual food poisoning, mass non-contagious diseases (poisonings) and radiation injuries, cases of violation of radiation safety standards, sanitary rules of work with radioactive substances, other sources of ionizing radiation;
- adoption of measures to eliminate the violations in accordance with the law.

In their work, specialists are guided by the Laws of Ukraine, Resolutions of the Cabinet of Ministers of Ukraine, Orders of the Ministry of Health of Ukraine, Norms of Radiation Safety of Ukraine, Sanitary Standards, Instructional and Methodological Guidelines approved by the Ministry of Health of Ukraine.

The main tasks of specialists in radiation hygiene are:

- study of the impact of ionizing radiation sources used in various sectors of the economy and related levels of radiation exposure to humans;
- study of radiation factors of Chornobyl origin and development of protective measures aimed at preventing of excessive radiation exposure on the population of Ukraine;
- study of radiation levels from sources of technologically enhanced naturally occurring radioactive materials and their impact on public health;
- study of the radiation state of the environment due to radioactive substances of Chornobyl origin, and enterprises with such technological processes in which radioactive waste is generated.

Along with practical tasks, specialists in radiation hygiene address the issues of regulation and development of normative and methodological literature and implementation of the results of their scientific activity into the practical activity of institutions.

The specific nature of ionizing radiation requires the use of special research methods, which include radiation and hygienic, nuclear and physical, radiobiological, radiation and chemical, dosimetric (radiation-monitoring), radiometric, spectrometric, calculation, statistical methods.

The extensive use of ionizing radiation sources in various areas of human activity dictates the need for qualified sanitary supervision over observance of the rules of radiation safety and protection of the environment from the negative effects of ionizing radiation. The reliable radiation safety system created in Ukraine opens prospects for further extensive use of ionizing radiation sources in various sectors of the economy.

28.3. Norms of Radiation Safety of Ukraine (NRBU-97), content and practical application

On January 1, 1998, the Norms of Radiation Safety of Ukraine (NRBU-97) were enacted by the relevant order of the Ministry of Health of Ukraine, which is the main state document in the field of radiation hygiene that establishes the system of radiation hygiene regulations to ensure acceptable exposure levels for both an individual and the society as a whole. NRBU-97 takes into account the recommendations of international organizations (ICRP, IAEA, WHO), the positive experience in application of NRB-76/87, and scientific developments in the field of radiation safety and radiation protection.

The purpose of NRBU-97 is to determine the basic requirements for:

- protection of human health from possible harm associated with exposure to SIR (prevention of deterministic effects and limiting the probability of stochastic effects);
- safe operation of SIR;
- protection of the environment from radionuclide contamination.

Compared to the previous NRB-76/87, the following modern conceptual provisions have been introduced in NRBU-97:

- the concept of effective dose;
- new system of substantiation of allowable levels with use of dosimetric models with age-dependent parameters;
- two categories of people exposed to radiation (personnel and population) and a system of four groups of radiation and hygiene regulations.

Radiation safety of the personnel, population and environment is considered to be ensured if the basic principles of radiation safety (reasonability, non-exceedance, optimization), and radiation protection requirements established by current radiation safety and sanitary regulations are observed.

The methodology of radiation protection of the population is based on the following principles:

- *reasonability* — any practical activity that leads to human exposure to radiation should not be carried out if the benefit does not exceed the total damage caused to the individual or society. This principle is used for all exposure situations;
- *non-exceedance* — total radiation dosage caused by practical activities should not exceed the established dose limits;
- *optimization* — individual doses and/or the number of exposed persons should be as low as can be achieved taking into account economic and social factors.

The principle of reasonability of the radiation technologies use is ensured by the fact that the use of SIR requires the permission of regulatory authorities: State Sanitary Supervision in the form of a sanitary passport, and a license issued by the state body responsible for radiation safety in the country. Today, such a regulatory body is the State Nuclear Regulatory Inspectorate of Ukraine.

The principle of non-exceedance of the established dose limits is guaranteed by a system of allowable levels, requirements for the design, location, construction of radiation and nuclear facilities, as well as radiation monitoring of the facilities and environment.

The principle of optimization is provided by a system of control levels, the order of their installation and use, as well as such requirements for projects that would guarantee the selection of technology with minimal harm and maximum benefit to an individual and the society.

Radiation safety of the country is determined by the protection state of its citizens from the negative effects of ionizing radiation. Compliance with the applicable regulations in the sphere of ionizing radiation use is mandatory for entities and persons who use ionizing radiation in order to obtain a certain benefit, which should exceed harm. At the same time, the search for ways to reduce exposure levels, taking into account economic feasibility, even when these levels meet the normative values, is a condition for creating of radiation safety for the population as a whole and for each person in particular.

The operation of NRBU-97 extends to the situation of human exposure to SIR in conditions of:

- normal exploitation of industrial SIRs;
- medical practice;
- radiation accidents;
- irradiation from sources of technologically enhanced naturally occurring radioactive materials.

NRBU-97 includes 4 groups of radiation-hygienic regulated values.

The first group — regulations for the control of practical activities.

The second group — regulations to limit human exposure from medical SIRs.

The third group — regulations on the averted (due to intervention) dose of the population exposure in case of radiation accident.

The fourth group — regulations on the averted (due to intervention) dose of the population exposure from sources of technologically enhanced naturally occurring radioactive materials.

NRBU-97 identified the following categories of persons exposed to radiation (Fig. 28.1).

Category A (personnel) — persons who permanently or temporarily (temporary assistance) work directly with sources of ionizing radiation.

Category B (personnel) — persons who do not work directly with SIRs, but due to the location of their workplaces may be additionally irradiated. This category may also include employees who do not work directly with SIRs, but their functional responsibilities are related to SIR operations (use of radionuclide devices, execution of works with the use of devices, etc.).

Category C — the entire population (except for the personnel category).

28.4. Radiation and hygienic regulations of the first group

Exploitation of ionizing radiation sources.

1. Dose limits.
2. Derivative levels:
   - allowable levels;
   - reference levels.

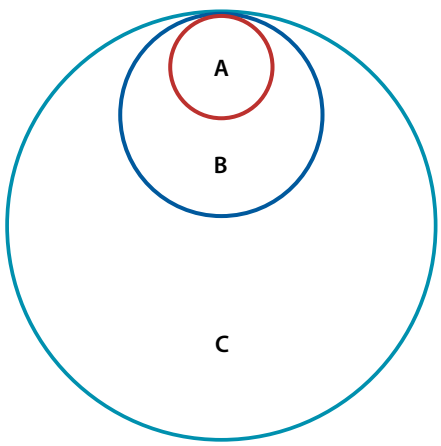


Fig. 28.1. The categorization of the population in terms of the nature of contact with sources of ionizing radiation

The first group of radiation and hygiene regulations includes dose limits from regulated sources; allowable levels, which are established differentially for each category of persons, and reference levels which are established for each group of employees and even for individual workplaces (Fig. 28.2).

The *dose limit (DL)* is the basic radiative-hygienic standard, which is introduced in order to limit the exposure of people of the relevant category from all industrial SIRs under normal operation for the planned irradiation situations. The values of these standards are given in Table 28.2.

For category A, the annual effective dose limit is the average over a period of 5 consecutive years, but not more than the maximum annual effective dose — 50 mSv. If a worker received 50 mSv, the average annual dose for the next 5 years should be less than 20 mSv, so that for 5 years the total dose shall not exceed 100 mSv.

The distribution of the dose by month is regulated only for women under 45 years of age and pregnant women. For women of category A, the average equivalent dose of external local irradiation of the skin of the lower abdomen should not exceed 2 mSv over period of two consecutive months. If a woman is pregnant, the management of the institution must create working conditions regarding occupational exposure in accordance with the requirements of NRBU-97 (mentioned above). Persons under the age of 18 are not allowed to work with SIRs.

NRBU-97 regulates the annual effective dose for volunteers, who assist in diagnostic procedures, at the level of 5 mSv per year.

Regulation and control of population exposure is carried out on the basis of calculations of annual effective and equivalent radiation doses of critical groups.

The limitations of the population irradiation are carried out by regulating and controlling of:

- gas-aerosol emissions and liquid discharges into water reservoirs during the operation of radiation-nuclear facilities;
- content of radionuclides in separate objects of the environment (water, food, air, etc.).

There are developed dose limit quotas, based on which allowable discharges (into water reservoirs) and allowable emissions (into the air) are set. This takes into account the migration of radionuclides in the food chains, the use of water bodies, land use conditions, etc.

The first group of radiation-hygienic regulations also includes allowable levels (AL), the lists of which for categories A, B and C are different. Values of allowable levels differ for people of each category.

For categories A and B:

- AI_{AB}^{inhal} — allowable inhalation of radionuclide;
- AC_{AB} — allowable concentration of radionuclide in the workplace air;
- AFD_A — allowable particle flux density;
- ADR_A — allowable dose rate of external radiation;
- ARC_A — allowable radioactive contamination of skin, working clothes and working surfaces.

For category C:

- AI_C^{inhal} — allowable inhalation through the respiratory system;
- AI_C^{ingest} — allowable intake through the digestive system;
- AC_C^{inhal} — allowable concentration in the air;
- AC_C^{ingest} — allowable concentration in drinking water;
- AD/AE — allowable discharge/emission of liquid/aerosol substances into the environment.

Table 28.2. Dose limits of total external and internal irradiation

Dose limits (mSv) (DL)	Categories of people exposed to radiation		
	A[a, b]	*B*[a]	*C*[a]
DL_E (effective dose limit)	20[c]	2	1
Limits of equivalent dose of external irradiation: DL_{lens} (for the lens of the eye)	150	15	15
DL_{skin} (for the skin)	500	50	50
DL_{extrim} (for hands and feet)	500	50	—

Notes:

a — the distribution of the radiation dose during the calendar year is not regulated;

b — for women of reproductive age (up to 45 years) and for pregnant women, there are restrictions of paragraph 5.6 (NRBU-97);

c — on average, for any period of 5 consecutive years, but not more than 50 mSv for a single year (DL_{max}).

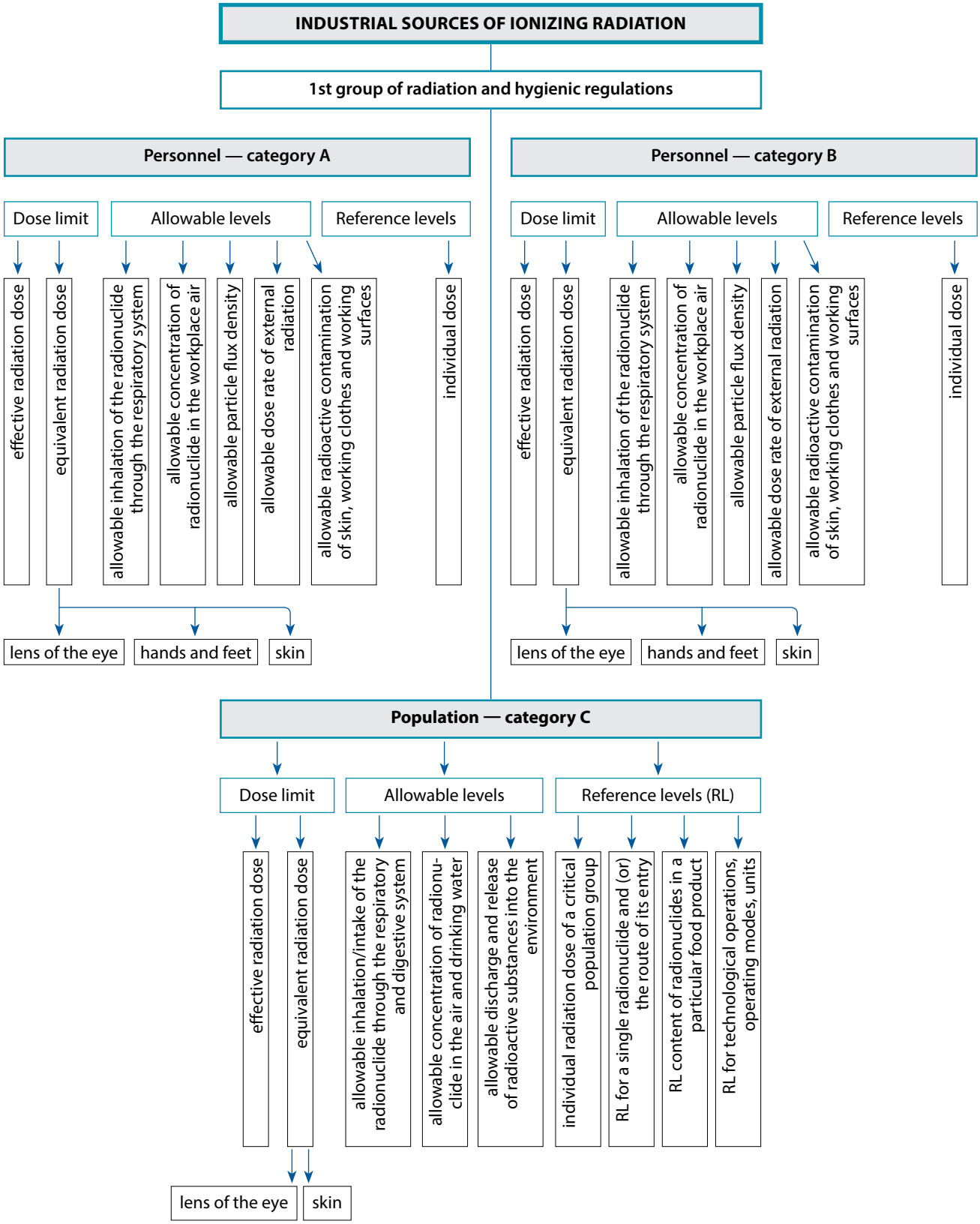


Fig. 28.2. The first group of radiation and hygienic regulations of irradiation

In view of the need to reduce the effects of radiation factors to the lowest level taking into account the real possibilities, the ICRP recommends to establish the reference levels, exceeding which indicates certain violations during the technological process and requires appropriate anti-radiation measures to recover the radiation indicators. These recommendations are reflected in NRBU-97.

Reference levels (RL) are radiation-hygienic standards of the first group, the numerical values of which are set based on the actual level of radiation safety at a particular radiation-nuclear facility, on its territory or at a particular workplace.

RL are set in order to fix the achieved level of radiation safety at the facility or for its separate premises, in the sanitary protection zone or in the radiation control area. The RL values must be at least 30 % lower than the relevant allowable levels.

RL can be set for the values of individual annual effective and equivalent external radiation dose of category A and B (personnel), annual effective radiation dose of critical groups of category C, radiation levels derived from personnel exposure limits or dose limits for the population. RL is not set for the value of the collective dose.

Exceeding the RL indicates a deviation in the technological process or violation of radiation safety rules, which have not yet led to serious consequences. If the RL is exceeded, the administration conducts an investigation in order to identify and eliminate the causes that led to the exceedance.

The numerical values of the RL are set by the facility administration and agreed with the local institution of the State Sanitary and Epidemiological Service in order to limit the exposure of personnel and/or the population below the dose limits, as well as for convenience of dosimetric control and evaluation.

28.5. Radiation and hygienic regulations of the second group

Medical irradiation of the population (Fig. 28.3).

1. Recommended levels of medical irradiation.
2. Occupational health check — 1 mSv/year.
3. Assistants (volunteers) — 5 mSv/year.

Medical exposure is the exposure of patients during diagnostic or treatment procedures using ionizing radiation, as well as volunteers who assist in the diagnostic procedure or participate in research.

Medical exposure is aimed at achieving a certain benefit for the patient or society in the form of obtaining diagnostic information or therapeutic effect. Medical irradiation of the population of Ukraine in terms of dosage takes second place after radiation exposure from natural sources.

As compared to the radiation and hygiene regulations of the first group, it is impossible for patients to apply strict regulations, such as dose limits. Instead, recommended levels have been introduced for patients undergoing medical examination. During X-ray and radionuclide procedures, 4 categories of persons are distinguished, for each of which there are recommended limit levels of medical diagnostic irradiation (effective doses):

Category AD:

- patients with cancer or people with diagnosed precancerous conditions;
- patients undergoing differential diagnostic procedure of congenital cardiovascular pathology and vascular congenital malformations;
- persons who are being examined for vital indicators.

Recommended exposure limit (effective dose) — 100 mSv × year^{-1}.

Category BD — patients whose examinations are conducted on clinical indications for somatic (non-oncological) diseases for diagnosis specification and/or selection of treatment strategy.

Recommended exposure limit (effective dose) — 20 mSv × year^{-1}.

Category CD — persons from the risk group, including employees of institutions with harmful factors, as well as persons who are hired to these institutions during the occupational selection.

Recommended exposure limit (effective dose) — 2 mSv × year^{-1}.

Category DD — persons who undergo all types of preventive examinations, except for persons classified in the category CD; in some cases, in accordance with the Ministry of Health, the dose may be increased; persons examined within the medical programs (volunteers).

Recommended exposure limit (effective dose) — 1 mSv × year^{-1}.

Persons who help patients with diagnostic procedures on a voluntary basis should not be exposed to doses above 5 mSv × year^{-1}. Participation of volunteers in medical and biological observations may be carried out with the permission of the Ministry of Health of Ukraine.

For persons of categories AD and BD, additional limits of irradiation of the most radiosensitive organs (tissues) are introduced — equivalent doses:

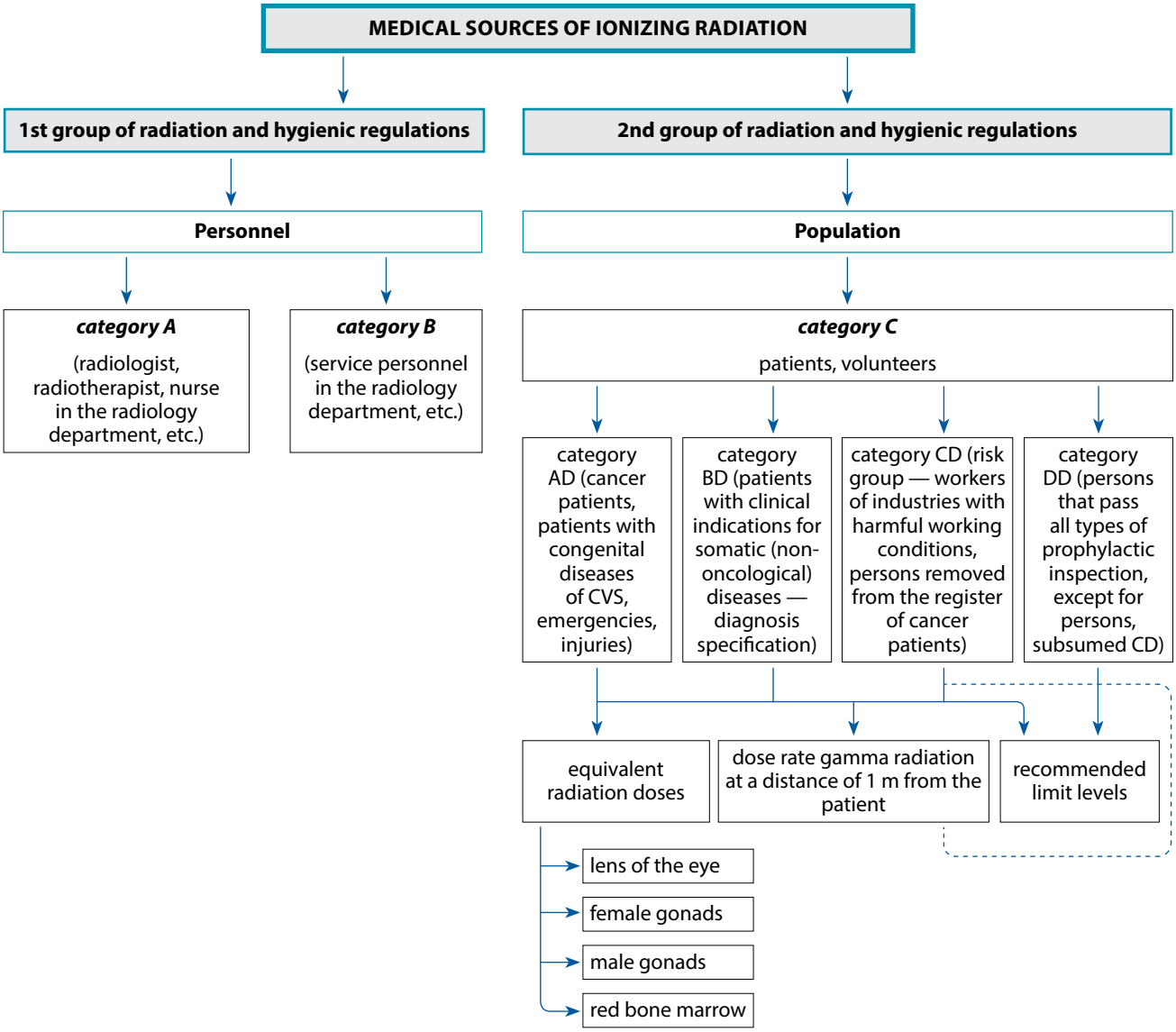


Fig. 28.3. The second group of radiation and hygienic regulations of irradiation

- lens of the eye — 150 mSv × year^{-1};
- female gonads — 200 mSv × year^{-1};
- male gonads — 400 mSv × year^{-1};
- red bone marrow — 400 mSv × year^{-1}.

If it is impossible to comply with the recommended levels, the physician must provide rationale for this in written form, agree with the chief physician, obtain permission from the patient or his relatives to exceed the recommended exposure limits. When performing radiological procedures with the administration of radiopharmaceuticals (RPh) into the patient's body, the dose rate should not exceed 10 μSv at a distance of 1 m from the patient when he leaves the radiology department.

Thus, when conducting medical examination using SIR, it is necessary to assess the value of the effective radiation dose for the patient.

In the case of radiotherapeutic procedures, it is necessary to ensure that the dose per patient will be as low as the diagnosis allows (to obtain the desired therapeutic effect).

28.6. Radiation and hygienic regulations of the third group

Intervention in the case of a radiation accident (Fig. 28.4).

- Intervention levels (averted dose).
- Action levels.

Averted dose is the dose that can be averted due to the application of a specific countermeasure and which is calculated as the difference between the dose without the use of a countermeasure and the dose after the cessation of the countermeasure.

Intervention level is the level of averted radiation dose, in excess of which it is necessary to apply a countermeasure in case of emergency or chronic exposure.

Action levels is a value derived from the level of intervention and is determined by the values of those indicators of the radiation situation that are measured (dose rate absorbed in the air; volumetric activity of radionuclides in the air; concentration of radionuclides in food; density of radionuclides in the soil, etc.).

In the case of unforeseen situations, there may be a need to perform work, as a result of which the radiation exposure on individuals may be higher than regulated under normal conditions. In this case, planning of increased exposure is allowed.

The planned increased exposure is the exposure of personnel (category A) above the established dose limits in unforeseen situations of practical activity.

Unforeseen situations are characterized by conditions that:

- need urgent elimination;
- cannot be eliminated without technological operations that involve exceeding the dose limits;
- may lead to the development of a radiation accident or significant socio-economic damage.

Persons who are referred to perform such work need to:

- be aware of the risks of overexposure to health;
- give their written consent.

It is forbidden to involve men under the age of 30 and women under the age of 45 in work related to increased exposure.

Justification of increased exposure is possible only if the damage from overdose for a particular person will be much less than the damage in case of non-routine work or the development of a radiation accident.

Planning for increased exposure at doses up to 50 mSv per year does not require additional approval from regulatory authorities. Exposure in doses from 50 to 100 mSv (i.e. not more than 2 DL_{max}) requires approval by the local bodies of the State Sanitary Supervision. Planned exposure of personnel in doses from 100 to 250 mSv (from 2 to 5 DL_{max}) is possible only in exceptional circumstances (only one occasion during the entire employment of the particular employee) by the permission of the Ministry of Health of Ukraine. After receiving a dose of 100 mSv and more, the employee must be removed from the irradiation zone and should undergo an unplanned medical examination. In the absence of contraindication for work with SIRs, the employee may obtain permission for further work with SIRs. Repeated increased exposure of the employee is prohibited if there is no complete compensation of the previous one. Increased exposure levels of persons of category B, as well as the population (category C) are not provided and prohibited by NRBU-97 regulations.

The standard values for personnel performing work related to the accident management are 100 mSv — doubled value of the maximum annual dose limit. In cases of rescue of people, conditions must be created for members of emergency teams in which the effective dose or equivalent dose to any organ must not exceed 500 mSv. Such doses are not grounds for removal of the worker from SIR-related work, but an unplanned medical examination is mandatory. All emergency activities must be performed under constant dosimetric control. Information on received emergency doses should be documented in an appropriate manner.

NRBU-97 defines urgent countermeasures with obviously reasonable interventions, and the delay in carrying out countermeasures moreover poses a threat of severe radiation injuries to those affected by the accident. Levels of unconditionally reasonable urgent intervention at acute (as a rule) external exposure can be found in NRBU-97.

28.7. Radiation and hygienic regulations of the fourth group

Protection against sources of technologically enhanced naturally occurring radioactive materials (TENORM).

1. Mandatory action levels.
2. Action levels.

Radiation and hygiene regulations of this group are aimed at reducing doses from long-term exposure to these sources at manufacturing sites and at the place of habitation. ICRP Publication 26 for the first time noted the need to limit the exposure of personnel and population, whose exposure is due to sources of natural origin,

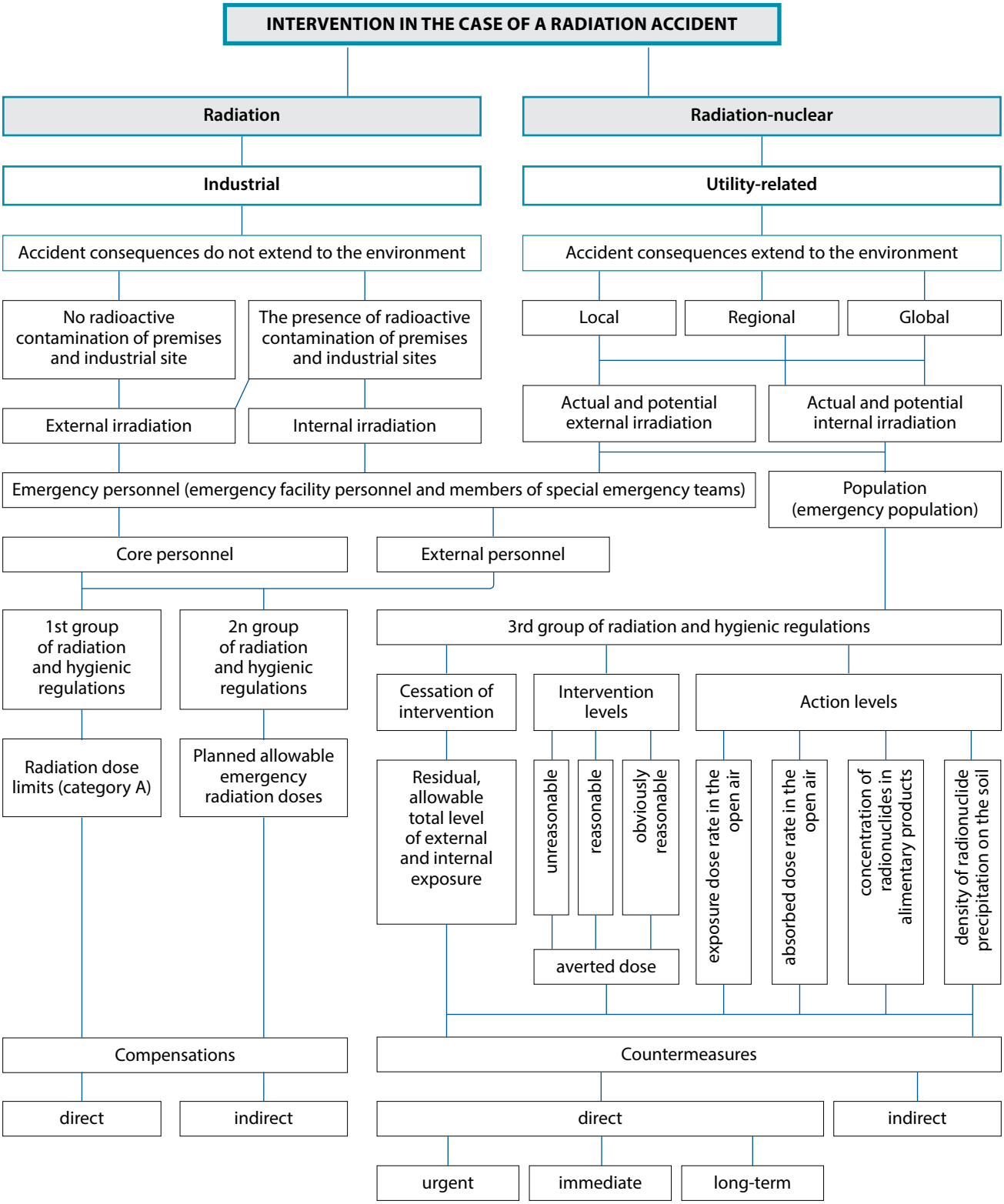


Fig. 28.4. The third group of radiation and hygienic regulations of irradiation

created as a result of human work activities. The idea of such a limit was specified in ICRP Publication 39, which is now defined as TENORM controllability. These sources cause additional background radiation, which cannot be influenced, to what is caused by artificial sources. When regulating the TENORM operation, two situations should be distinguished: the existing irradiation from an already created source and the future irradiation from a source that is planned to be created. Future irradiation is quite easy to regulate by choosing the appropriate raw materials for construction, building an artesian well, the water from which will meet current standards and the quality needs of the population. Existing exposure from TENORM is poorly regulated, because it requires significant material and other costs.

Quantitative criteria that provide radiation protection against TENORM are the levels of mandatory precautionary action and the level of action for ongoing radiation hygiene surveillance.

Levels of mandatory actions and levels of actions for the implementation of current radiation and hygienic supervision are determined by the following values:

- effective specific activity of naturally occurring radioactive materials (NORM) in building materials and mineral construction raw materials;
- rate of absorbed in the air (indoor) dose of gamma-radiation due to NORM, including a component from the natural radiation background;
- annual average equivalent equilibrium volumetric activity (EEVA) of radon isotopes in indoor air;
- specific activity of NORM in drinking water;
- effective specific activity of NORM in mineral fertilizers, porcelain, faience, glass, clay, mineral dyes and glazes.

If the required level of mandatory action is exceeded, the intervention is always appropriate and of a precautionary nature. Exceeding the appropriate level of action for the appropriateness of the intervention is considered in each case, so that the harm from the intervention does not exceed the benefit.

Mandatory action levels. The effective specific activity of naturally occurring radioactive materials in building materials and mineral building materials is calculated by the formula:

$$A_{ef} = A_{Ra} + 1.31\,A_{Th} + 0.085\,A_{K}$$

A_{ef} — the weighted sum of the specific activities of radium-226 (A_{Ra}), thorium-232 (A_{Th}), potassium-40 (A_{K}).

All building materials and construction raw materials are divided into four classes according to the following indicator:

- class I — $A_{ef} \le 370$ Bq/kg (for all types of construction without any restrictions);
- class II — $A_{ef} \le 740$ Bq/kg (for industrial construction, construction of highways);
- class III — $A_{ef} \le 1350$ Bq/kg (for construction of underground constructions, communications, highways, dams);
- class IV — $A_{ef} \le 3700$ Bq/kg (for finishing materials of aesthetic value).

The level of mandatory action for the absorbed dose rate inside premises under construction or reconstruction and intended for permanent residence of people is 0.26 μGy × h^{-1} (30 μR × h^{-1}), including the component from the natural radiation background.

The level of mandatory actions for the average annual EEVA of radon isotopes in indoor air: for radon-222 — 50 Bq/m^3, for radon-220 (thoron) — 3 Bq/m^3. The same values will be the levels of action for children's and health-related institutions. Allowable EEVA of radon is 50 Bq/m^3.

The levels of action for premises commissioned for operation before 1991 are 0.44 μGy × h^{-1} or (50 μR h^{-1}).

The levels of action of the average annual EEVA of radon isotopes in the air of rooms in which the permanent presence of people is provided, for radon-222 — 100 Bq/m^3, for radon-220 (thoron) — 6 Bq/m^3. If the above levels of action are exceeded, it is mandatory to carry out countermeasures for children's and residential accommodations.

The action levels for NORM in water sources of domestic and drinking water supply are:

- for radon-222 — 100 Bq/kg;
- for uranium (natural activity of a mixture of isotopes) — 1 Bq/kg;
- for radium-226, radium-228 — 1 Bq/kg.

Lower action levels for production facilities:

- dose rate — 0.5 μSv/year;
- EEVA of radon — 60 Bq/m^3;
- EEVA of thoron — 10 Bq/m^3.

If exceeded — anti-radon measures are mandatory!

If the annual dose exceeds 5 mSv, personnel are transferred to category A and anti-radon measures are taken.

According to the literature, the assessment of the contribution of radiation sources to radiation in the workplace can be carried out according to the following criteria:

- at an annual effective dose of less than 1 mSv, the situation is not controlled, the doses are not taken into account, radiation control is not mandatory;
- at annual doses from 1 to 2 mSv, it is necessary to carry out selective radiation control;
- at annual doses higher than 2 mSv, it is necessary to carry out constant radiation control and countermeasures to reduce doses;
- at annual doses higher than 5 mSv, it is necessary to carry out constant radiation monitoring and take all necessary measures to reduce doses. If it is impossible to limit the exposure to 5 mSv per year, the personnel is transferred to category A, and the State Sanitary Supervision should be informed about it.

The concept of allowable levels, which is the basis of NRBU-97, is to establish their values for the reference conditions of irradiation.

Values of allowable levels are determined using the following parameters: reference age, reference duration of irradiation, reference volume of drinking water consumed by a person during one year, reference volume of air inhaled during one year by a reference person, reference masses of organs and tissues exposed to radiation, etc. Allowable levels of radionuclide inhalation through the respiratory system, allowable concentrations of radionuclides in the air of working premises and other allowable levels are given in NRBU-97.

29 CHAPTER SANITARY PROTECTION OF THE ENVIRONMENT FROM RADIOACTIVE CONTAMINATION AS A HYGIENIC PROBLEM

I. M. Pelo, S. T. Omelchuk

29.1. Nuclear energy, its advantages and risks

On March 3, 2019, Henri Becquerel's discovery of the radioactivity phenomenon marked 123 years. Albert Einstein called it the large-scale revolutionary force of technological progress since the discovery of fire by early humans. Significant advances in the development of radiation technology and nuclear energy have benefited greatly for humanity and, at the same time, have posed a number of new challenges. One such challenge is radioactive contamination of environment due to the accidents on the facilities with radiation and nuclear technology, and, thus, there is a negative impact on public health. And although the frequency of accidents at such facilities is low, the probability of their occurrence increases along with an increase in the number of radiation and nuclear hazardous facilities.

The growth of energy needs in the 20th century has led to a significant reduction in stocks of fossil fuels (coal, oil, gas) and necessitated the conversion to nuclear technology for electricity production (Fig. 29.1).

Nuclear power industry originates from the world's first NPP, which was built in the USSR (Obninsk, Kaluga region, Russia) under the supervision of of I. V. Kurchatov and put into operation on June 27, 1954.

Nuclear (atomic) power engineering is a branch of energetics that uses nuclear energy for electrification and district heat supply, as well as a branch of science and technology that develops methods and means of converting nuclear energy into electric and thermal energy.

Nuclear power plants play an important role in the electric power industry of developed countries, producing cheaper electricity. Many countries around the world now have industrial nuclear power plants of various capacities. Today, the largest in Europe is the NPP in Zaporizhia with a capacity of 6 million kW.

In 2014 (according to the IAEA), the NPP generated about 11 % of electricity, which exceeds the volume produced in the world by all types of power plants in 1960.

According to the IAEA forecast, the share of nuclear energy will remain in the range from 12.4% to 14.4% of world energy production until 2030. As of 2014, 439 nucle-

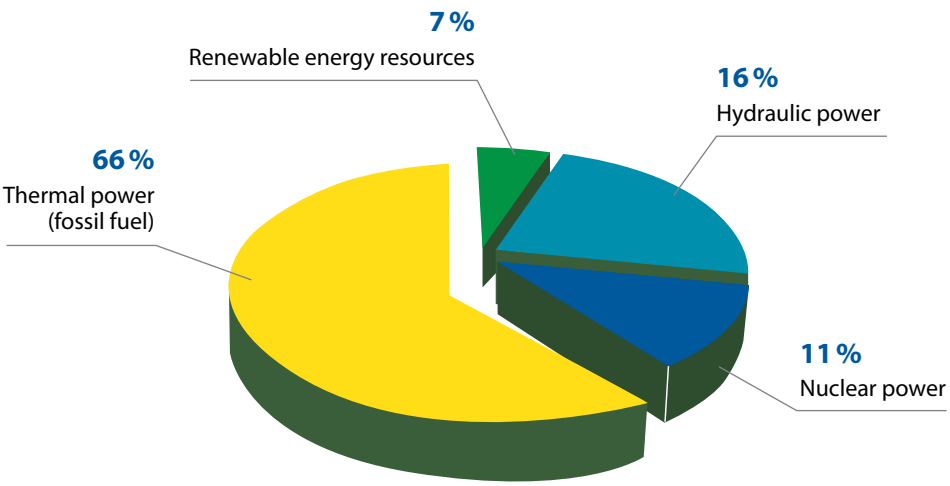


Fig. 29.1. Status of nuclear power around the world (2014)

Table 29.1. The share of nuclear energy in the total energy consumption of individual countries as at 2014

Country name	Number of reactors	Total capacity (MW)	Generation (%)
France	58	63130	76.9%
Ukraine	15	13107	49.4%
USA	100	99244	19.5%
Russia	34	24654	18.6%
United Kingdom	16	9373	17.2%
Canada	19	13500	16.8%
Germany	9	12074	15.8%
China	29	24140	2.4%
Japan	48	42388	0.0%
In total:	439	376821	10.9%

ar power reactors were operating at NPPs in 31 countries (Table 29.1).

Currently, NPPs are still the only efficient source of energy in the absence of fossil fuels and water resources. One kilogram of uranium can provide as much heat as is obtained by burning 3.000 tons of coal.

Today, 15 WWER power units operate at four Ukrainian NPPs: Zaporizhzhia NPP (Energodar) — 6 power units, Yuzhnoukrainsk — 3, Rivne (Kuznetsovsk) — 4, Khmelnytskyi (Netishyn) — 2. They have a total capacity of 13.8 GW, which is about 60% of the total capacity of the power complex of Ukraine (Fig. 29.2, Table 29.2).

The energy strategy of Ukraine envisages maintaining the dominant role of nuclear energy in electric power supply of Ukraine. Over the next 20 years, nuclear power generation should increase 2.5 times mainly due to the construction of new nuclear power units, as well as increasing the capacity of existing units through their modernization (Fig. 29.3, Fig. 29.4).

The conversion of nuclear energy into electric takes place at NPPs, the main part of which is a nuclear reactor. Many types of nuclear reactors have been developed in the world. They differ in the types of nuclear fuel (by methods and degree of its preparation), moderators, coolants, mechanisms of neutron use, etc. Nuclear reactors with thermal neutrons are preferred in use as simpler ones.

Ecological factors are of importance for the development of thermal energy. They include the entry into the atmosphere of significant amounts of carbon diox-

Table 29.2. Nuclear power plants of Ukraine

NPP name	Year of commissioning of NPP Unit I	Number and type of nuclear reactors	Total capacity, GW
Chornobyl NPP	1977	4 LWGR[1]	4.0
Rivne NPP	1980	4 WWER[2]	4.0
Zaporizhzhia NPP	1983	6 WWER	6.0
Yuzhnoukrainsk NPP	1983	3 WWER	3.0
Khmelnytskyi NPP	1984	2 WWER	2.0

Notes:

1 — LWGR — light water graphite-moderated reactor (out of operation); 2 — WWER — water-water energetic reactors.

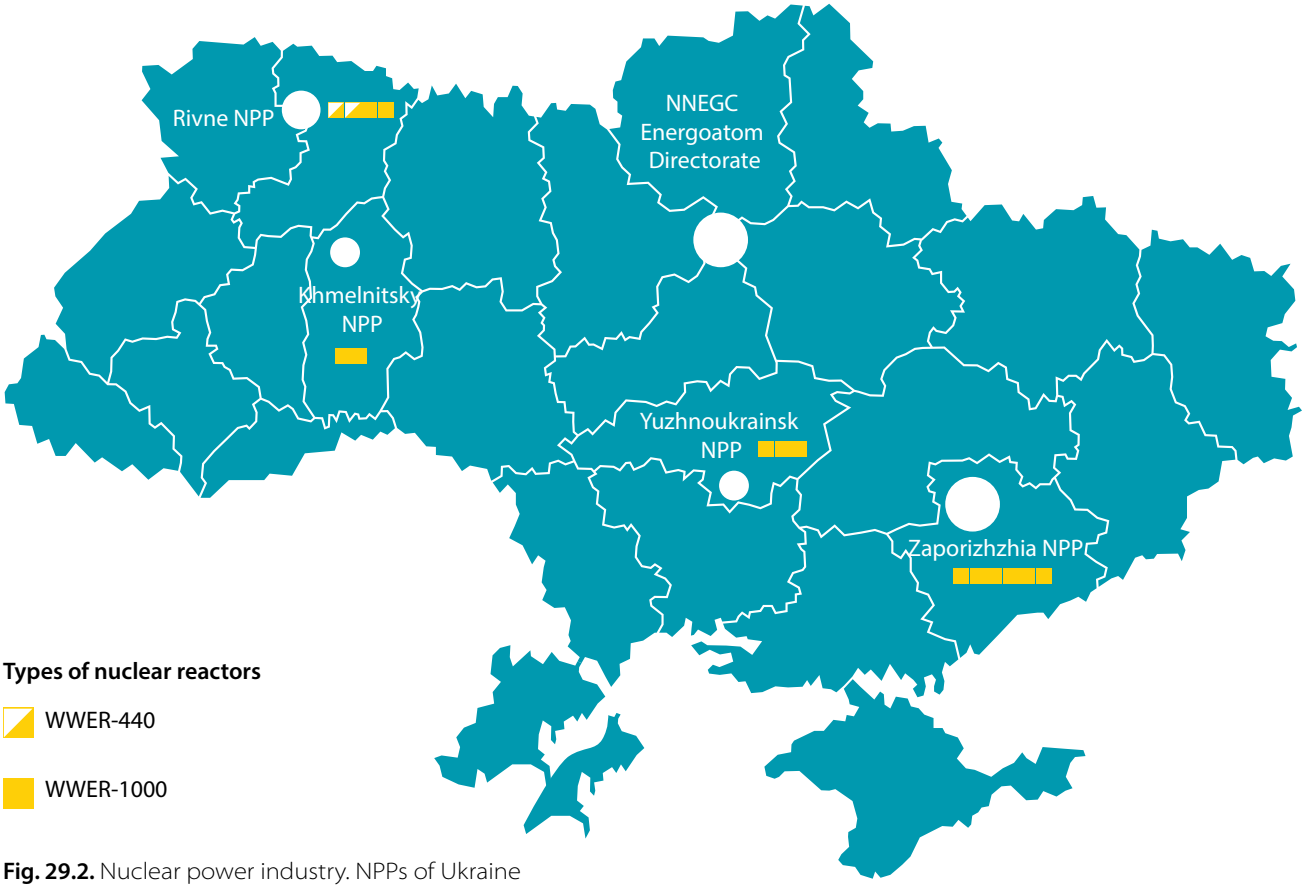


Fig. 29.2. Nuclear power industry. NPPs of Ukraine

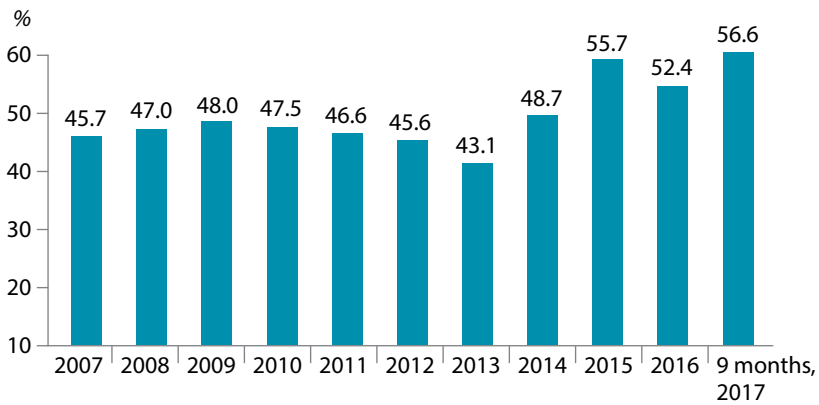


Fig. 29.3. Share of electricity of State Enterprise "National Nuclear Energy Generating Company "Energoatom" (SE NNEGC "Energoatom")

ide, sulfur and nitrogen oxides, concentrated radioactive substances of natural origin (man-made sources) contained in natural fuels for TPPs, and takeover of large areas of agricultural lands for the construction of TPPs (Table 29.3, Table 29.4).

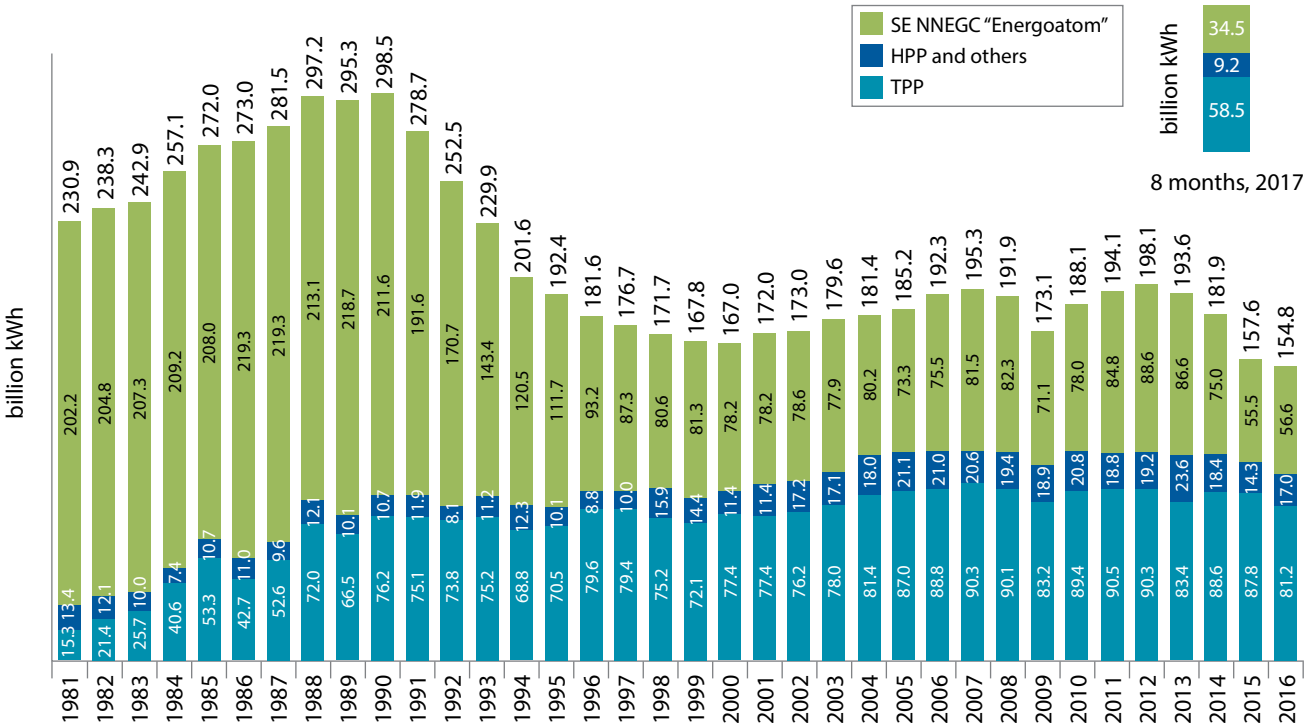


Fig. 29.4. Electricity generation in Ukraine *(1981–2017)*

Table 29.3. Areas of land takeover and waste volume

Indicators	NPPs	TPPs
Areas of land takeover for plant (1000 MW)	1–4 km^2	4000–6000 km^2
Volume of wastes from plant (1000 MW)	20 tonnes	≈ 7 million tons

Table 29.4. Toxic waste emissions into the atmosphere

Type of plant	CO_2 million t/year	NO_x thousands t/year	SO_2 t/year	Heavy metals t/year
TPP (1000 MW)	6.5	4.5	900	400
NPP (> 1000 MW)	0.4–0.6	—	—	—

29.2. Construction, operating principle and classification of nuclear reactors

A **nuclear reactor (NR)** is a physical device, in which a controlled chain reaction of nuclear atoms fission is carried out. A chain reaction is a sequence of nuclear transformations that occur under the influence of neutrons, if their number is sufficient for the fission of new nuclei.

The main part of the nuclear reactor is the core, in which the fuel elements (FE) with nuclear fuel, neutron moderators and neutron-absorbing rods, by means of which the nuclear fission chain reaction is controlled, are appropriately located. To remove heat from the FE, coolant is continuously pumped through the core.

Natural uranium enriched with the isotope of a mass number of 235 in the form of dioxide (the enrichment level is 3–5 %) is used as a nuclear fuel in most reactors.

Uranium with an enrichment of ^{235}U up to 20% is called low-enriched uranium. Uranium with 20% or more U_{235} content is classified as highly enriched uranium and is used in fast neutron reactors. Uranium, which is more than 90% enriched in U_{235}, is called weapons-grade uranium. It can be used in the manufacture of nuclear weapons.

Moderators include substances that significantly reduce the energy and, at the same time, the speed of neutrons (graphite, light and heavy water, etc.).

Control rods and emergency shutdown rods contain substances that adequately absorb neutrons (boron, cadmium, hafnium, etc.). The coolants can be water (light

Table 29.5. Arrangement, operating principle and classification of NRs

Reactor type	Coolant	Moderator
Slow-neutron reactors		
WWER LWGR	Light water under pressure Light boiling water Gas Heavy water Light water	Light water Light water Graphite Heavy water Graphite
Fast-neutron reactors		
FNR	Liquid metal	None

Notes:
WWER — water-water energetic reactors; LWGR — light water graphite-moderated reactor; FNR — fast-neutron reactors.

or heavy), gas (helium, nitrogen, carbon dioxide), liquid metal (sodium) and some other substances (Table 29.5).

Nuclear reactors are classified by purpose into power reactors, which are used to generate thermal energy, and research reactors, which are a unique source of neutron fluxes and other types of ionizing radiation used for scientific purposes.

In Ukraine, only one type of nuclear reactor is currently used — a water-water (double-circuit) power reactor with light water as the coolant and neutron moderator. At the Chornobyl NPP, high power single-circuit nuclear reactors (RBMK-1000) were used. They have worse properties and are more dangerous. In light water reactors (LWR), the coolant is light water, and the moderator is graphite.

The fundamental difference between these two types of reactors is that in a WWER the coolant is pumped through the entire core, so the entire reactor vessel is under pressure, and in LWGR the coolant circulates through the fuel channels, and they alone are under pressure. Due to these features, the first type is called vessel-type reactor, and the second type — channel-type reactor.

29.3. Characteristics of radionuclides generated during the operation of a nuclear reactor

A nuclear reactor is a generator of a large number (about 700) of radionuclides. During the operation of NR in the core, nuclear fission products (about 200 isotopes of 35 chemical elements) and products of induced activity (about 400 species) are formed, as well as isotopes of transuranium elements (about 60 species) which arises from uranium-238 irradiation with slow neutrons (Table 29.6). All these radionuclides cause extremely high radioactivity of nuclear fuel that has been in the core. The radioactivity of freshly discharged nuclear fuel is 107–108 times higher than that of non-irradiated fuel. 95 % of this radioactivity is due to fission products, which are γ-irradiators. The greatest role in creating high radioactivity of spent fuel elements is played by short-lived isotopes of iodine, cesium, cerium, technetium, molybdenum, zirconium, etc. They all poison the reactor, because they capture neutrons reducing the intensity of the chain reaction and the process of heat release.

The United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) believes that the

Table 29.6. Characteristics of radionuclides formed during reactor operation

Number of radionuclides	Position in the periodic table	IR type	Half-life
Fission products of fuel atom nuclei			
About 200	The middle of the periodic table (sequence numbers) — from 30 (zinc) to 64 (gadolinium).	β, γ	Fractions of a second – decades
Products of induced activity			
About 400	The beginning and middle of the table	β, γ	Seconds – tens and thousands of years
Isotopes of transuranium elements			
About 60	The end of the table (after 92 number)	α, β	Tens and millions of years

greatest role in the exposure of the population caused by nuclear accidents at nuclear reactors is played by 20 radioisotopes of 14 chemical elements: hydrogen-3 (tritium), carbon-14, magnesium-54, iron-55, krypton-85, strontium-89 and -90, zirconium-95, ruthenium-103 and -106, iodine-131, cesium-134 and -137, barium-140, cerium-141 and -144, plutonium-238, -239, -241, americium-241. However, the greatest role in the exposure of the population is played by only 8 radionuclides. The share of each radionuclide in the effective equivalent dose exceeds 1 %. These include: carbon-14, cesium-137, zirconium-95, ruthenium-106, strontium-90, cerium-144, hydrogen-3, iodine-131.

In the long-term periods after the nuclear reactor accident, the largest role belongs to cesium-137 and strontium-90. The activity of the formed radionuclides and their qualitative composition depend on the duration of the reactor operational period before the accident, as well as on enrichment level of nuclear fuel. A significant role in the discharge of radionuclides into the atmosphere depends on the volatility of radionuclides formed during the operation of the reactor. Thus, krypton and xenon (boiling points are 152 and 107 °C respectively), in the event of a core explosion, completely evaporate from nuclear fuel. Isotopes of iodine, cesium, and tellurium enter the atmosphere in slightly smaller quantities. Radioisotopes of molybdenum, zirconium, cerium, plutonium, which have high boiling points, are more strongly associated with fuel and can enter the atmosphere only in the form of fine dust.

During the reactor core destruction or during other critical events, radionuclides accumulated in the reactor enter the biosphere causing radiation pollution of the environment and exposure of humans and animals.

Improper process management can cause the core overheating, and the coolant and neutron moderator consequently evaporate in water-water reactors, and, with a significant increase in temperature, even graphite can burn in LWGR.

Normally, a nuclear reactor, despite a specially designed system of reusable barriers, however, causes the contamination of environment with small activities of radionuclides, which are dispersed in the air, while decaying. Argon-41, hydrogen-3, and carbon-14 can be considered as sources of irradiation of the population living near the NPP.

The most biologically significant radionuclides include inert gases (krypton and xenon isotopes), volatile radionuclides (iodine and cesium radioisotopes), non-volatile (strontium isotopes), and tritium, which is formed as a result of the fission reaction in the core.

29.4. General overview of accidents and classification of nuclear reactor accidents

In the field of radiation safety, two terms are used to refer to cases involving human overradiation: radiation and nuclear accident.

A radiation accident, in a broad sense, is an unexpected event associated with the loss of regulatory control over any source of ionizing radiation resulting in the release of radioactive substance or ionizing radiation outside the intended protective barriers, which causes or may cause accidental exposure.

A **nuclear accident** (narrower term) is an event associated with the loss of control over fissile nuclear material (uranium-233, uranium-235, plutonium-239, etc.) that causes or may cause a spontaneous chain reaction of nuclear fission with the release of radioactive products and the radiation itself beyond the prescribed protective barriers. This leads or may lead to accidental exposure of people (the consequences of a nuclear accident can significantly exceed the radiation accident).

Nuclear material is spontaneously fissionable radioactive material, except for natural or depleted uranium which can emit energy through a self-sustaining nuclear fission chain process outside the nuclear reactor, and radioactive products and wastes (except small quantities not exceeding the established limits).

The history of the nuclear energy use includes a large number of nuclear accidents that have occurred at nuclear power plants, as a result of which personnel and the population received significant doses of radiation. Thus, in 1976, the secret of a powerful nuclear accident occurred in 1958 as a result of an explosion and fire at the nuclear waste disposal plant in the Southern Urals, was revealed. Radioactive fallout has spread over large areas, and, as a consequence, tens of thousands of people have been exposed to high radiation doses, and there have been numerous fatal cases.

There have been **four world's largest nuclear accidents** in the history of nuclear power plants operation**:**

- 1961 — Idaho Falls (USA);
- 1979 — Three Mile Island NPP in Harrisburg (USA);
- 1986 — Chornobyl NPP;
- 2011 — Fukushima NPP.

The Fukushima NPP accident on March 12, 2011, which was caused by a 7-magnitude earthquake, is considered quite severe.

During the first decade after the use of nuclear weapons over the territory of Japan, information about the hazard of radiation exposure in the USSR was strictly prohibited. Only after the Chornobyl accident and the collapse of the Soviet Union, the information on radiation and nuclear accidents became available to the population of Ukraine.

The most probable causes of radiation-nuclear or nuclear accidents are disregard of radiation safety rules during installation, commissioning, testing of nuclear reactors, recharging of core zones, transportation and storage in breach of requirements to the technological process with spent nuclear fuel or any nuclear material. A nuclear accident can occur, when the core of a reactor is destroyed by orthodox explosive weapon.

The inherent features of accidents are:

- unexpectedness of the phenomenon itself;
- loss of regulatory control over SIRs;
- irradiation of people in doses exceeding the allowable levels;
- probability of occurrence of radioactive contamination foci.

In terms of the probability of occurrence and aftermath, the nuclear reactor accidents are divided into design-basis and beyond-design-basis.

Design-basis accidents are predictable situations that are relatively easy to eliminate and that are not accompanied by significant overexposure of personnel and certain groups of population. The characteristics of design-basis accidents are given in the documents of radiological facilities. Precautionary and anti-radiation measures are developed for such situations. These measures are aimed at rectification of the negative consequences and recovery of the facility operation.

Beyond-design-basis accident is an accident caused by events that are not provided for when developing documents regarding the prevention and elimination of radiation accidents. The beyond-design-basis accident is characterized by the destruction of the facility with the impossibility of recovering of its operation. Such accident, without termination and confinement, could turn into an irreversible nuclear disaster causing transboundary and even global spread of radiation factors. A distinctive feature of a nuclear disaster is its irreversibility. The high speed of the destruction process eliminates the possibility of confinement a radiation disaster at the first stages. The need to strength the emergency preparedness for large-scale radiation accidents and disasters, as well as the development and improvement of safety systems at the technical and organizational levels, is becoming apparent. This requires the forming of regulations and legal framework for the implementation of countermeasures, development of methods for forecasting the radiation situation, studying the possible consequences of accidents, developing a monitoring system, determining the necessary countermeasures for different scenarios and monitoring their implementation, and studying their effectiveness.

In terms of the scale of the consequences, radiation (including nuclear) accidents are divided into two classes: industrial and municipal.

Industrial accidents include radiation accidents with consequences (ionizing radiation and radioactive contamination) that do not extend beyond the production areas and industrial sites of the facility, and therefore only personnel is exposed to accidental irradiation.

Municipal accidents include such radiation accidents the consequences of which are not limited to the production areas and industrial sites of the facility probably leading to accidental exposure of both personnel and population.

By scale of radionuclide dispersal, **municipal radiation accidents** are divided into: local, regional, global.

Local accident is such a municipal radiation accident which covers an area with a population of up to 10 thousand people.

Regional accident is such a municipal radiation accident which covers the territory of several settlements or administrative districts and even regions with a population of over 10 thousand people.

Global accident is municipal radiation accident that covers a large part or all of the country with its population.

There is a concept of an accident situation. It is the state of the (nuclear) facility characterized by a violation of the conditions of safe operation, which did not turn into an accident.

In order to unify the system of information exchange on nuclear accidents for specialists, public and press upon an initiative of the IAEA and other international organizations, an expert group developed the International Nuclear and Radiological Event Scale (Table 29.7).

The essence of this scale is that according to the consequences for the environment (the amount of radioactive release, which is estimated by iodine-131) and population (radiation dose), as well as for the nuclear reactor and plant personnel, all NPP events are divided into 7 levels. Any radiation accident consists of a series of events that develop over time. Knowledge of these

Table 29.7. International Nuclear and Radiological Event Scale

Level	Industrial site situation	Situation outside the industrial site
Deviation	No changes in terms of security	No changes
Abnormality	Abnormality of the operating mode. There are conditions for a safety inhibition	No changes
Event	Radionuclide contamination, exposure of personnel above dose limits	No changes
Serious event	Significant pollution, accidental exposure, acute impact on personnel health	Damage of security layers. There is no exposure of population
Accident	Significant damage to the core, lethal exposure of several workers	Significant environmental pollution, minor exposure of population
Accident	Almost similar	Significant environmental pollution, partial implementation of countermeasures
Severe accident	Lethal irradiation of all workers of the operating shift, significant release of radionuclides	Full implementation of countermeasures
Large-scale accident	Destruction of the industrial site, numerous lethal and acute radiation injuries	Pollution of large areas, over-irradiation of large contingents

periods and their characteristics allows to determine adequate radiation protection measures.

Level 0 called deviations, level 1–3 are events, and level 4–7 — accidents. Level 1 and Level 2 do not result in accidental exposure of either facility personnel or population. Level 3 is accompanied by irradiation of only facility personnel. Level 4 to Level 7 cause over-irradiation of both facility personnel and population.

29.5. Characteristics of phases (stages) of nuclear accident progression. Main ways of radiation exposure to different categories of population

The main potential danger of an accident at a nuclear reactor is the release into the environment of radioactive fission products accumulated in the core at the time of the accident. In world practice, it is usual to distinguish several periods in the progression of a nuclear accident, which in the publications of various international organizations are called differently, but the essence of events does not change. Each of periods has its own time limit and its own quantitative and qualitative characteristics (Table 29.8).

The early (acute) phase lasts from several hours to 1–2 months. In this phase:

- gas-aerosol emissions occur;
- the plume of the radioactive "torch" forms a radioactive trail;
- short-lived radionuclides are dominated in the environment;
- high levels of dose rate and surface contamination of plants and other environmental objects.

The main role belongs to radioactive isotopes of iodine and other short-lived beta-gamma emitters that enter the air and food, especially milk.

The middle (stabilization) phase lasts from 1–2 months to 1–2 years. In this phase, there are a rapid decrease in dose rate, root contamination of plants and almost no short-lived radionuclides in the environment. In addition, external irradiation is of some importance, but internal irradiation due to radioactive cesium and strontium, which accumulate in locally produced food of plant and animal origin, is beginning to prevail.

The late (recovery) phase begins after the end of the stabilization phase and can last for many tens and hundreds of years. In this phase, the internal irradiation with long-lived radionuclides comes to the fore, the external irradiation is almost irrelevant, and it is represented mainly by gamma radiation of cesium-137.

Table 29.8. Characteristics of the progression of nuclear accidents at NPPs

Accident phases (WHO, 1981)	Accident stages (ICRP, 1984)	Accident phases (IAEA, 1988)
Early phase	***Early stage***	***Early phase***
Covers the period from the moment of threat of emission to several hours after the accident		
Intermediate phase	***Intermediate stage***	***Middle phase***
Covers the period from the first few hours to several days after the accident. It is believed that a large portion of the emission has already taken place and radioactive substances have already settled on the soil surface		
Late phase	***Recovery stage***	***Late phase***
This period could be long-term. It is characterized by the gradual repeal of protection measures that were introduced earlier and the adoption of decisions related to the return to normal life of population and the activities of the territories		

The ways of radiation exposure to specific categories of people depend on the phase of a nuclear accident progression. Knowledge of this information allows determining adequate measures of radiation protection.

In the early phase outside the accident facility (irradiation of the population):

- external irradiation from the accidental release of radioactive cloud;
- external irradiation from the plume and fallout of the radioactive cloud;
- external irradiation from radionuclide precipitation on the soil and other surfaces;
- contact irradiation from contamination of skin, clothing and other surfaces;
- internal irradiation via inhalation of radionuclides;
- internal irradiation via alimentary intake.

Within the accident facility (irradiation of personnel and liquidators of the accident aftermath):

- external irradiation from the destroyed reactor and fragments of the core;
- external irradiation from a radioactive release plume.

In the middle phase:

- external irradiation from radionuclide fallout on the soil;
- internal irradiation via inhalation of radionuclides due to re-formation of the dust.

In the late phase:

- radionuclides are ingested mainly when consuming radioactively contaminated food and water.

29.6. Countermeasures depending on the accident phase

Protection of the population under emergency conditions is based on a system of anti-radiation measures (countermeasures), which are divided into direct and indirect.

Direct measures include countermeasures the implementation of which leads to the prevention or reduction of individual or collective doses of irradiation exposure of the population.

Indirect measures are all types of countermeasures that do not prevent individual or collective doses of radiation to the population, but compensate for the amount of health damage associated with emergency exposure.

In terms of the scale and phase of the accident, and the level of projected radiation doses, direct countermeasures are divided into urgent, immediate and long-term.

Urgent countermeasures are aimed at preventing such levels of radiation doses to the population (acute or chronic) which pose a threat of radiation effects with clinical manifestations.

Immediate countermeasures are intended to prevent deterministic effects.

Long-term countermeasures are implemented towards averting doses of radiation (acute or chronic), the values of which are below the thresholds of induction of deterministic effects.

Immediate measures in the early phase of a radiation accident are divided into main and supportive (Table 29.9).

Table 29.9. Countermeasures depending on the phase of the accident

Phase	Countermeasure
Early	Sheltering, evacuation, limitation of behavior mode*
Early	Sheltering, encapsulating of premises, external ventilation isolation*
Early	Sheltering, limitation of behavior mode and nutrition regimen. Prevention of iodine radioisotopes entering*
Early Middle	Sheltering, evacuation. Limitation of behavior mode.* Radioactive decontamination**
Middle Late	Evacuation.* Temporary relocation. Resettlement. Limitation of behavior mode and nutrition regimen. Radioactive decontamination of territories, buildings and structures**
Middle Late	Temporary relocation. Resettlement. Radioactive decontamination of territories, buildings and structures**
Late	Agricultural and hydraulic measures**

Notes:
**direct urgent and immediate; **long-term.*

Main (direct) measures:
- sheltering people in the contaminated area or evacuation if there is a legally justified ground;
- iodine prophylaxis;
- restriction of walks and prohibition of open-air workplace (if possible).

Supportive measures:
- organization of control points when leaving the most polluted areas;
- dust suppression, road washing;
- changes in the working hours of child welfare and medical-recreational institutions;
- indoor maintenance of cattle transporting to a clean area;
- restrictions on hunting, fishing;
- health communication — explanation of the radiation situation, recommendations on the behavior of the people living in radioactively contaminated areas.

There are also indirect countermeasures. They include various compensations that do not reduce radiation exposure, but are aimed at improving the quality of life, reducing the amount of health damage.

Protective measures are divided into emergency and long-term. Emergency measures are implemented to divert acute deterministic effects (radiation sickness, local radiation injuries). Emergency countermeasures provide not only unconditional justifiability for the intervention, but also a rapid response. The levels of unconditionally/reasonably justified urgent interventions are intended to prevent the occurrence of deterministic effects from general (whole-body) or local irradiation. Thus, under the general irradiation of the whole body on the level of unconditionally/reasonably justified intervention receiving an acute single-moment irradiation (for not more than 2 days), there is a certain absorbed dose: for the whole body 1 Gy, for the lungs — 6 Gy, for the skin — 3 Gy, for the fetus — 0.1 Gy, for the thyroid gland — 5 Gy, for the lens and gonads — 2 Gy. Annual equivalent doses for chronic (prolonged) irradiation, when an urgent intervention is definitely justified, are the following: for the gonads — 0.2 Sv × year^{-1}, for the lens — 0.1 Sv × year^{-1}, for the bone marrow — 0.4 Sv × year^{-1}.

Long-term countermeasures include reducing the frequency of long-term non-deterministic (stochastic) effects: temporary relocation or resettlement for permanent residence, decontamination of territories and buildings, restriction of the use of certain radioactively contaminated agricultural products (detected by radiation monitoring). Quantitative and qualitative characteristics of a radiation accident and its impact on the environment are taken into account when making decisions on long-term countermeasures.

It should be noted that countermeasures should be implemented at a period of their maximum efficiency. At the same time, after the Chornobyl accident, the population continued to be resettled for several years. This measure did not significantly reduce the radiation load, but caused psychological and social damage at high material costs. In practice, the calculated value of the dose averted by the implementation of this countermeasure is compared to the corresponding value of the justification/reasonability limit.

The justification/reasonability limit is determined by the value of the averted dose, at which the health benefits from the countermeasure are almost equal to the amount of damage caused by it. A countermeasure is justified if the benefits outweigh the losses. If this outweigh is significant, such a countermeasure is considered unconditionally/reasonably justified (Table 29.10).

Evacuation of the population is an urgent relocation of people to a safe place for temporary or permanent residence (resettlement). The optimum time for evacuation is the time before the pollution plume appears, because, when evacuating during the pollution plume passage, the radiation loads may be higher than when people are in temporary shelters at the contaminated area. If the radioactive emission has already started and is expected to increase, the population should be evacuated even during the pollution plume passage using vehicles, as well as respiratory and skin protection, and iodine prophylaxis.

Table 29.10. Justification limits for countermeasures

Countermeasure — sheltering (2 weeks doses):	
For the whole body	5 mSv
For the thyroid gland	50 mSv
For the skin	100 mSv
Countermeasure — evacuation (2 weeks doses):	
For the whole body	50 mSv
For the thyroid gland	300 mSv
For the skin	500 mSv
Countermeasure — iodine prophylaxis (2 weeks doses):	
For the thyroid gland in children	50 mSv
For the thyroid gland in adults	200 mSv
Countermeasure — restriction of open air stay (2 weeks doses):	
Children	1 mSv
Adults	2 mSv

In order to protect hair and body, people should use headwear, coats, jackets, closed shoes. Personnel carrying out work during the evacuation of the population must have special protective clothing and personal protective means. After the population leaves the contaminated areas, it is necessary to carry out complex decontamination (personal cleansing) with a shift of clothes. Radiation control after decontamination is mandatory.

Countermeasures, in particular, iodine prophylaxis for large cohorts, are carried out if there are appropriate indications — probable certain radiation exposure. For small cohorts, evacuation and other countermeasures are justified even at small diverted doses (Table 29.11, Table 29.12).

Ukraine has established an emergency medical service — a centralized state service that functionally unites medical teams and health care facilities to provide medical care and treatment of victims of emergencies, in particular, in the case of radiation and radiation-nuclear accidents.

In a case of a small number of victims, medical care due to a radiation-nuclear accident is provided by the personnel of aid posts, primary healthcare units of the facilities where the accident occurred, or pre-determined specialized health care facilities of radiological type. Specialists from various specialties of other medical institutions may be involved in providing special medical care.

In the case of a large number of victims, medical institutions of the Ukrainian Emergency Medical Service (UEMS), established in the system of the Ministry of Health of Ukraine at both national level (central level) and regional level, are involved in providing medical care. The first-level medical institutions include the Ukrainian Scientific-Practical Center of Emergency Medical Care and Disaster Medicine of the Ministry of Health (USPCEMDM).

At the regional level, there are 24 centers (for each region) of the UEMS, centers of the Autonomous Republic of Crimea, centers of the cities of Kyiv and Sevastopol.

Organizational and methodological management of the UEMS is provided by the Ministry of Health of Ukraine. In case of emergencies, the activity of this Service is coordinated by the central and local coordination commissions.

Table 29.11. Bottom justification/reasonability boundaries and unconditionally/reasonably justified levels of intervention for resettlement

Criteria for decision making	Bottom justification/ reasonability limits	Unconditionally/ reasonably justified levels of intervention
Averted dose during the resettlement period (Sv)	0.2	1.0
Averted dose over a 12-month period (Sv)	0.05	0.5
Outdoor dose rate (μGy/h): ■ cesium-137 contamination; ■ fission fragments	 1.2 20	 12 200

Table 29.12. Bottom justification/reasonability boundaries and unconditionally/reasonably justified levels of intervention for temporary relocation

Criteria for decision making	Bottom justification/ reasonability limits	Unconditionally/ reasonably justified levels of intervention
Total dose for the temporary relocation period (Sv)	0.1	1
Average monthly dose (Sv)	0.005	0.05
The absorbed dose rate in the air (μGy/h)	10	100

CHAPTER 30

MEDICAL CONSEQUENCES OF THE CHORNOBYL DISASTER FOR THE POPULATION OF UKRAINE

S. T. Omelchuk, I. M. Pelo

The history of the nuclear energy use includes a large number of nuclear accidents that have occurred at nuclear power plants, as a result of which thousands of people were affected by significant radiation doses.

From 1954 to the present day, about 300 accidents have been reported at radiation-hazardous facilities around the world, including more than 30 major ones. These accidents had been accompanied by release of radionuclides into the environment and, in some cases, human losses.

One of the largest radiation accidents, the Kyshtym disaster, occurred in the Southern Urals (USSR) on September 29, 1957.

Due to the cooling system failure relating to the concrete tank with nitrate-acetate highly radioactive waste, an explosion occurred which led to the release of radionuclides into the atmosphere followed by their fallout in the Cheliabinsk, Sverdlovsk and Tiumen regions.

The total emission activity is estimated by experts at about 200 thousand curies.

On October 10, 1957 at the Windscale (now Sellafield) NPP (Great Britain), due to malfunction of control and measuring equipment and erroneous actions of personnel, the reactor core overheated and the fuel rod claddings were destroyed. This accident led to the release of radionuclides into the atmosphere.

The total emission activity is 50–75 thousand curies.

According to the International Nuclear and Radiological Event Scale (INES), the accident was rated level 5.

$ 78 million was spent to eliminate the consequences of the accident.

On March 28, 1979, at the Three Mile Island NPP (Pennsylvania, USA), due to erroneous actions of the personnel, almost 50 % of fuel rod claddings melted. This led to the release of radionuclides into the atmosphere.

The total emission activity is estimated at about 200 thousand curies.

The accident was rated as INES 5.

$ 2.4 billion was spent on the aftermath of the accident.

The Three Mile Island accident, before the Chornobyl disaster occurred, has been considered the largest one.

The Fukushima NPP accident on March 12, 2011, which was caused by a 7-magnitude earthquake, is considered quite severe. On the territory of Ukraine, no increase in the radiation background was observed due to this accident.

30.1. Peculiarities of the Chornobyl NPP accident

Assessment of radiation circumstances at different stages of remedial actions in the wake of the Chornobyl accident.

On April 25, 1986, preparations were made for the shutdown of Unit 4 of the Chornobyl NPP. Tests were supposed to be conducted under the conditions of disabled protection systems in the complete blackout mode of equipment. In order to generate electricity, it was decided to use the mechanical energy of the rotor in the turbine-generator set to pump cooled water through the core. The main violations of the regulations: the experiment was performed on a running reactor with the cooling system switched off; the absorbing rods — "emergency reserve" — were removed from the core section. The system of local automatic regulation and the protection system for maximum design-basis accident (or maximum credible accident) were erroneously switched off.

In response to the lack of cooling of the core, thermal explosion occurred with its complete destruction (Fig. 30.1, Fig. 30.2, Fig. 30.3).

The total emission activity is estimated at ≈ 50 million curies.

31 people died from direct contact with radiation.

About 4.000 people died as a result of radiation in the remote period after the accident.

According to the International Nuclear and Radiological Event Scale, it is classified as level 7.

$ 6.7 billion was spent on the aftermath of the accident.

Peculiarities of the Chornobyl NPP accident

1. **The magnitude of the accident**. According to official information, the total radioactivity emission amounted to 50 million Ki. The territory of the exclusion zone was contaminated with "hot particles".
2. **Duration of the emission**. Intensive emissions continued from 26.04.1986 to 06.05.1986.
3. **Unstable weather conditions**. Over the 10-day period radionuclides and "hot particles" release into the atmosphere, the direction of air mass movement changed several times, which was accompanied by meteorological phenomena (precipitation, fog, temperature inversions, etc.). This led to uneven contamination of the territory with significant differences in both the density of contamination and the radionuclide composition. There were zones of radioactive contamination in three main directions — north-western, western and southern.
4. **The scale of radioactive contamination of the territory**. The Chornobyl accident caused an intensive radioactive contamination that affected not only large areas of Ukraine (about 55.000 km^2), but also the territories of other countries in Europe and Asia.

For example: *Cs-137 contaminated the territories in approximately the following respect (of the total amount): the USSR ~ 43 %, Europe ~ 38 %, other territories and waters of the Northern Hemisphere ~ 8 %.*

5. **The accident occurred in the conditions of Polissia**. Polissia is an endemic region in terms of iodine content in the environment. The tropism of the thyroid gland to iodine is 100 %. There is a large amount of unstable iodine isotopes in the environment. Polissia soils promote the migration of radionuclides. Dietary habits of the population include a large proportion of wild mushrooms and berries.

NB! *This led to much higher doses of thyroid gland irradiation of the population of Polissia.*



Fig. 30.1. The fourth reactor of the Chornobyl NPP

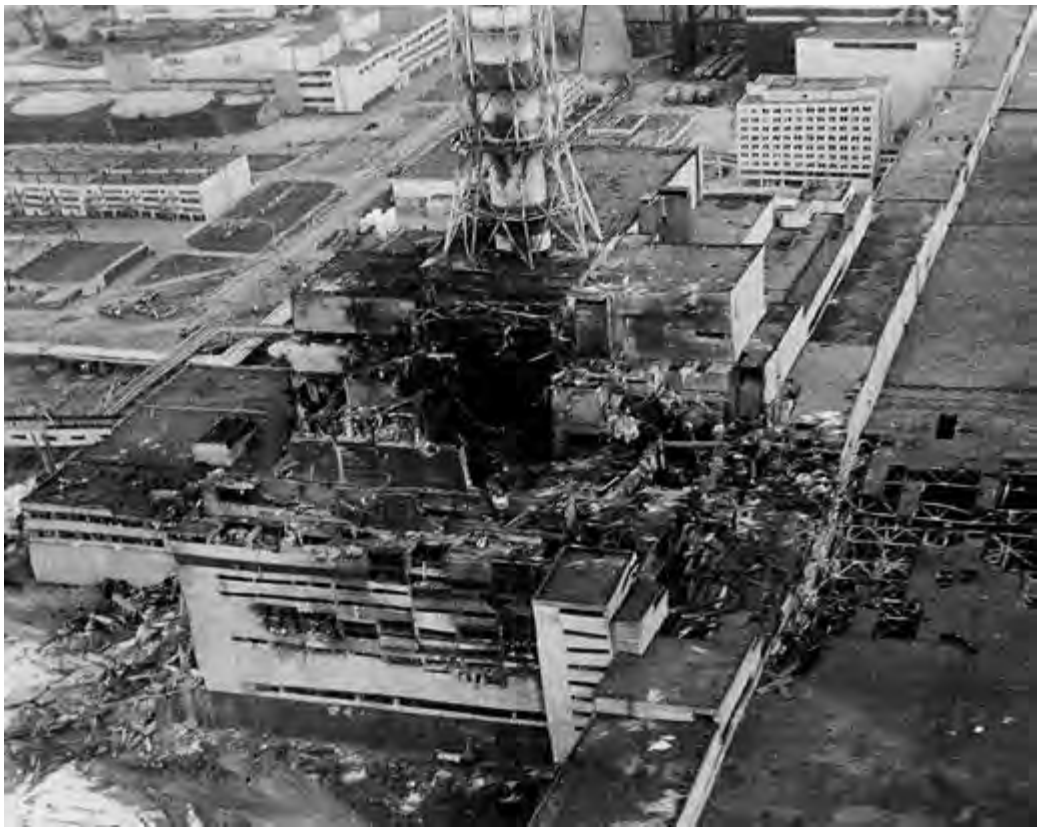


Fig. 30.2. The fourth reactor of the Chornobyl NPP after the accident



Fig. 30.3. The fourth reactor of the Chornobyl NPP after the accident

Radioactive products that were emitted into the atmosphere from the core of the destroyed reactor, the total activity of which is estimated at 2×10^{18} Bq, were aerially dispersed over long distances for 10 days. Immediately after the accident, more than 200 NPP workers and firefighters were irradiated. Health problems of persons affected by radiation doses over 1 Gy and suffered from acute radiation sickness are treated mainly as radio-induced, and the immediate changes in critical systems (hematologic, digestive, etc.), including occurrence of tumors, — as dose-related. Initially, acute radiation syndrome (ARS) was diagnosed in 237 patients. Later, after a detailed examination, the ARS diagnosis remained in 134 patients, extremely severe radiation sickness was in 20 patients, and more than 30 people died in the first few months.

At the same time, the vast majority of people exposed to radionuclides following the Chornobyl accident were irradiated in the range of 0.25 Gy, which is considered as small doses of radiation. The long-term effect of small doses of ionizing radiation on large population segments in contaminated areas is still observed.

30.2. The concept of the population habitation on the territories of Ukraine with elevated levels of radioactive contamination

Immediately after the accident, large-scale monitoring began: measurements of radioactive contamination of the atmosphere and soil, comprehensive studies of the radioactivity of the entire natural environment, including vegetation and water sources. As a result of the Chornobyl accident on the territory of Ukraine, 12 regions, 73 administrative districts, 2293 settlements, where about 2 million 600 thousand inhabitants lived at that time, including 600 thousand children, were contaminated with radiation.

The most polluted are Zhytomyr, Kyiv, Rivne, Volyn, Vinnytsia, Chernihiv and Ternopil regions. More than 53.4 thousand square meters are contaminated with radionuclides (with a density of more than 37 kBq/m^2), i.e. 4.8 % of the country's territory, including 4.6 million hectares of agricultural land, which is 12 % of the total area of agricultural land, and 25.3 thousand square meters of forests, i.e. 40 % of the total forest area.

The results of these studies were used to address the evacuation of the population. More than 165.000 people were evacuated from the most polluted areas and resettled during the first 5 years after the accident. About 2 million people, including 25 % of children, continue to live in the areas classified as radioactive contamination zones.

Due to the evacuation of the population from Ukrainian and Belarusian settlements, it was possible to prevent the occurrence of deterministic effects among the evacuees and to reduce the collective dose by almost 70 % (4.000 man Sv instead of 10.000 man Sv). In large areas contaminated with radionuclide precipitation of Chornobyl origin, iodine prophylaxis was not carried out in a timely manner by reason of the prohibition by the executive administrative structures of the government in order to prevent public panic. At the same time, iodine prophylaxis was carried out in Prypiat and many settlements of Belarus, albeit belatedly, which reduced its effectiveness by almost 70 %.

The relocation of 200.000 children from the settlements of Ukraine to clean regions for health improvement (May–June 1986) reduced the total dose by only 30 %.

Ukraine, Belarus and the Russian Federation have most adversely affected from radioactive pollution. Minor contamination occurred in the Baltic republics, the countries of Northern and Central Europe, as well as in the Balkans. In the years since, radioactive contamination of Chornobyl origin in greater or lesser quantities was further found in almost all corners of the globe (Fig. 30.4, Fig. 30.5, Fig. 30.6).

The Chornobyl catastrophe is a social phenomenon formed from a complex of ecological, medical, social-legal, domestic-practical, and other problems. This phenomenon posed the following problems to the world community: ensuring the technological safety of facilities that use nuclear technology, environmental and radiation safety of citizens and the environment, socio-psychological protection of people and society as a whole.

In 1991, the Supreme Soviet of Ukrainian SSR approved the "Concept of population residence on the territories of Ukrainian SSR with increased levels of radioactive contamination as a result of the Chornobyl accident" and, on the basis of this concept, adopted the Law of Ukraine "On the legal status of the territory subjected to radioactive contamination as a result of the Chornobyl catastrophe".

The purpose of the concept is to reduce the adverse impact of the Chornobyl disaster on public health.

Its basic principle lies in the fact that the value of the effective equivalent radiation dose (associated with the



Fig. 30.4. Exclusion zone territory in summer



Fig. 30.5. Exclusion zone territory in winter



Fig. 30.6. Exclusion zone territory

Chornobyl disaster) for a critical population group (children born in 1986) should not exceed 1 mSv (0.1 Ber) per year and 70 mSv (7 Ber) across the lifespan in excess of the dose received by the population in the pre-accident period.

Legal and executive support of the provisions of the concept is carried out under and in accordance with the Laws of Ukraine:

- On the legal status of the territory subjected to radioactive contamination as a result of the Chornobyl catastrophe;
- On the status and social protection of the citizens who suffered as a result of the Chornobyl catastrophe;
- regulations on the National Commission of Radiation Protection of Ukrainian Population.

According to these documents, the Ukrainian radioactively contaminated territories include only those areas where there has been persistent contamination of the environment with radioactive substances, which may lead to irradiation with a dose exceeding 1 mSv (0.1 Ber) per year and which require radiation protection measures for the population and other interventions aimed at limiting additional exposure of the population and ensuring normal economic activity.

Since adoption of laws, the following plans were practically implemented:

- medical and social protection of the population;
- resettlement and creation of conditions for normal life of citizens affected by the Chornobyl accident;
- decontamination and partial remediation of contaminated areas.

A wide range of work was carried out to mitigate the consequences of the accident aftermath.

Employees of the Bogomolets NMU departments also took an active part in these researches (Fig. 30.7, Fig. 30.8, Fig. 30.9, Fig. 30.10, Fig. 30.11).

30.3. Characteristics of the main dose-forming radionuclides. Categories of victims and how accidents affect health

The most important anti-radiation measures should be considered those carried out in the early phase of the accident, when their implementation has the greatest impact on reducing radiation exposure to the population.

The population was affected by radiation exposure in the early phase of the accident due to external, internal and contact irradiation. The greatest damage was caused by contamination of milk with radioactive iodine, which was present in significant concentrations in large areas. However, there were some reasons that led to untimely countermeasures, which made the consequences of the accident more severe: the hiding the real situation from the population or under-reporting, insufficient system of emergency countermeasures given the need to numerous coordinated approvals, misconduct of the lower-level employees.

Unfortunately, due to the non-disclosure of the information on a large-scale nuclear accident at the ChNPP for a whole week, there was no exclusion of cattle grazing, and iodine prophylaxis of the population and, in particular children, was carried out with long delay, which largely reduced to zero its effectiveness. Unfortunately, there was no ban on the consumption of milk and leafy vegetables. The consumption of milk and dairy products contaminated with radionuclides of Chornobyl origin, mainly iodine-131, has led to its



Fig. 30.7. Access documents of the member of the Bogomolets NMU stuff to the exclusion zone



Fig. 30.8. Extended abstracts of dissertations of the members of the Bogomolets NMU stuff on the study of the ChNPP accident

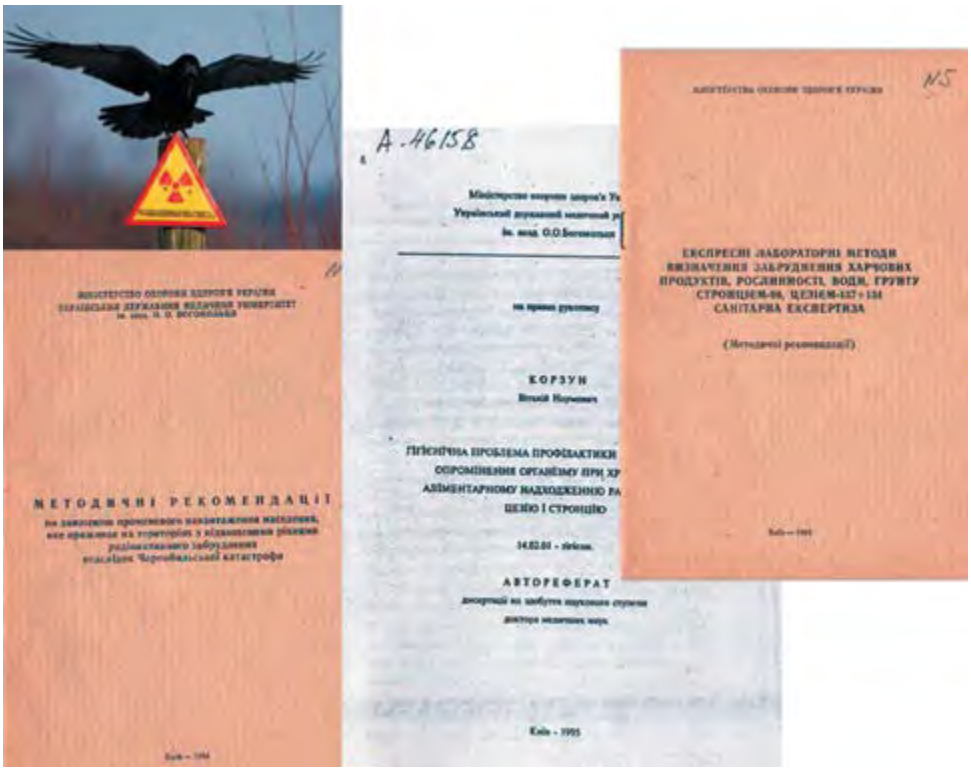


Fig. 30.9. Research insights of the members of the Bogomolets NMU stuff



Fig. 30.10. Research insights of the members of the Bogomolets NMU stuff



Fig. 30.11. Research insights of the members of the Bogomolets NMU stuff

intensive accumulation in the thyroid gland of children and adults; hence, people were radioactively affected in biologically significant doses. The total number of thyroid cancer cases at the end of 2011 was about 7.300.

Recommendations for milk processing to reduce the specific activity in the final product in a timely manner and on a large scale were implemented almost only in Kyiv and Kyiv region, where differentiated milk collection from conditionally clean and conditionally contaminated farms was organized. Milk was sent to various dairy plants for processing. As a result, there was a significant reduction in the activity of the final product.

Dose quotas for the population for 1986 were set at 100 mSv (50 mSv — external irradiation, and 50 mSv — internal irradiation). Based on these quotas temporary allowable levels of radioactive contamination of food, medicinal plants, and fodder were calculated. The shortage of clean products has caused a dietary imbalance of children and adults.

The same permissible levels of irradiation and radioactive contamination were applied to the military personnel deployed in the territories contaminated with radionuclides as to the population.

The health deterioration of the population, especially children living in contaminated areas, as well as those resettled from areas of radiation pollution, has necessitated changes in legislation to protect the rights of citizens affected by the Chornobyl disaster. Among the main provisions of the Concept of population residence on the territories of Ukrainian SSR with increased levels of radioactive contamination as a result of the Chornobyl accident, an important place is occupied by the regulation of the effective dose for a critical group of the population (children born in 1986) at a level not exceeding 1 mSv per year or 70 mSv across the lifespan in excess of the dose received by the population in the pre-accident period in certain natural conditions.

According to the Law On the legal status of the territory subjected to radioactive contamination as a result of the Chornobyl catastrophe (1991), the territory of Ukraine was conditionally divided into 4 zones depending on the density of radioactive contamination by radioisotopes of three chemical elements — cesium, strontium and plutonium.

I. Exclusion Zone with a radius of 30 km from the ChNPP is prohibited for permanent residence (Fig. 30.12, Fig. 30.13).

II. Zone of Unconditional (Mandatory) Resettlement, in which the density of soil contamination by radioactive cesium was more than 15 Ki/km^2, radiostrontium — 3 Ki/km^2, plutonium — 0.1 Ki/km^2. The dose of the population irradiation could exceed 5 mSv per year.

III. Zone of Guaranteed Voluntary Resettlement, in which the density of soil contamination by radioactive cesium was 5–15 Ki/km^2, radioactive strontium — 0.15–3 Ki/km^2, plutonium — 0.01–0.1 Ki/km^2. The dose of the population irradiation could exceed 1 mSv per year.

IV. Zone of Enhanced Radioecological Monitoring, in which the density of soil contamination by radioactive cesium was 1–5 Ki/km^2, radioactive strontium — 0.02–0.15 Ki/km^2, plutonium — 0.005–0.01 Ki/km^2. The dose of the population irradiation should not exceed 1 mSv per year.

Over time, the radiation situation changes, so it is necessary to systematically adjust the territorial zoning and the status of citizens living in these territories.

Due to the accumulated experience in handling of protection of the population from the consequences of radiation accidents, mass resettlement has become unadvisable since 1990. This has been due to the improvement of the radioecological situation in the areas contaminated with radionuclides of Chornobyl origin (1986), deterioration of the socio-economic situation, as well as obtaining scientific information on changes in public health under the influence of combined radiation and non-radiation factors. Over the last 20 years, the number of settlements with an annual dose exceeding 1 mSv has significantly decreased (from 293 settlements in the first years after the accident to 42 in 2008). Back in 1992, it was proposed to amend the Law On the legal status of the territory subjected to radioactive contamination as a result of the Chornobyl catastrophe and On the status and social protection of the citizens who suffered as a result of the Chornobyl catastrophe. The draft of the new concept was approved by the ordinance of the Cabinet of Ministers, according to which the basic principle of zoning should be the dose, not the density of radiation contamination, because the first and second factors were not correlated. This largely depended on the coefficients of radionuclides transfer into plants, which, in turn, depend on the type of soil, chemical composition and other factors.



Fig. 30.12. "Red Forest" after the Chornobyl disaster



Fig. 30.13. "Red Forest" after the Chornobyl disaster

According to the draft of the new concept, on the territory of Ukraine there are three zones and the territory of enhanced radioecological monitoring, namely:

1. Exclusion zone and unconditional (mandatory) resettlement zone.
2. Voluntary residence zone; the annual dose may exceed 5 mSv/year.
3. Zone with beneficial economic environment; the annual dose is 1–5 mSv/year.

And area of enhanced radioecological monitoring; the annual dose is from 0.5 to 1 mSv/year.

The Chornobyl problems are not so topical nowadays, but this does not mean the actual adaptation of the victims. The use of pollution density as a criterion does not meet international requirements for radiation protection, as evidenced by the latest ICRP and IAEA recommendations (ICRP Publication 103 on 21 March 2007, IAEA Basic Safety Standards (BSS)). As of January 2009, more than 1.300 settlements cannot be classified as radioactive contamination zones according to the radiation dose criterion, and about 350 settlements, which today belong to a certain zone, cannot be classified as radioactive contamination zones according to the cesium-137 contamination criteria.

Today, more than 33 years after the accident, radiation monitoring and precautionary measures can be, however, significantly reduced in a large part of the areas contaminated with radioactive substances of Chornobyl origin without harming the health of the residents of these areas. Accordingly, certain benefits should be reduced for the population living in these areas. The change in benefits for targeted financial support and its reduction will inevitably cause dissatisfaction among the population. This should be taken into account when carrying out awareness-raising activities among the victims through the media, as well as during lectures among the population. Budget funds should be spent more efficiently to improve the situation of people with health deterioration caused by the Chornobyl accident or to improve the situation of people with increased potential risk due to the significant impact of radiation factors. The change in the status of the territories should not be accompanied by a change in the status of people living in these territories and affected by the Chornobyl disaster. Masures to improve the health of the population should also be more effective by addressing a range of radiation, medical and rehabilitation issues.

In 2008, the ordinance of the Cabinet of Ministers of Ukraine approved the concept of activities in the exclusion zone and the zone of unconditional (mandatory) resettlement. The exclusion zone and the zone of unconditional (mandatory) resettlement occupy an area of 2600 sq. km. These zones are the most contaminated with radionuclides of Chornobyl origin and have a special form of management. The State Agency of Ukraine on Exclusion Zone Management was established in 1992.

The Law of Ukraine On the legal status of the territory subjected to radioactive contamination as a result of the Chornobyl catastrophe prohibited permanent residence in the exclusion zone. Agricultural activity was prohibited in this territory, and its lands were withdrawn from agricultural circulation. Nuclear-hazardous and radiation-hazardous facilities are located in this zone: three ChNPP power units, the Shelter Object, which contains about 180 tons of nuclear fuel, as well as radioactive waste (RW) disposal and temporary storage facilities throughout the territory, the ChNPP cooling pond. The ecological hazard of the exclusion zone is determined not only by the presence of radiation-hazardous objects, but also by the probability of occurrence and spread of forest fires, floods, as well as other negative processes in the natural environment. The main task is the gradual transformation of the Exclusion Zone into an environmentally safe system with the preservation of natural resources, material and cultural wealth and their further use for economic purposes to the possible and appropriate extent.

Radioactive contamination of this zone is uneven mainly due to radionuclides ^{137}Cs, ^{90}Sr, as well as a small amount of plutonium isotopes. About 90% of radionuclide activity is distributed in the upper soil layer (up to 10 cm). Concentrations of radionuclides in groundwater and surface water are generally below allowable levels. Potential sources of groundwater pollution are large activities at temporary RW disposal facilities (Fig. 30.14, Fig. 30.15).

Pollution of deep horizons of drinking water supply has not been reliably recorded. There is a possibility of spreading radioactive contamination outside the exclusion zone due to unauthorized human intervention through the agricultural use of forests and lands, as well as the secondary transfer of radionuclides in fires and other hydrometeorological phenomena.

The reason for the prohibition on living in the exclusion zone and mandatory resettlement is the presence in these areas of a number of makeshift RW disposal facilities, the position data of which are lost. It is, therefore, impossible to allow the construction of the private sector, which will be difficult to monitor.

One of the reasons for the prohibition on living in the exclusion zone and mandatory resettlement is the excess of radionuclides in alimentary products produced by private farms and grown in these territories, namely: in milk — 2–3 times, in honey — 2 times, in fish — 2.5–9 times, in mushrooms — 10–50 and more, in wild berries — up to 100 times relative to allowable levels.

In the long-term period after the rectification of the consequences of Chornobyl accident, as well as after any large-scale nuclear accident, measures for radiation protection of the population are aimed mainly at reducing of internal irradiation exposure. The most important measures are the following:

1. Irradiation regulation, systematic revision of normative values.
2. Regulation of the population return in the territory from which it was evacuated.
3. Restriction of production activities, determining the list of types of production of the least contaminated products.
4. Operation of checkpoints to control the export of products from contaminated areas to clean, as well as non-propagation of the spread of mechanical pollution.
5. Radiation control of food products produced in areas with high levels of soil radioactivity.
6. Technological and cooking processing of food in order to reduce activity in finished products compared to raw materials.
7. The consumption of food products with protective properties.
8. Dose reduction due to other dose-forming factors, in particular during X-ray diagnostic procedures.
9. The intake of pharmaceutical preparation (if necessary, in cases of a sharp increase in the content of radionuclides in the body of a particular person, for a limited time, for a limited number of people).
10. Restricting the population's access to contaminated areas.
11. Psychological and radiation-hygienic training of the population living near radiation-hazardous objects and in territories with a high level of radioactive contamination.
12. Providing appropriate training of personnel regarding the fact that the elimination of the consequences of radiation accidents is carried out by the administration and industry specialists without special training in the field of radiation protection.



Fig. 30.14. Temporary RW storage facilities



Fig. 30.15. Temporary RW disposal facilities

13. Legal and preferential provision of the population through the issuance of compensation, provision of children with vitamin products (free for the population), etc.

The most available and simple way to reduce the activity of finished foods is cooking. It should be taken into account that the term "decontamination" involves the transfer of radionuclides from the edible part of the product to the inedible one — decoctions, wastes formed during machining of raw materials. For example, meat and fish, when boiled to readiness with pre-soaking, contain the specific activity reduced by 70–90 %. Boiling the meat in salted water for the first 5 minutes, followed by a water change, reduces the radioactive cesium content of the boiled meat by 60–70 %.

Peeling and boiling of potatoes reduces the activity to 40–50 %; the activity of beetroot is reduced by 60 %; shredded boiled cabbage has an activity of 50–60 % lower than fresh. The salt, added during boiling, doubles the transition of radioactive cesium and radioactive strontium into the broth. When vegetables are salted, half of the radionuclides go into the brine.

Boiling dried mushrooms 2 times for 15 minutes with the salted water change reduces the activity of the finished product by 90–95 %. In the production of dairy products, the activity of soft and hard cheeses is reduced by 65 and 85 %, sour cream — by 50 %, butter — by 75–95 %, depending on the fat content of the finished product. Desiccated milk, however, will have an activity about 8 times higher than natural, from which it is made.

Measures to reduce doses from internal radiation include:

1. Balanced diet which contains a sufficient amount of animal proteins, carbohydrates (pectins, etc.), mineral compounds (Ca, P, K, Co, Cu, Mg, Fe, Zn, Se, J), vitamins A, C, E, PP, B_{12}, β-carotene.
2. Pharmaceuticals that reduce accumulation, absorption, accelerate excretion: sorbents, complexing agents, blockers.
3. Food that have similar radioprotective properties.

Violation of the nutrition rules leads to increased absorption of radionuclides by the organism.

There are many ways to reduce the intake of radionuclides with food. Among them are the following:

1. Technological processing.
2. Cooking.
3. Reduction of uncontrolled consumption of forest food.
4. Application of fertilizers and ameliorants to the soil.
5. Liming of soils.
6. Selection of appropriate crops that accumulate less radionuclides.
7. Conversion of agricultural sector.
8. Phytodeactivation (cultivation of plants that intensively accumulate radionuclides, followed by disposal of these plant products). It is advisable to apply such a measure only for the first two years after the accident.
9. Special animal feed additives (in the early periods of the accident). Products from such cattle have the worst properties in terms of its chemical composition.
10. Carrying out personal, social and health education aimed at the application of appropriate anti-radiation measures and a healthy lifestyle.

One of the most effective measures to reduce internal radiation exposure is the consumption of clean products through the implementation of radiological control of food and fodder. To do this, it is necessary to have highly sensitive methods of radiation control, appropriate equipment, as well as developed and approved in an appropriate manner allowable levels of radionuclides in food. Such regulatory documents should be systematically reviewed in order to reduce the permissible activities due to the reduction of radionuclide concentrations in food in consequence of the radioactive decay of radionuclides in the environment, along with other measures to reduce the activity of food products. The development of regulations should be guided by information about the negative consequences of consumption of food with a certain amount of radionuclides, as well as the real possibility of reaching a lower level (the ALARA principle — As Low As Reasonably Achievable). When developing regulations for food activity, it is necessary to ensure that the use of such products within the physiological norm throughout life does not cause more harm to health, but rather much less than the usual environmental factors that affect the entire population. Today, the lowest allowable activities are contained in drinking water, alcohol-free beverages, bread and food products for infants.

30.4. Medical consequences of the Chornobyl accident

The Chornobyl catastrophe is a social phenomenon formed from a complex of ecological, medical, social-legal, domestic-practical, and other problems. Numerous observations of health of the population living in contaminated areas after the ChNPP accident indicate the

impact of a complex of factors on the incidence of children and adults, especially critical groups. The most important sources of information on incidence rates are the State Register of Ukraine and the National Cancer Registry of Ukraine.

The definition of the categories of persons affected by the Chornobyl catastrophe is regulated by the Law of Ukraine On the status and social protection of citizens who suffered as a result of the Chornobyl disaster.

The victims of the Chornobyl disaster include:

- citizens who took a direct part in the Chornobyl accident management (cleanup workers);
- persons with health deterioration (disabled Chornobyl victims) caused by radiation factors of Chornobyl origin;
- persons evacuated in 1986 or resettled in accordance with the legislation;
- persons at increased risk of health deterioration — citizens affected or citizens who may be affected by effective radiation dose of more than 70 mSv within 70 years since the Chornobyl accident (people living in contaminated areas);
- persons, under the age of 3 years, affected by a dose of thyroid irradiation over 50 mGy, or at the age of 3 to 18 years — more than 100 mGy.

Determining the category of persons at increased risk of health deterioration is based on the data of dosimetric certification of places of high density residence.

Thus, the ChNPP accident was an example of the fact that large-scale accidents at nuclear power plants can not be local or regional, and they are always global in nature, often transboundary, causing to some extent radioactive contamination of the whole globe. The consequences of the Chornobyl accident reached well-beyond one country and clearly demonstrated the need for international cooperation in the field of nuclear energy.

The Chornobyl accident highlighted a number of global issues of mankind at the present stage of development of advances in science and technology, and above all — the threat of extermination of the human race in a case of a missile and nuclear war. Even the bombing of nuclear power plants and other nuclear and chemical facilities can result in significant human and environmental losses.

31

CHAPTER

HYGIENIC FUNDAMENTALS OF TEMPORARY LOCATION OF MILITARY AND CIVILIAN UNITS IN EMERGENCIES

A. A. Borysenko, K. Yu. Zahorodniuk, V. D. Aleksiichuk, O. M. Vlasenko, N. D. Kozak

31.1. Fundamentals of organization of sanitary and hygienic measures in the Armed Forces of Ukraine

The Armed Forces of Ukraine (AFU) is a military unit, which, in accordance with the Constitution of Ukraine, is responsible for the defense of Ukraine, protection of its sovereignty, territorial integrity and inviolability.

In peacetime, only healthy people, mostly men, aged 18 to 25 (conscript personnel) are recruited to serve in the Armed Forces of Ukraine. If so desired, men can serve in the Armed Forces for up to 60 years, and women — up to 50. If necessary, men aged 20 to 60 can be called-up, if provided that they have experience of active duty.



Fig. 31.1. Consequences of non-compliance with sanitary and hygienic recommendations on the selection of a land plot for temporary accommodation. Source: *tsn.ua*



Fig. 31.2. Consequences of non-compliance with sanitary and hygienic recommendations on the selection of a land plot for temporary accommodation. Source: *tsn.ua*

The additional detail: at the age of 50 to 60, call-up takes place exclusively on a voluntary basis. The conscription age for women is up to 50 years. There are certain categories of citizens who are eligible for military duty due to their specialty. These include healthcare professionals and communication personnel.

Thus, the Armed Forces composition does not include the so-called decreed groups (children, pregnant women, the disabled, etc.), for which more favorable conditions are needed.

The health state of armed forces personnel is constantly influenced by environmental factors, which by their nature are divided into: physical, chemical, biological, psychogenic and social. Ensuring sanitary and hygienic measures in the Armed Forces of Ukraine is an integral part of achieving high and stable combat capability (performance) of armed forces personnel.

Neglect of hygienic recommendations and violation of established standards can lead to both complex and combined effects of adverse factors on the body of the serviceman and, as a consequence, to a decrease or loss of combat capability (performance).

For the purpose of implementation of sanitary and hygienic measures in the Armed Forces of Ukraine, a functioning system of organizational and administrative, sanitary and technical, economic, medical and other measures has been created. Military hygiene is distinguished as a separate branch of hygiene among other subdisciplines (Fig. 31.3).

High combat capacity of personnel and a high level of the body resistance, both military and civilian persons, is ensured through the implementation of preventive and current sanitary and epidemiological supervision in four main areas (Fig. 31.4). Proper sanitary supervision is of particular importance during temporary accommodation.

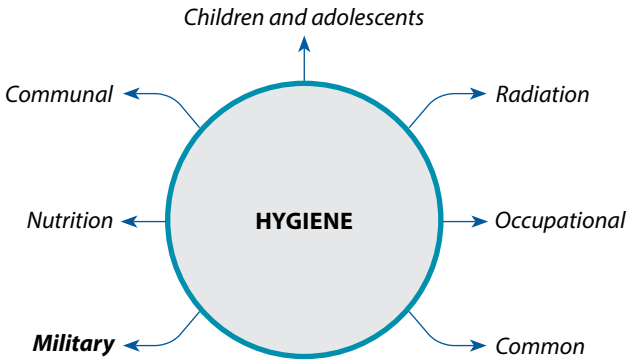


Fig. 31.3. The scheme of hygiene subdisciplines



Fig. 31.4. The main components of sanitary supervision

The following methods of hygienic research are used to ensure proper preventive and current sanitary and epidemiological surveillance:

- epidemiological — to study the patterns of spread of non-infectious and infectious diseases among military servicemen under the influence of certain harmful environmental factors, including physical, biological, chemical, etc.;
- method of sanitary survey and description; during the study of the environmental state, sanitary inspection is carried out according to special schemes or records of sanitary survey, which contain questions the answers to which give a comprehensive picture of the inspected object;
- method of hygienic experiment which is divided into two types: field method and method of laboratory experiment. An example of the field hygienic experiment is the health examination for servicemen in the conditions of stay in a military-technical facility, and method of laboratory experiment — the development of hygienic standards through animal experiments to establish maximum permissible levels, maximum permissible concentrations, etc.;
- method of sanitary-epidemiological expertise is usually used during preventive sanitary supervision to determine the compliance of project designs with current hygienic standards and requirements;
- statistical method is used to process the data retrieved.

Sanitary and epidemiological supervision, in terms of the timeliness, completeness and effectiveness of sanitary and hygienic measures, is carried out by the forces and means of the chief medical officers of military and civilian units, state sanitary and epidemiological services of the Ministry of Defense and the Ministry of Health of Ukraine and other agencies.

Sanitary and hygienic measures in the Armed Forces of Ukraine include sanitary supervision and medical control.

Medical control is focused on the health of personnel.

Sanitary supervision is aimed at (Fig. 31.4):

- location;
- cleaning of location places;
- water supply;
- nutrition;
- bath and laundry supply of personnel;
- working conditions of personnel.

Table 31.1 presents the forces and means of medical service intended for the sanitary and hygienic supplies of army.

31.2. Types of temporary military and civilian location (affected population, special units, etc.). Sanitary-epidemiological reconnaissance

Temporary location is the organization of short-term stay of military and civilian units, and affected population in emergencies, at a time of war, etc. outside the stationary buildings, which are intended for their permanent stay/residence (Fig. 31.5, 31.6, Table 31.2).

In order to reduce the risk of the impact of negative environmental factors on military personnel and the affected population, their temporary accommodation must be preceded by a sanitary-epidemiological reconnaissance.

Sanitary-epidemiological reconnaissance aims to establish:

- number, size and sanitary condition of residential and public-administrative buildings;
- availability of water supply sources;
- availability of sewer lines, latrine toilets, garbage cans;
- sanitary state of a territory;

Table 31.1. Forces and means of medical service intended for the sanitary and hygienic supplies of army

Name of the military unit	Medical service	
	forces	*means*
Troop unit (brigade)	Personnel of the medical service of the regimental units and the regimental aid post	Roentgen radiometer DP-56 (V) or dose level-measuring device (VPD-1), military chemical reconnaissance medical and veterinary device (VPHR-MV)
Division level unit	Personnel of the medical service of the division and specialists of the garrison sanitary-epidemiological laboratory (GSEL) — epidemiologist, hygienist, radiologist, toxicologist, bacteriologist	Medical laboratories of military type VML (VPD-1 device, medical field chemical laboratory MPHL, hygienic military laboratory LG-1), decontamination shower facility of DDP-2 type
Army corps (army)	Personnel of the medical service and units of the army corps (army), specialists of GSEL and territorial sanitary-epidemiological squads (TSES) (main departments — epidemiological, sanitary-epidemiological (mobile), bacteriological of highly infectious diseases, sanitary-hygienic, toxicological and radiological, health improving of health-improving measures, sanitary-epidemiological reconnaissance, disinfection, deratization, decontamination, sanitary-control point)	Medical laboratories of military type VML (medical field laboratories of LMP, MPHR, MPHL, VPD-1 types, radiometric laboratory in cases of RLU-2 type, hygienic main laboratory — LG-2), decontamination shower facilities of DDA-3 and DDA-66 types
Troops of administrative-territorial areas of responsibility	Personnel of the medical service of the operative command troops, specialists of GSEL, TSES and regional sanitary-epidemiological squads — RSES (main subdivisions — epidemiological, sanitary-hygienic, department of sanitary-epidemiological reconnaissance, sanitary-control point)	Medical laboratories of military type VML, medical laboratories of field type LMP, decontamination shower facilities of DDA-3 and DDA-66 types
Troops of central subordination	Personnel of the medical service of the central subordination forces, specialists of GSEL, TSES, RSES (main subdivisions — epidemiological, sanitary-hygienic, radiology and toxicology departments)	Medical laboratories of field type LMP, decontamination shower facilities of DDA-3 type

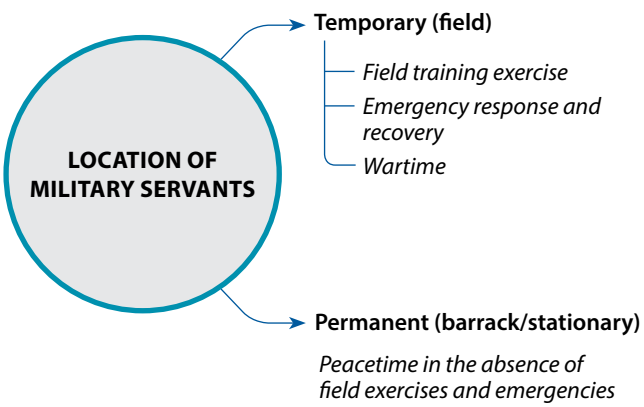


Fig. 31.5. Location types of military and civilian units

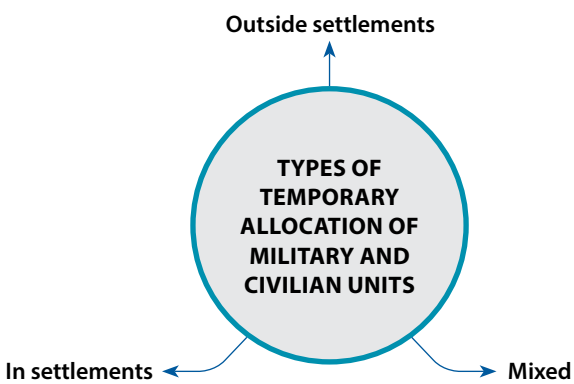


Fig. 31.6. Types of temporary allocation of military and civilian units

Table 31.2. Types of accommodation of militaries and their characteristics

In settlements		Outside settlements		Mixed
Who?	*Where?*	*Who?*	*Where?*	Provides a combination of all types of dwellings, office premises and protective structures
Personnel of military units	In public and administrative buildings: schools, cinemas, recovery centers	Personnel of military units	In training centers or camps (in tents, dugouts, shelters, barracks, etc.)	
		Civilian population	In camps (in tents, dugouts, shelters, barracks, etc.)	
Civilian population	In protective constructions	Personnel of military units	In military fortifications	
Commanding officers	In special shelter areas			

- infectious morbidity among the population and epizootics among livestock, wild animals and rodents, activity of zoonotic diseases;
- availability and conditions of local facilities that can be used for sanitary and anti-epidemic support of troops and affected population.

The reconnaissance group must include a representative of the military medical service. At the stage of land selection for temporary accommodation, it is necessary to decide on its suitability. The main criteria are:

Epidemiological safety — collection of data on cases of infectious diseases in the locality among humans and animals; the history of land use (human/animal cemeteries; biological waste disposal, etc.), the height of groundwater.

Toxicological safety — collection of data on cases of chemical intoxication in the locality among people and animals when consuming water and food; history of land use (chemical disposal); taking into account wind diagram.

Radiation safety — collection of data on cases of radiation injuries in the locality among people and animals when consuming water and food; the history of land use (disposal of radioactive substances).

Ease of maintenance — access roads, shape, distance from the "red zone", availability of water sources.

When accommodating of militaries and civilians in a camp outside settlements, the requirements for environmental factors, regardless of the nature of their origin, should be as close as possible to the requirements for them under normal living conditions.

At the same time, when providing an air cube up to 0.7 m^3 per person (tent with a "nest") or up to 1.3 m^3 per person (tent with a pit) with insufficient ventilation, for example, when in rainy cold weather the tarpaulin gets wet and loses air permeability, humidity in tent can increase up to 90–100% and CO_2 concentration — up to 1.3%.

The main parameters of sanitary supervision over temporary accommodation:

- Area size for 1 person.
- Distance between tents.
- Bed/board bed height above the floor.
- Waterproofing and water disposal.
- Air temperature.
- Humidity.
- Illumination.
- Ventilation.

Sanitary supervision plays a key role in preservation and promotion of health and work (combat) capabilities of militaries and affected population. The implementation of measures is entrusted to the chief medical officer, who organizes their implementation in two forms — preventive and current sanitary supervision (Fig. 31.7).

The participation of the Chief medical officer includes, but is not limited to the following activities:

1. *For preventive sanitary and epidemiological supervision:*
   - selection of sites (districts) for location of units (accommodation of the population);
   - control over the implementation of sanitary and hygienic requirements in the design and construction of protective structures (fortifications);
   - participation in the commissioning of facilities for units allocation (for affected population).
2. *For regular sanitary and epidemiological supervision:*
   - control over the implementation of sanitary and hygienic requirements for the arrangement and maintenance of engineering constructions (cleaning of the territory, sewage disposal);



Fig. 31.7. Forms of sanitary supervision

- examination of the health status of the Armed Forces;
- control over the personal hygiene activities of the Armed Forces;
- implementation of disinfection, disinsection, deratization measures;
- control over the implementation of environmental protection measures.

3. *Problems that arise during the temporary location of military and civilian units:*
   - reduction of the level of municipal-domestic services;
   - high population density;
   - insufficient protection against adverse weather conditions;
   - complexity of the organization of water supply, nutrition, disposal of household waste;
   - increased risk of contact with dangerous floral and faunal forms.

31.3. Types of protective structures and their hygienic characteristics

Protective structures can be used for temporary allocation of civilian population. According to the main characteristics, the following types of protective structures are distinguished:

- Refugee shelters.
- Fallout shelters.
- Dual-capable constructions.
- Rapidly erectable light mobilization structures.
- Simple protective constructions.

Refugee shelter is a structure for the protection of people, in which for some time due to the reliable separation of environments inside the premises of these structures and the environment, conditions are created that exclude the impact of dangerous factors arising from emergencies, military (combat) actions, terrorist attacks, etc. on people refuged in them.

Fallout shelter is a structure for the protection of people, which creates conditions that reduce to safe levels excessive exposure to ionizing radiation in the case of radioactive contamination.

Rapidly erectable light mobilization structures for civil defense is a protective structure erected from special structures in a short time to protect people from the effects of destructive agents in an exceptional period.

Dual-capable construction is a surface or underground structure that can be used for its main functional purpose and to protect the military personnel and civilian population.

Simple protective construction is a fortification, basement or underground accommodation, which reduces the combined damage of people from the dangerous consequences of emergencies, as well as from the action of destructive agents in an exceptional period.

To ensure compliance with proper sanitary and hygienic conditions in protective structures, the following technical systems are provided:

- Ventilation system.
- Water supply system.
- Heating system.
- Sewerage system.
- Artificial lighting system.

Elements of the above systems are located in auxiliary rooms (Fig. 31.8). Basic requirements for refugee shelters and fallout shelters (Tables 31.3, 31.4):

- capacity not less than 150 persons;
- location in the immediate proximity of places of people concentration at a distance not exceeding 400–500 m;
- for Fallout shelter, the collection radius can be increased up to 1000 m in the predicted light damage areas, and outside these zones — up to 3000 m;
- area per person in compartments for two-level arrangement — not less than 0.5 m^2, for three-level — not less than 0.4 m^2. Air volume per person — 1.5 m^3;



Fig. 31.8. Shelter premises (main and auxiliary)

- distance from the upper tier to the floor slab or protruding structure — not less than 0.75 m;
- seating capacity in the case of two tiers — 80%, three tiers — 70% of the total number of seats.

31.4. Conclusions

1. The organization of sanitary and hygienic measures in the Armed Forces of Ukraine is entrusted to chief medical officer, who ensures control of their implementation through the implementation of preventive and current sanitary and epidemiological surveillance.
2. Proper organization of sanitary and hygienic measures in the Armed Forces, in particular during the temporary allocation of military and civilian units, allows to preserve and promote the health of personnel/affected population, to maintain a sufficient level of their combat and work capacity.
3. Observance of hygienic recommendations at temporary accommodation allows to minimize negative influence of environmental factors on military personnel and civilian population.
4. According to the main characteristics, protective structures are divided into several types. For each of the types of protective structures there is a list of sanitary and hygienic requirements for their construction and operation.

Table 31.3. Standards of area, cubic volume, MAC of CO_2 in closed fortifications and shelters

Type of shelter	Area per 1 person, m^2	Cubic volume per 1 person, m^3	MAC of CO_2 at different ventilation modes,%		
			I	II	III
Special purpose shelters for long term occupancy	4	10.0	0.5	1.0	2.0
Military field-type shelters	0.8–2.0	1.5–4.0	1.0	2.0	3.0
Fallout shelters for civil safety	0.5–1.0	1.0–2.0	1.0	2.0	3.0

Table 31.4. Sanitary parameters of the microclimate of closed fortifications and shelters

Microclimate indicators	Mode I	Mode II	Mode III
Maximum air temperature, °C	28	30	32
Allowable air humidity, %	75	80	80
Equivalent-effective temperature (EET), °C	19	20	21.5

CHAPTER 32

HYGIENIC PECULIARITIES OF WATER SUPPLY OF MILITARY AND CIVILIAN UNITS IN EMERGENCIES AND IN EXCEPTIONAL PERIODS

A. A. Borysenko, K. Yu. Zahorodniuk, V. D. Aleksiichuk, O. M. Vlasenko, N. D. Kozak

32.1. The role and place of water supply in the formation of combat (work) capacity of militaries and the body's resistance in emergencies and in exceptional periods

Emergency is an impairment of normal living conditions and activities of people at facilities or territories caused by an accident, catastrophe, epidemics, disaster, epizootic, epiphytoty, conflagration, the use of destructive agents that have caused or may cause human and material losses, as well as large-scale damage to humans and animals.

An exceptional period is the period of functioning of the national economy, government authorities, other government bodies, local self-government bodies, the Armed Forces of Ukraine, other army units, civil defense forces, enterprises, institutions and organizations, as well as fulfillment by citizens of Ukraine of their constitutional duty to defend the Fatherland, independence and territorial integrity of Ukraine, and this perid occurs from the moment of announcing the decision on call to active duty (except special-purpose) or bringing it to the executors regarding covert call to active duty or from the moment of imposing martial law in Ukraine or in certain regions. This period covers call to active duty time, wartime and partially reconstruction period after the termination of armed hostilities.

Water (in terms of hygiene) is a complex dispersed system, the dispersion medium of which are molecules of the chemical substance H_2O, and the dispersed phase is represented by a complex of dissolved gases, mineral salts, organic compounds and microorganisms.

Among the measures to ensure the health of the civilian population in emergencies and military personnel during wartime, water supply is one of the most important (Fig. 32.1). The most critical from the epidemiological and hygienic point of view is the regular provision of the civilian population in emergencies and military personnel during wartime with good quality water for food and drinking purposes, personal hygiene (bath and laundry) and especially, if necessary, for decontamination of civilians and troops, their uniforms, equipment.

Ensuring epidemiological safety, harmlessness and satisfactory organoleptic quality of water requires of medical service explicit medical knowledge regarding the se-



Fig. 32.1. The main components of sanitary supervision

lection of water source, its extraction, general and special methods of purification, disinfection, stock accumulation, transportation, as well as means and methods of hygienic control of water supply for civilian population in case of emergencies and for military personnel during wartime.

The all-arms commander is responsible for the field water supply. The logistics (rear) service (administrative commandant) along with the medical service determines the need for water and develops a plan for water supply and water delivery (Fig. 32.2).

Engineering units together with chemical and medical services conduct water point reconnaissance, organize its extraction, purification, and operation of specially equipped water supply points.

The representative of the medical service personally conducts:

- sanitary and topographic survey of water sources;
- sanitary-epidemiological inspection of the area of water sources;
- laboratory testing of water;
- participation in sanitary-engineering inspection.

The responsibilities of the unit medical officer are the following:

- sanitary and hygienic control over water quality and sanitary condition of the water source, as well as issuing a conclusion on the suitability of water for drinking and housekeeping needs;
- monitoring over compliance with the standards of utility and drinking water supply;
- participation in the selection of water source, issuance of a conclusion on the construction project of water supply systems and establishment of protective sanitary zones;
- control over the operation and sanitary condition of pumping stations, water pipe-lines and intake of water works;
- carrying out medical supervision over the personnel maintaining water treatment facilities.

32.2. Selection of water supply source. Methods of water treatment in the field conditions. General requirements for drinking water quality

Summarizing the above information, one may state that the purpose of a medical officer in providing water in emergencies and in an exceptional period is the organization and sanitary supervision of obtaining, accumulating and distributing adequate volume of water sufficient to solve each individual quality task.

When conducting an attack, water supply rate is 8–12 liters per 1 person per day. In especially difficult circumstances, troops are given only drinking water: 5 liters (up to 3 days) in temperate climate, and 8 liters (up to 3 days) in hot climate. In a field mobile medical center — 30–40 liters per 1 person per day, in evacuation hospital — 180 liters per 1 person per day. For sanitary treatment (decontamination), 45 liters are necessary per 1 person. Details of water consumption for the purpose intended are given in Table 32.1.

Requirements for drinking water quality:

1. ***Strictly mandatory:***
   - epidemiological safety;
   - toxicological safety;
   - radiation safety.
2. ***Desirable:***
   - good organoleptic properties;
   - optimal mineral composition.

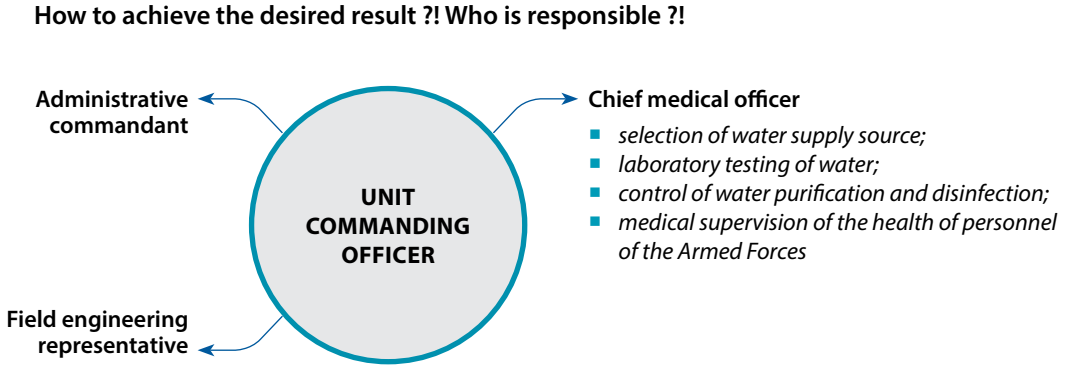


Fig. 32.2. Organization of water supply supervision

Table 32.1. Minimum norms of water supply in the field conditions (for 1 serviceman in liters per day)

Purpose of water	At a moderate temperature liter/day	At high temperature, liter/day
Tea making, water supply in personal canteens	2.5	4.0
Cooking, washing of kitchen utensils	3.5	3.8
Washing of personal utensils	1.0	1.2
Face washing	3.0	6.0
For drinking only	2.5	4.0
In total:	10.0	15.0

When generating a water supply plan for civilian population in emergencies and troop personnel during wartime, the following factors must be taken into account:

- Personnel strength.
- Field water consumption standards.
- Reconnaissance data on the number of water supply sources, their capacity, and water quality.
- Availability of organic equipment for water extraction, treatment, accumulation, and transportation.
- The need for additional forces and operating facilities.
- Service units to ensure the operation and protection of field water supply facilities.

Determination of the amount of water in the water source and its capacity is of practical importance. Taking into account the capacity of the source and water quality, which in the future will form the need for its preparation, a rank ordering for choosing a source for field water supply can be formed.

Rank order of water supply sources in the field environment and in emergencies:

- first of all, wells should be used that capture interstratal confined aquifers and unconfined aquifers;
- in the second place, well and spring water should be used only with preliminary disinfection;
- in the third place — open circulating water reservoirs with preliminary purification and disinfection;
- in the last turn — trucked decontaminated and preserved water.

In accordance with the sanitary and hygienic requirements, sanitary protection zones are established for each source of water supply. There is a special regime of economic and other activities to prevent pollution, clogging, siltation of these water bodies and water depletion. **The first zone of sanitary protection is a strictly controlled zone** (zone that is protected by special health regulations) (radius 50–100 m). Extent of zone can vary and depend on the type of water source, terrain and the nature of soil. **For the second zone of sanitary protection (sanitary restricted zone) and the third — zone of sanitary supervision**, extent is established depending on environmental conditions.

The fence can be made of wooden, metal, reinforced concrete constructions, but in any case it should prevent access of unauthorized persons and animals to the territory.

A significant role in ensuring of epidemiological safety, harmlessness and good organoleptic properties of water is played by water treatment methods (used if necessary), Fig. 32.3.

Water clarification — removal of suspended solids from its composition (composition of the dispersed system).

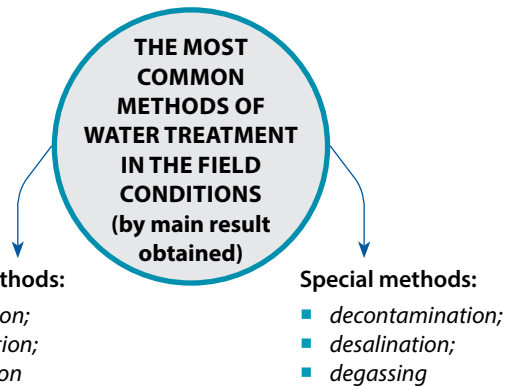


Fig. 32.3. Methods of water treatment in the field environment (by main result obtained)

Water decoloration — removal from its composition (composition of the dispersed system) of colored colloids/dissolved impurities that cause its color, or their transformation in the process of water treatment into colorless.

Water disinfection — destruction in it or removal from its composition (composition of the dispersed system) of pathogenic microorganisms, viruses, prions.

Water decontamination — removal of radioactive substances from its composition (the composition of the dispersed system) or ensuring the loss in the process of water treatment with a molecule of harmful substances, energy, which is necessary for its entry into chemical reactions.

Water desalination — reduction of its total mineralization.

Water degassing — removal of dissolved gases from its composition (composition of the dispersed system).

All methods of water treatment, which involve the removal of unacceptable components from its composition (the composition of the dispersed system), are called methods of water purification. Water treatment methods are implemented through the following processes or their combinations: coagulation, flocculation, desilting, filtration, sorption, etc.

In the field conditions and in emergencies, coagulation with filtration through high-rate filters (organic or improvised) are used. Desilting, which is used under usual conditions after coagulation before filtration through high-rate or low-rate filters in the field environment, is not used or its time is minimized in emergencies or during wartime.

Methods of water disinfection used in the field: chlorination (sodium hypochlorite, dichloroisocyanuric acid, sodium salt of isocyanuric acid (tablets "aquacept"), benzoic acid parasulfodichloramide with soda (tablets "pantocide"), chlorinated lime, two-thirds-alkaline salt of calcium hypochlorite); water treatment with chlorine dioxide; boiling; less often — UV irradiation. The most common method of disinfecting water is still chlorination. This is due to the relatively low cost of using the method, high activity and a wide range of antimicrobial action of chlorine, its ease of dosing and control of residual amounts. Although water chlorination is the most common method of disinfection, it has a number of significant disadvantages the most common of which are the following:

- as a result of chlorination, about 260 names of organochlorine compounds are formed in water. The use of water containing organochlorine compounds leads to the immune system suppression, hepatic, nephritic, pancreas gland, thyroid gland, and central nervous system diseases, and the most important thing — a number of these compounds are carcinogenic;
- in many cases, routine chlorination schemes are not a reliable barrier to the penetration of certain bacteria and viruses into drinking water;
- chlorine is a highly toxic substance; during its transportation, storage and use, it is necessary to observe special measures to ensure the safety of personnel, population and environment.

Overchlorination is a chlorination of water with doses of chlorine, which significantly exceed those required for its disinfection. Used in case of suspicion of possible disregard by the laboratory of rapidly changing quality indicators.

Overchlorination is used to ensure the reliability of disinfection. Overchlorination requires further removal of excess chlorine from water. The process of removing excess chlorine from water is called dechlorination. It is the introduction of substances into the chlorinated water that can bind excess chlorine.

For the purpose of dechlorination, carbon filters is also used.

32.3. Basic means for field water supply

The following basic means may be used for field water supply of the civilian population in emergencies and personnel during wartime:

1. **Means of water extraction:**
   - shaft well digger KSHK-40;
   - auto well-drilling machine — ACU-100;
   - rotary drilling apparatus — URB-3 AM.
2. **Means of water lifting:**
   - manual piston pump BKF-4;
   - manual rod pump RShP-25,
   - mechanized rod pump IBE-40;
   - power-driven pump M-600,
   - motor pump — EP-1.
3. **Means of water treatment:**
   - fabric and carbon filter TVF-200;
   - military filtering station VFS-2.5; VFS-10;
   - modernized autofiltering station MAFS-3;
   - field desalination plant POU-4;
   - field desalination station OPC-2;
   - reagents: coagulant — aluminum sulfate, ferrous chloride, ferrous sulfate; 15 % solution of sodium

hypochlorite, chlorinated lime, sodium salt of chloroisocyanuric acid, cation exchange resin — carbopherogel, anionite — sulphated coal.

4. **Means of accumulation and transportation of water:**
   - water tanks — RDV-50; RDV-100; RDV-1000; RDV-5000;
   - tank trucks — AVC-15; AVC-28; AVC-40.

For sanitary supervision over the organization and implementation of water supply of military units and affected population, the Armed Forces of Ukraine have the following laboratory equipment: hygienic military laboratory — LG-1 and main laboratory — LG-2; bacteriological laboratory — LB; medical field chemical laboratory — MPHL-54; toxicological laboratory — LT; radiometric laboratory in cases — RLU-2; hydrochemical set — NGH; set for control of chlorination and water coagulation — NHC; field roentgen radiometer DP-5A, DP-5B.

32.4. Sanitary supervision over the organization and implementation of water supply of military units and affected population

Control over the organization of water supply of military units and the affected population is carried out both at the stage of preventive sanitary and current supervision, which makes it possible to minimize the risk of health damage to servicemen and the affected population (Fig. 32.4).

32.5. Conclusions

1. Proper organization of water supply and proper sanitation of water supply, especially in emergencies and during exceptional periods, allow to maintain health and ensure a high level of combat capability/efficiency of military and civilian units/affected population.
2. Rational selection of water supply source and adequate methods of water treatment in the field (if necessary) are the basis for providing military and civilian units and the affected population with water of appropriate quality and in reasonable volume. It is the key to maintaining their health, efficiency and combat effectiveness.

Compliance with sanitary and hygienic requirements for water supply in emergencies and in an exceptional period is implemented with the help of organic and improvised means of field water supply by implementing appropriate measures of preventive and current sanitary supervision.

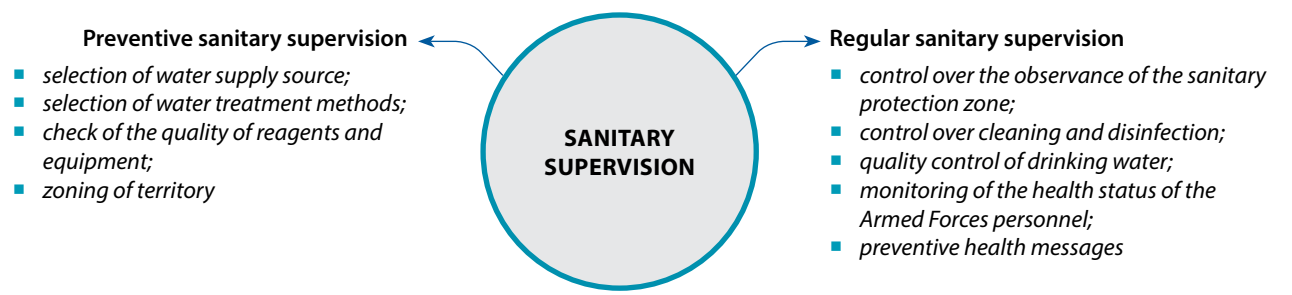


Fig. 32.4. Sanitary supervision during the organization of water supply of military units and affected population

33

CHAPTER

NUTRITION HYGIENE IN THE FIELD CONDITIONS IN EMERGENCIES

A. A. Borysenko, V. D. Aleksiichuk, O. M. Vlasenko, N. D. Kozak, A. M. Hrynzovskyi

33.1. Fundamentals of organization and carrying-out sanitary supervision over the nutrition of personnel

Sanitary supervision over the nutrition of personnel of civilians, military units and affected population is carried out in order to ensure its full value condition, which will help preserve their health and increase resistance to adverse environmental factors, as well as prevent diseases of servicemen and population that can be transmitted through food and foodstuff. Sanitary supervision over nutrition in the field conditions is divided into current and preventive (Table 33.1). Nutrition must meet the needs of the body and provide high work capacity (combat capability), taking into account working conditions, the specifics of the service, climatic conditions, age, and condition of the body state of military servicemen (MS). The nutrition of servicemen is scientifically grounded and has many features, i.e. it differs from the rational nutrition of the civilian population.

At first sight, the principles of nutrition of servicemen do not differ from the principles of nutrition of civilians in peacetime, but when ranking these principles, a certain feature can be noticed (Fig. 33.1).

Rank order of requirements for nutrition of servicemen in the field environment:

1. Epidemiological safety of products and ready meals.
2. Toxicological safety of products and ready meals.
3. Radiation safety of products and ready meals.
4. Caloric full value condition of products and ready meals.
5. Qualitative ratio of nutrients in foods and ready meals.
6. High digestibility of food.
7. Nutrition regimen.

The first three positions are occupied by indices of food and ready meals safety in emergencies, because in these terms the risk of contamination is much higher than in peacetime (accidents at radiation, chemical, biologically hazardous facilities). Another important component is the high probability of mass destruction weapon use during wartime. The latter positions are of secondary importance, given the conditions that may arise in emergencies and during wartime.

Features of meal arrangements in the field environment:

1. Difficulties in providing of foodstuffs and food for military units.
2. Complexity of food transportation, storage, cooking and delivery.

Table. 33.1. Sanitary supervision over nutrition in the field conditions

Preventive sanitary supervision	Regular sanitary supervision
Approval of the nutrition regimen and menu-schedule Selection of nutrition form Checking of the products and equipment quality Checking of readiness for transportation, storage and preparation Compliance of personnel with the qualification level	Monitoring the implementation of hygienic requirements at all stages Checking of undergoing medical inspection Checking of the quality of washing and disinfection of individual cooking tins, mugs, spoons, etc.; Health status monitoring Conducting sanitary and educational work

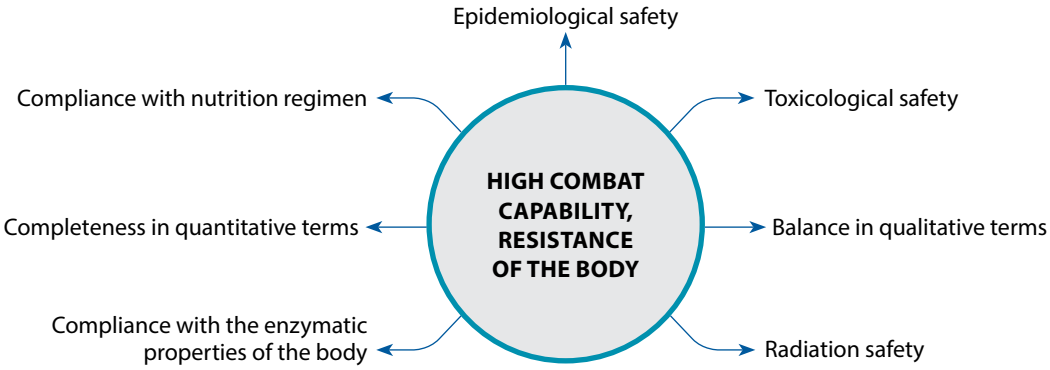


Fig. 33.1. Basic principles of rational nutrition of servicemen

3. Deterioration of foodstuff and food quality using canned foods.
4. The possibility of contamination of food service facilities, food and foodstuff with radiation, biological, chemical factors.

The organization and control over the nutrition of the troops in the field is carried out by:

1. Unit commanding officer.
2. Deputy commanding officer of the rear unit.
3. Chief food supply officer.
4. Chief medical officer.
5. Chief chemical officer.

Responsibilities of the medical service:

1. Control over the quantitative and qualitative full value condition of nutrition.
2. Quality control of food products, manufacturing technology.
3. Medical supervision over the state of health of the food service employees and MS.
4. Organization of measures for the prevention of hypovitaminosis and food poisoning.

33.2. Nutrition standards for servicemen of the Armed Forces and other military units

Military personnel ration is supplied according to the standards approved by the ***Resolution of the Cabinet of Ministers of Ukraine dated March 29, 2002 No426 "On Nutrition Standards of Military Personnel of the Armed Forces and other military groups [...]"***. In recent years, the standards of wartime are close to the standards of peacetime. In 2002 and 2015, new nutrition standards were developed and existing nutrition standards were improved for the Armed Forces in Ukraine. In detail, let's consider 3 rations:

- Standard No1 — Overall military ration.
- Standard No10 — Daily set of dry products.
- Standard No15 — Daily field set of products (Resolution of the Cabinet of Ministers of October 3, 2016 No696).

Nutrition standards for servicemen of the Armed Forces of Ukraine

- **Standard No1 — Overall military ration.**
- Standard No2 — Flight.
- Standard No3 — Marine.
- Standard No4 — Submarine.
- Standard No5 — Treatment.
- Standard No6 — Lyceum.
- Standard No7 — Treatment and preventive.
- Standard No8 — For donors.
- Standard No9 — Dietary.
- **Standard No10 — Daily set of dry products.**
- Standard No11 — Autonomous nutrition.
- Standard No12 — In-flight catering for aircraft and helicopter crews.
- Standard No13 — For military personnel in sea distress.
- Standard No14 — Emergency ration for aircraft and helicopter crews.
- **Standard No15 — Daily field set of products (Resolution of the Cabinet of Ministers of October 3, 2016 No696).**

The above nutrition standards are used in the organization of the following types of nutrition in the field in emergencies (Fig. 33.2).

Individual nutrition is used in the most acute period of emergency, war, the use of weapons of mass destruc-

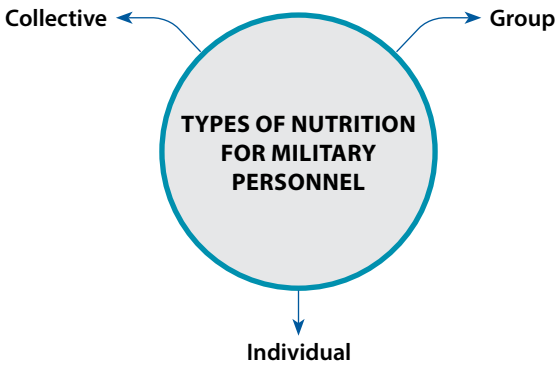


Fig. 33.2. Types of nutrition for military personnel

tion. It provides for the use of daily sets of dry products or daily field sets of products (ration packs) given to each serviceman separately.

Collective nutrition is used under the following conditions: peacetime, absence of armed actions, low risk of personnel damage and pollution of the environment and equipment of the weapon of mass destruction (WMD), sufficient time to organize this type of nutrition. It provides for the use of nutrition standard No1 (all-arms ration, Table 33.2).

Group nutrition is an intermediate form of nutrition that can be used in the subacute period of emergency, during a route march, while waiting for further instructions from the commander.

In terms of caloric value, the all-army ration is 4050–4170 kcal (on average — 4112 kcal), which is not significantly different from the caloric content of rations in other countries. Does this value correspond to the energy consumption of the military personnel?! As a rule, the energy consumption of the military personnel does not exceed 4000 kcal, but in some cases the caloric content of the ration may vary. The doctor's task is to control energy expenditure, weight of the military personnel and, if necessary, recommendations for reducing the load. The vast majority of products are fresh, not canned!

It can be noted that the ration contains an average of 105 g of protein, of which 30 g — of animal origin (30 %), and assuming that the average body weight of the military serviceman is 70 kg — it will be 1.5 g per 1 kg of body weight (which corresponds to the norm). On the positive side, the ration contains 30 g of butter, which is not only a source of biologically valuable fat, but also a source of vitamin A. The carbohydrate content is very high — 687 g (68 % of calories); this is due to the need to quickly restore energy consumption, as the soldier's work is very hard (dominated by the physical component). An im-

Table 33.2. STANDARD No1 (collective nutrition of servicemen of the Armed Forces of Ukraine)

Product name	Quantity per person per day, grams
Dry biscuits from wheat flour of the first grade	300
Canned meat (premium meat breakfasts)	325
Canned meat (liver pate)	100
Canned meat and vegetables (cooked whole grains with meat assorted)	650
Natural honey	40
Sugar	90
Dry coffee extract	2
Natural black tea	4
Paper napkins, pcs	3
Sanitary napkins, pcs	3
Tea	1.2
Bay leaf	0.2
Pepper (spices)	0.3
Mustard powder	0.3
Vinegar	1
Tomato paste	6
Potatoes and vegetables, total	900
Including:	
potato	600
cabbage	130
beets	30
carrots	50
onion	50
cucumbers, tomatoes, roots, greens	40
dried fruits	20
or fruit juices (fruit and berry)	100
Multivitamin supplement type "Hexavit", pills (used from March 15 to June 15)	1

portant source of carbohydrates is bread (400 g). This is a national feature of Ukrainian ration.

For procurement, processing, transportation and storage of foodstuff, as well as for cooking hot food in the field environment and delivering it to personnel, the catering service has the appropriate technical means (Fig. 33.5).

The kitchen of trailer-type KP-125M on the basis of GAZ-66 has a plate on the trailer, dixies. 7 dishes can be simultaneously cooked in this kitchen. KP-130 has a more efficient heating system (Fig. 33.3).

The bakery unit — an operating cycle of 55 minutes. Fully supplies the squadron with bread (8–10 tons per day). It is maintained by 5 people (Fig. 33.4).

The main unit of food supply in the field is the battalion ration supply station (BRSS), which is deployed by the forces and means of the administrative supply section.



Kitchen of trailer-type KP-125M



Kitchen of trailer-type KP-130, prepared for operation

Fig. 33.3. Technical equipment of the catering service in the field environment



Mobile messing facility PKI-2M in the expanded view



Automobile bakery unit AHB-2.5, prepared for movement

Fig. 33.4. Technical equipment of the catering service in the field environment



Refrigerating unit of trailer-type PRHU



Meat point of trailer-type PM-40



Fig. 33.5. Technical equipment of the catering service in the field environment

Maximally meets the requirements
Fresh and quality products
Food preparation by a military cook
Transported, stored, used by means of special equipment
Sanitary and hygienic control
Investigation of food poisoning



Complicated use in the "acute period"
Time for organization
High necessity in technical equipment
Need to involve people
High vulnerability when using weapon of mass destruction

Fig. 33.6. Advantages and disadvantages of collective nutrition

Given the rapid pace of movement of troops and limited time for cooking process, it is desirable to use products at the BRSS that do not require long processing: canned food, concentrates.

For units that are on the front line, precooked meal, bread, sugar are delivered to distribution points, from where hot food is delivered by handcarry (2 soldiers) to the front line.

As of today, the University of Food Science & Technology has developed new types of concentrates and canned food, new preservative agents, constantly improved methods of canning (sublimation), developed and improved recipes for instant cereals and dishes, recipes for slow firming bread, heat sterilization bread, i.e. there is no need to use dry biscuits. As an example — salt saturated with vitamin C: per 100 g of salt — 500 mg of vitamin C. An important component is soda, which is used as a preservative: without it, the loss of vitamin C for 3 months is 52 %, and with it — 5 %.

In terms of hygiene, the Daily set of dry products No10 (ration pack, Table 33.3) is unreasonable, and it can be used only for a limited period (3–5 days). This restriction is due not only to its insufficient caloric content, but also to possible digestive disorders, the appearance of dyspeptic disorders (Fig. 33.7).

Table 33.3. STANDARD No10 (Daily set of dry products) nutrition for servicemen of the Armed Forces and other military units

Product name	Quantity per person per day, grams
Dry biscuits from wheat flour of the first grade	300
Canned meat (premium meat breakfasts)	325
Canned meat (liver pate)	100
Canned meat and vegetables (cooked whole grains with meat assorted)	650
Natural honey	40
Sugar	90
Dry coffee extract	2
Natural black tea	4
Paper napkins, pcs	3
Sanitary napkins, pcs	3

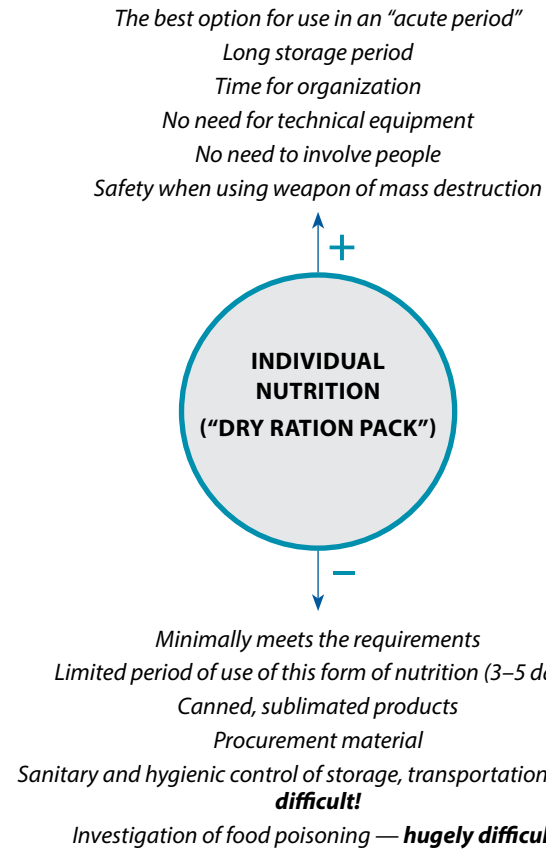


Fig. 33.7. Advantages and disadvantages of individual nutrition

When using a daily set of dry products in the field environment for more than one day, it is allowed to give:

- one portable heater;
- 40 grams of dry fuel (technical urotropin);
- 1 tablet for water disinfection;
- 6 pcs wind- and waterproof matches or 1 box of regular matches. If necessary: when using an individual form of nutrition more than 5 days, it is necessary to apply Standard No15 (Daily field set of products, Table 33.4).

To each meal (breakfast, lunch, dinner) of Standard No15 the following products are additionally added: bottled drinking water at the rate of 0.5 liters per meal, regardless of the season, and in the period from June 1 to September 1 — 1 liter for each meal.

For persons directly involved in an anti-terrorist operation (joint forces operation), the Standard No15 additionally includes:

Table 33.4. Standard No15 – Daily field set of products

Product name	Breakfast/dinner meal, grams	Lunch meal, grams	Quantity per person per day, grams
Dry biscuits from wheat flour of the first grade	50/50	50	150
Rusks from wheat flour of the I grade or rye flour	0/50	50	100
Ready to eat first course		500	500
Ready to eat first course	350/350	350	1050
Dry coffee extract	2/0		2
Tea	0/2	2	4
Sugar	10/10	10	30
Natural honey	0/20		20
Fruit jam		20	20
Black powdered pepper		0.3	0.3
Salt	1/1	1	3
Plastic tablespoon, pcs	1/1	1	3
Paper napkins, pcs	1/1	1	3
Sanitary napkins, pcs	1/1	1	3

- 30 g of dried fruits (assorted), 35 g of dark chocolate (cocoa not less than 56%), one chewing gum, one flameless food heater — for breakfast;
- one chewing gum, one flameless food heater — for dinner;
- 200 g of ready-to-eat meat dish (premium beef stew, unsorted pork stew) in a retort package, one chewing gum, one flameless food heater, 2 g of instant coffee, 10 g of sugar — for dinner.

33.3. Stages of medical inspection of foodstuff in the field environment

Sanitary and epidemiological inspection of food products is one of the sections of the activity of sanitary and epidemiological institutions of the Ministry of Defense of Ukraine in conducting sanitary supervision over the organization of nutrition of military personnel. It aims to determine the nutritional value or safety of food for servicemen. Sanitary and epidemiological inspection of products is carried out in order to determine:

- changes in their organoleptic properties and the causes of these changes;
- harmful impurities or any substances in quantities exceeding the permissible values provided by standards and hygiene norms;
- deviations of chemical content and their causes;
- epidemiological data on a particular product as a possible route (factor) of transmission of infectious agents.

Options of a preliminary expert conclusion may be as follows:

- product is edible without restrictions;
- product is inedible and subject to disposal;
- product of dubious quality; requires laboratory inspection.

The fourth stage of inspection — substantiation and execution of the final expert conclusion. It provides the following options:

1. Product is of good quality, edible without restrictions.
2. Product is conditionally edible; it can be consumed for a limited time, or by mixing with pure products in the ration.

Stage I	• data collection, sanitary inspection of the food facility on site; • indication of containers, food for contamination with toxic substances; • assessment of organoleptic characteristics of products; • substantiation and execution of a preliminary expert conclusion
Stage II	• sampling of products of dubious quality; • packing of samples, transportation and execution of accompanying documents
Stage III	• laboratory studies: sanitary-toxicological, sanitary-epidemiological, radiological, organoleptic
Stage IV	• substantiation and execution of the final expert conclusion

Fig. 33.8. Stages of inspection of food products in the field environment

3. Product is subject to special processing (degassing, decontamination, sterilization) with re-inspection.
4. Product is inedible and subject to disposal (in case of contamination with persistent toxic substances, in case of exceeding the radioactive contamination by 10 and more times from the permissible levels, in case of spoiled condition above the permissible level, rotten condition).
5. Product is inedible; it can be used for animal feed.
6. Product is inedible; it can be used for technical purposes or processed into fertilizer.

33.4. Features of the nutrition organization in the presence of an area of contamination with radioactive, chemical substances, and biological agents

In the case of the use of mass destruction weapons, it provides for carrying out of:

- continuous monitoring and informing on the nature and area of infection;
- maneuvering to select uninfected or less infected areas;
- special protection of foodstuff and ready-to-eat food;
- control of contamination of foodstuff, food, utensils of the catering service;
- compliance with the rules of cooking and eating;
- instructing military servicemen and staff on the conduct rules in contaminated area.

33.5. Conclusions

1. The organization of sanitary supervision over the nutrition of servicemen (affected population) allows to maintain a sufficient level of combat capability and work capacity of military personnel.
2. Nutritional standards of servicemen meet the needs of the body in balanced in qualitative and quantitative terms food products.
3. Proper control of edibility of products is ensured by medical inspection of foodstuff in the field environment.

34 CHAPTER OCCUPATIONAL HYGIENE WITHIN THE RECTIFICATION OF THE CONSEQUENCES OF EMERGENCIES

A. A. Borysenko, V. D. Aleksiichuk, O. M. Vlasenko, N. D. Kozak, A. M. Hrynzovskyi

34.1. Hygiene of military labour: subject, tasks

The health of military personnel, according to researchers, is 20% dependent on pattern and conditions of military labour, as they are in a special social space and within the legal framework, which is strictly regulated by Service Regulations of the Armed Forces of Ukraine.

Occupational hygiene in the field of Armed Forces is a section of military hygiene and a section of occupational hygiene, which studies all the factors of the labor process and their impact on the health and combat readiness of military personnel.

This section is an important subdiscipline of military hygiene which includes sanitary supervision of military labour conditions (labor of liquidators and population), carried out by the military medical service to prevent or reduce the negative impact of harmful factors, that can cause occupational diseases, impairments and injuries, on health of personnel of units (affected population), preservation of combat capacity of military personnel and working capacity of liquidators and population (Fig. 34.1).

The subject of military occupational hygiene:

- factors and conditions of the labor process;
- impact of the labor process and working conditions on health and combat effectiveness of servicemen.

The main tasks of military occupational hygiene:

- study of the impact on the body of physical, chemical, biological factors;
- development of hygienic standards of the production environment, military equipment;
- study of the labor process in order to develop rational work-rest distribution;
- study of production processes in order to identify intermediate, final harmful products and develop recommendations to protect people from adverse effects;
- development of sanitary and hygienic measures aimed at preventing occupational diseases and improving working conditions;
- study of the health status of personnel, their general morbidity, occupational pathology and physical development.

34.2. Characteristics of the main factors determining working conditions

In the conditions of military training and combat operations of troops and in the elimination of the consequenc-

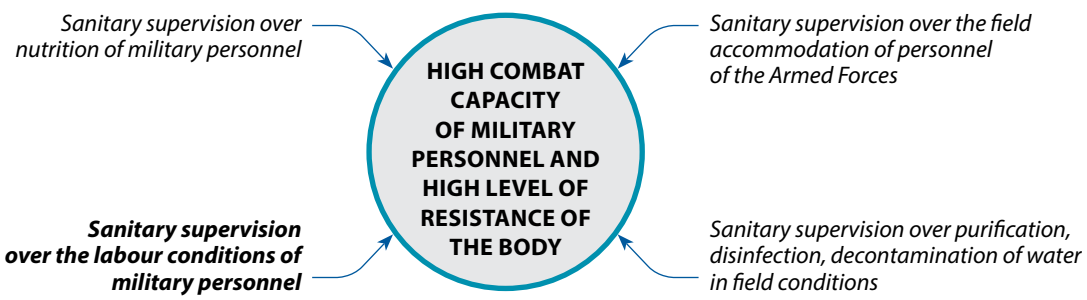


Fig. 34.1. The main components of sanitary supervision

es of emergencies, the human body can be affected by various factors, including harmful and dangerous. The main factors that determine working conditions are physical, chemical, biological and psychophysiological. There is a separate group of psychogenic (informational) factors that affect a person as a social being.

Harmful factors of labour conditions of servicemen are divided into:

Physical:

- high and low temperatures of air and fences;
- non-ionizing electromagnetic radiation (infrared, laser, microwave, radio frequency and low frequency);
- static electricity, electric and magnetic fields, ionizing radiation;
- noise, vibration;
- ultrasound;
- shock wave;
- gas flame;
- acceleration;
- lighting;
- reduced or increased atmospheric pressure, etc.

Chemical:

- harmful impurities in the air (powder, battery gases, fuel combustion products, etc.);
- technical fluids (solvents, cooling, brake, hydraulic, starting mixtures, antidetonation additives, etc.);
- various types of fuels and products of their incomplete combustion, oils;
- battery fluids;
- aerosols, which are formed during electric and gas welding, etc.

Biological factor is an impact of biological agents on humans; it is associated with the use of biological weapons or as a result of social and living conditions.

Socio-psychological factors:

- military-political and combat situation;
- fairness of goals and objectives;
- presence of a team or isolation from it;
- the character of mutual relations between people;
- style of interpersonal relationships;
- psychological compatibility of people working or living together;
- the presence of danger to health and life associated with the maintenance and use of military equipment and weapons;
- well-established living conditions;
- psychological atmosphere in the family, etc.

The most significant groups of harmful factors of the Armed Forces:

- sources of ionizing radiation;
- radioactive substances;
- rocket fuel components;
- sources of electromagnetic fields.

The basic principle underlying the hygienic classifications of labour is the principle of differentiation of labour conditions depending on the actual levels of factors of the production environment and labor process compared to hygienic standards, as well as taking into account their possible harmful effects on workers' health (Fig. 34.2).

Class 1 — *optimal* working conditions that maintain the health of employees and create the conditions for maintaining a high level of work capacity.

Microclimatic parameters and factors of the labor process meet the optimal hygienic standards of production factors. The influence of other adverse factors of the production environment does not exceed safe levels for the population.

Class 2 — *acceptable* working conditions. The levels of factors of the production environment and labor process do not exceed the established hygienic standards for workplaces, and possible changes in the functional state of the body are restored during the regulated rest during the working day or before the next shift and do not adversely affect the health of workers and their offspring in the near and distant periods.

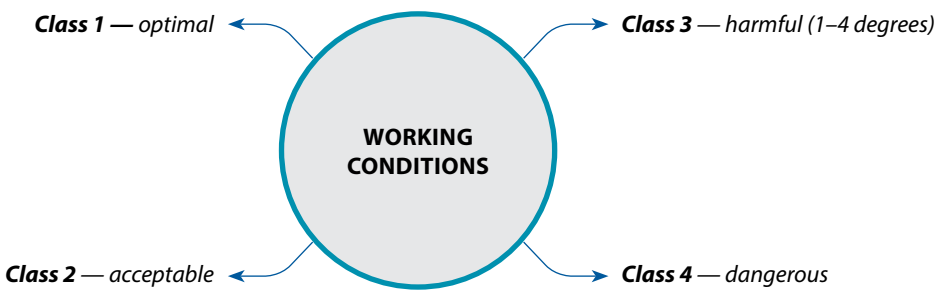


Fig. 34.2. Classification of working conditions

Class 3 — *harmful* working conditions that are created in the presence of harmful production factors that exceed hygienic standards and can adversely affect the body of the worker and/or his/her offspring.

Grade 4 — *dangerous* (extreme) working conditions under which the levels of factors of the production environment can create a high risk of severe occupational injuries, poisoning, damage, life-threatening condition during the work shift. An example is the work of liquidators of the Chornobyl accident consequences, when the shift sometimes lasted 1.5–2 minutes and was the first and last, because they received the absorbed radiation dose above the permissible levels.

34.3. Features of working conditions in different branches of troops of the Armed Forces of Ukraine

For a more detailed consideration of the features of working conditions of different branches of troops, it is necessary to analyze the structure of the Armed Forces of Ukraine (Fig. 34.3).

According to the hygienic classification, the work of motorized infantry, armored and artillery troops belongs to the category of heavy labour (average daily consumption of 4000–4500 kcal) and has a number of features:

- shooting from conventional small-arms weapon, including confined spaces;
- long stay in dug-in positions and other fortifications;
- long-distance march movements;
- forced movement on foot during the destruction of roads.

The most significant harmful production factors in the tank troops:

- limited workspace. The small size of the working space in an armored vehicle makes it difficult for crew members to work, forcing them to be in a constrained working position and to avoid hitting the surrounding surfaces during shocks and jolts while the vehicle is moving. It constantly requires significant muscle tension. Accordingly, there is increased fatigue of crew members. The tank cabin space is on average 4 m^3;
- shocks and concussions when vehicles are moving, loud noise;
- unfavorable temperature conditions in the cold and warm periods of the year;
- air contamination with harmful gases and dust. Impinging gases can enter the compartments of combat vehicles from empty cartridge cases and from the barrels of machine guns or cannons when opening the lock. Their concentration during firing exceeds the permissible norm by 4–5 times, which sharply worsens the functional condition of armored crewmen. As a result, the rate of fire is reduced by 40–50 %, and the time of homing on a target increases by 20–30 %;
- increased contamination of clothing and body with fuels and lubricants, solvents, colorants and dust;
- damage by laser radiation in case of non-compliance with safety rules. Present-day tanks are equipped with laser rangers, a powerful narrowly directed light pulse of which is dangerous for the unprotected human eye. It can cause vision damage of varying severity (from temporary blindness to retinal burns and permanent vision loss). The use of optical devices for observation increases the risk of damage to the organ of vision by a laser beam;
- low light conditions (with open manhole — 30–250 lux, closed one — 10–20 lux) causes high eye-strain, frequent transition from natural to artificial lighting and vice versa;

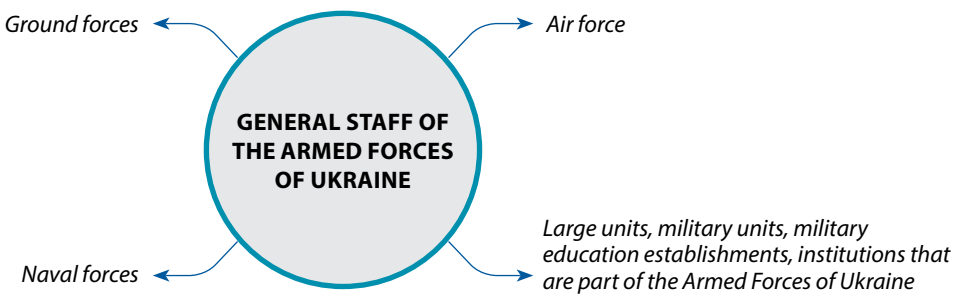


Fig. 34.3. Structure of the Armed Forces of Ukraine

- the noise level in the tank during movement can reach 130 dBA, which is much higher than the limit of human auditory adaptation, which is within 90 dBA. Such noise at long effect essentially reduces auditory sensitivity, which is restored only for the second day.

Medical measures for the hygienic provision of tank troops include:

1. Selection of people by professional suitability, "man — machine".
2. Medical examination of the Armed Forces (primary, periodic).
3. Control during maintenance of equipment.
4. Supervision over methods of training of specialists.
5. Development and implementation of regulatory and technical documentation.
6. Use of personal protective equipment.

Features of service in the artillery are, first, high levels of physical activity and the impact on the hearing system of shots from guns and explosions of bombs, shells, aerial bombs, etc.:

- excessive physical activity: ammunition delivery (mass of one ammunition in large-caliber systems reaches more than 50 kg);
- large amount of ground/grubbing works (trenches, ditches, entrenchments);
- high probability of injury;
- shock wave effect;
- effect of impulse noise;
- effect of a gas-flame jet;
- effect of powder gases;
- freezing injury of hands in winter.

One of the specific harmful factors for this type of troops is the effect of the shock wave. Therefore, it is necessary to consider this section in more detail.

Air shock wave is formed during the firing and shells or bombs burst.

There are the following types:

1. ***Barrel wave*** occurs due to the emission of powder gases from the barrel channel under high pressure (3000 atm and more).
2. ***Ballistic wave*** is formed due to the oscillation of air particles, which is caused by the flight of a bomb.
3. ***Explosive wave*** is formed at the time of burst of mines, bombs, etc.

Reactions of the auditory organ to cannon fire can occur in the following types:

- mechanical, when a sharp increase in external pressure damages the eardrum;
- pain caused by a sharp irritation of the nerve endings in the eardrum;
- acoustic which causes traumatic injury to the organ of Corti (spiral organ), which is accompanied by a loud ringing in the ears.

Features of working conditions in the Air force:

- low atmospheric pressure and the associated phenomenon of oxygen starvation;
- low temperature and low humidity at altitude;
- acceleration and associated overload;
- noise, vibration;
- air pollution in cabins by vapors of fuels and lubricants, pyrolysis products, etc.;
- exposure to ionizing radiation, sunlight;
- psychological and mental stress.

Features of working conditions in the Missile forces (main negative factors):

- impact of rocket fuel components;
- a set of factors that arise during the launch of missiles;
- long stay in limited spaces;
- high psychological and mental stress;
- unfavorable work and rest schedule (shift work);
- influence of ionizing and ultrahigh-frequency radiation;
- a large number of rigging works, elevated works.

Particularly dangerous for personnel can be emergencies that occur during work directly related to refueling rockets and draining rocket fuel components, which include extremely dangerous compounds — heptyl and oxidant — amyl. In the presence of oxygen, heptyl is oxidized to form formaldehyde, free nitrogen and other highly toxic compounds. The maximum allowable concentration (MAC) of heptyl for work spaces is 0.1 mg/m^3. Heptyl causes acute and chronic intoxication in humans. Amyl is a liquid with a sharp choking odor that make smoke in the air with the release of brown vapors of nitrogen oxides. The MAC of amyl is 5 mg/m^3. In contact with skin, it causes burns. Even short-term inhalation of amyl leads to damage to the respiratory tract and lungs with the development of toxic edema. Prolonged exposure to small concentrations of amyl is accompanied by the development of chronic intoxication, which is the result of local (irritant) and resorptive effect.

Features of working conditions in radio-technical troops

The main elements of the radio detection and ranging system (RDRS): antenna system, radio frequency emitter

and receiving equipment, interference protection equipment, output devices (indicators), computers for controlling the operation of the RDRS and signal processing, power sources.

There are the following types of RDRS: by method of location — active, semi-active and passive; by location — ground, ship, aviation, satellite, etc.; by type of radiation — pulsed (discrete) and with continuous (quasi-continuous) radiation; by working range of wavelength — meter, decimeter, centimeter and other ranges; by purpose — target detection, reconnaissance, weapons control, flight support, meteorological and navigation support, etc.

The main source of microwave radiation is an antenna. The intensity of microwave radiation is measured in units of power flux density (PFD is the amount of electromagnetic energy that falls on 1 cm^2 of surface per 1 second, μW).

The intensity of the effects of microwave radiation on the body depends on:

- radiation intensity;
- irradiation time;
- wavelengths;
- the size of the area of the irradiated surface;
- morphological features of organs.

Pathogenesis of microwave radiation:

- energy transfer to tissue molecules and change in the spatial orientation of these tissues, which is expressed in the strengthening of their oscillating (thermal) motion;
- tissues and organs, that rich in water, absorb energy better and heat up more due to the dipole structure of the water molecule;
- threshold of thermal effect of microwave radiation — 10 mW/cm^2;
- non-thermal effect (neurocirculatory dystonia, asthenic syndrome, etc.).

The biological effect of the microwave field is due to the penetrating power of microwaves into the body, their selective interaction with tissues, intensity and time of exposure and the size of the irradiated surface. The depth of its penetration into the body is approximately 1/10 of the wavelength and reaches: at a millimeter length — the depth of the upper layers of the skin; centimeter — the subcutaneous tissues and muscles; decimeter — the internal organs. If other conditions are equal, the latter are the most dangerous for the human body that has been exposed to radiation.

Protection against microwave radiation:

- Distance — moving away from the radiation source to the maximum possible distance.
- Shielding — the use of protective properties of the terrain, building materials, greenery, personal protective equipment.
- Quantity — the use of microwave sources of smaller power.
- Time — reducing the working hours of the personnel.

34.4. Conclusions

1. Carrying out sanitary supervision over the conditions of military work (liquidators' work) is a guarantee of saving lives, working capacity and combat capability of servicemen.
2. There are a number of harmful factors in the working conditions of military personnel and factors that affect the conducting of activities in emergency areas that require strict control.
3. Certain branches of troops of the Armed Forces of Ukraine are characterized by specific factors of the production environment and factors of the labor process, which are subject to mandatory hygienic standards.

35 CHAPTER HEALTHY LIFESTYLE AND PERSONAL HYGIENE

Ye.M. Anisimov

"Each person is endowed with an invaluable gift from birth, and its name is HEALTH; it is a pity that one begins to understand this only when he or she loses it!"

Max Pettenkofer

Actuality of the health problem:
- the importance of public health as a component of the progressive development of society;
- the importance of each person's health for the implementation of a personal life program;
- negative trends in population health;
- the growing impact of socio-economic and environmental determinants on health;
- inequality in the health of the population of individual countries within the country.

35.1. Health, definition. Indices, types and levels of health

It should be noted that the category of "health" is a composite, complex concept which can not be definitely described by a single indicator.

On the one hand, this is a methodological, philosophical concept.

On the other hand, it should be a practical concept that can be used in the daily activities of a health worker.

It is the lack of a constructive, universal definition of "Health" that poses great difficulties and considerable uncertainty about the results of scientific research to assess the impact of various factors on human health.

Existing definitions, including those in the preamble to the Constitution of the World Health Organization (WHO), are based on the primacy: **"Health is a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity."**. In addition, the concept of social well-being is subjective, and a person's social well-being cannot always be quantified.

The American sociologist-hygienist I. B. Richmond in his monograph on trends in health care and education, rightly noted that "medicine is so deeply absorbed in the concept of disease that we have neither terminology nor classification of health. This is especially true of social and psychological aspects of health, where only rough terms are used and there is no necessary classification."

In order to determine health, the following **"fundamental" provisions** should be considered:
- there is no absolute health; individual and population health are indivisible;
- health is determined not by one indicator, but by a set of characteristics;
- the definition of health is impossible without assessing the interaction of an individual and the environment;
- health assessment is not possible without exercise, necessary test tasks, load, etc.

That is why different definitions of "health" have a right to exist, but the use of each is limited in its purpose.

Based on this, there are several concepts of "health", which have different meanings:

The first is the general pathological (or philosophical) concept of health.

General pathological health is an interval within which quantitative fluctuations of psychophysiological processes are able to keep the living system at the level of functional optimum (optimal zone within which the body does not reach the pathological level of self-regulation).

The second is population health, i.e. the health of a group of people, inhabitants, the population.

Population health is a conditional statistical concept that is quite fully characterized by a set of demographic indicators, level of physical development, morbidity and frequency of premorbid conditions, disability of a certain group of the population.

The third is individual health, or the health of an individual.

In this case, individual health should be considered from two points of view:

The first position is theoretical, as the maximum possible optimum for a person to whom one should ideally strive, but which is practically very difficult to achieve. **Individual theoretical health** is a state of complete social, biological and mental well-being, when the functions of all organs and systems of the human body are balanced with the environment; there are no diseases, painful conditions and physical defects.

The second position is practical, as an actual characteristic of the level of health of a particular person. **Individual actual health** is a state of the organism in which it is able to fully perform its social and biological functions.

There is also a comprehensive approach to health as an average, which can be characterized by the following provisions:

1. The health status is determined in groups with identical socio-economic conditions.
2. Health (norm) is a condition that is determined in persons who are part of the 95 % confidence interval of the population.
3. The confidence interval is also considered as the optimal zone within which the body does not move to the pathological level of self-regulation.

Three main groups of health indicators are used to characterize health: the first group — medical indicators, the second group — indicators of social well-being, the third group — indicators of mental well-being.

The first group (medical indices) includes:

1. Demographic (fertility, mortality, life expectancy).
2. Morbidity (general, infectious, hospital).
3. Physical development (morphofunctional development, biological development, harmony).
4. Disability (primary and general).
5. Pre-nosological condition (immunity, resistance of systems, activity of enzymes).

The second group (indices of social well-being) includes:

1. Demographic situation.
2. The state of the environment.
3. Lifestyle.
4. The level of medical care.
5. Socio-hygienic indicators.

The third group (indices of mental well-being) includes:

1. Incidence of mental illness.
2. Frequency of neurotic states and psychopathy.
3. Psychological microclimate.

It should also be noted that WHO has developed a list of criteria for social well-being. This list includes:

1. Percentage of gross national product spent on health care. According to WHO, the average global health care and sanitation costs account for 8 % of world gross domestic product.
2. Availability of primary health care.
3. Coverage of the population with safe water supply.
4. Percentage of persons who were immunized against six particularly common infectious diseases among the population: diphtheria, pertussis, tetanus, measles, polio, tuberculosis.
5. Percentage of women served by qualified personnel during pregnancy and childbirth.
6. Percentage of children born with low body weight (less than 2500 g).
7. Average life expectancy.
8. The level of sanitary literacy of the population.

Basic criteria of individual health:

- genetic — a feature of the structure and functioning of the human genotype;
- physiological — a feature of the structure and functioning of anatomical and physiological systems of a person;
- mental — a feature of the structure and functioning of the nervous system, a feature of the psyche and personal status of a person;
- social — social activity of a person.

Aspects of individual health:

- socio-biological;
- socio-psychological;
- economic;
- moral and ethical;
- psychophysical.

Terms that reflect a certain aspect of individual health:

- mental health;
- sexual health;
- reproductive health;
- general somatic health;
- environmental health.

The distribution of the population according to the health state, developed at the Semashko Institute of Social Hygiene and Health Care Organization (now National Research Institute of Public Health named after N. A. Semashko, Moscow, the Russian Federation), related to the registration of the presence or absence of chronic diseases during the examination, the following:

Group 1 — healthy people, who do not get sick during a year or rarely get sick (0–1 case of acute respiratory diseases per year);

Group 2 — practically healthy (persons with risk factors, premorbid condition, no more than 2–3 acute diseases per year);

Group 3 — persons with chronic diseases at a compensated state without exacerbations or with frequent acute illnesses (more than 4 cases of acute illnesses per year and more than 40 days of disability);

Group 4 — patients with subcompensated condition (persons with exacerbations of chronic diseases during a year);

Group 5 — patients with decompensated condition (chronic patients at the stage of decompensation).

The distribution of the population into health groups is shown in Table 35.1.

Public health as an integral criterion for assessing the state of the environment

The health of the Earth's population in the past centuries has been determined by epidemics. The importance of the problem of public health has increased recently, due to intensive anthropogenic denaturation of the environment, as the state of human health has changed significantly and new patterns of prevalence and nature of human pathology have emerged. Demographic processes began to run differently.

Table 35.1. Distribution of the population into health groups

Health group	Proportion of population in group, %	
	men	*women*
I	27–28	20–21
II	20–21	16–17
III	39–40	47–48
IV	11–12	14–15
V	1	0.8

Based on this, in the 80–90s, some hygienists, such as academicians Goncharuk E. G., Sidorenko G. I., Izmerov M. F., Kundiev Y. I., professors Voronenko Y. V., Zvinyatskivsky Y. Y., Bardov V. G., Bushtueva K. A. and others proposed an alternative approach to assessing the state of the environment.

This alternative, non-traditional approach can be formulated as follows: "What is the level of health of the population, so is the state of the environment".

What were the prerequisites for such a conclusion?

First, the share of the environment in shaping the health of the population is about 20 %.

Secondly, there are a large number of hygienic standards, but not all factors can be measured and normalized; it is not always possible to comply with these standards.

Third, among the nine principles of hygienic standardization is the principle of threshold and the principle of relativity of the maximum concentration limit — any approved hygienic standard is not absolute truth and can be revised.

35.2. Risk factors and their role in the formation of population pathology

Etiological factor — the cause, the driving force of a pathological process, which determines its features (Fig. 35.1).

Risk factors are potentially harmful factors of behavior, biological, genetic, environmental, social, environmental and industrial environment, which increase the likelihood of developing diseases, their progression and adverse consequences.

Hierarchical distribution of risk factors:

Group 1: general, group, individual.

Group 2: constant, periodic, intermittent.

Group 3: primary, secondary, tertiary.

Group 4: major, minor.

Risk factors:

1. *Endogenous:*
   - manageable (hypertension, dyslipidosis, dysmenorrhea);
   - unmanageable (age, sex, heredity).
2. *Exogenous:*
   - manageable (state of the environment, lifestyle, shortcomings of medicine);
   - manageable (climate, natural conditions).

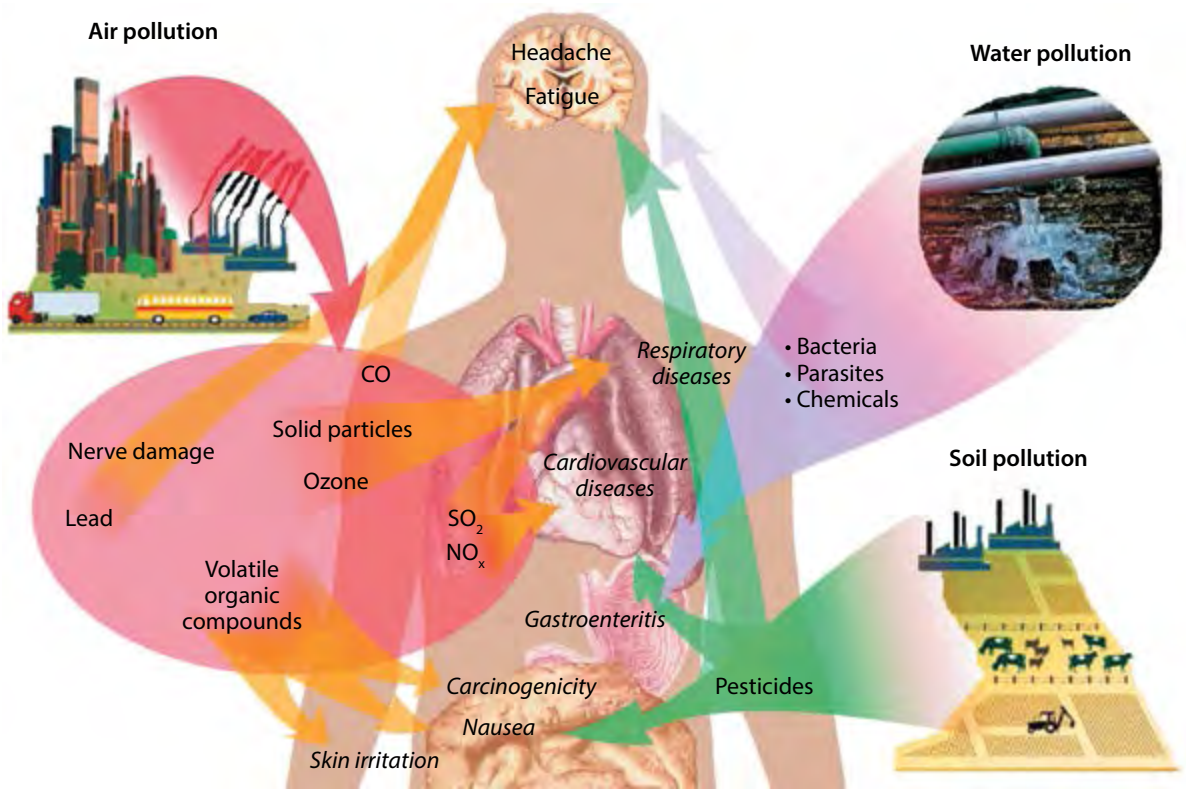


Fig. 35.1. Modern risk factors. Photo source: *https://www.researchgate.net*

The contribution of risk factors to the formation of public health:

- lifestyle — 49–53 %;
- ecological — 18–22 %;
- genetic — 17–20 %;
- medical — 8–10 %.

35.3. Healthy lifestyle and its main components (Fig. 35.2)

Lifestyle concepts:

1. ***Standard of living*** (structure, level of material security per person).
2. ***Quality of life*** (measured parameters that characterize the degree of material security of man).
3. ***Lifestyle*** (psychological, features of individual behavior).
4. ***Life type*** (national, social order, life, culture).

Recommendations for improving your lifestyle:

- daily 7–8 hours of sleep;
- 3 meals a day;
- daily breakfasts;
- maintaining a normal body weight;
- daily physical exercises;
- abstinence from excessive alcohol consumption;
- complete abstinence from smoking.

The basis for maintaining and strengthening the health of a person and the population is a healthy lifestyle and the use of methods and means of personal hygiene.

A healthy lifestyle of a person is a large set of biologically and socially oriented and appropriate methods and means of life that meet the needs and capabilities of man, which he consciously follows in order to ensure the formation, maintenance and strengthening of health, ability to procreate and achieve active longevity.

A healthy lifestyle of the population is a way of life that combines the full biological and social adaptation of each person with the possibility of maximum self-expression of the people, nation, class, social group in specific living conditions and that determines and ensures the further development of society.



Fig. 35.2. The main components of a healthy lifestyle. Photo source: *open internet sources*

A healthy lifestyle is a way of life aimed at maintaining and strengthening human health.

Methods and means of a healthy lifestyle include a whole set of subjective and objective conditions and factors on which the health of an individual and the society as a whole depends.

35.4. Objective and subjective methods and means of a healthy lifestyle

Objective methods and means of a healthy lifestyle:

- material support of the individual;
- provision of cold and hot water supply;
- psycho-hygienic microclimate;
- completeness, sufficiency, balance, variety of food;
- compliance with hygienic requirements for household and industrial clothing and footwear;
- compliance with hygienic requirements of severity, intensity, labor intensity and factors of the production environment.

Subjective methods and means of a healthy lifestyle:

- observance of personal hygiene;
- observance of a mode of work and rest, sleep and wakefulness, a diet;
- regular physical exercises;
- use of methods and means of hardening of an organism;
- prevent the abuse of bad habits;
- the level of personality culture.

35.5. Healthy lifestyle program

- observance of personal hygiene;
- nutrition;
- compliance with the regimen of work and rest;
- optimal motor activity;
- comprehensive and regular hardening of the body;
- abandonment of bad habits;
- accounting and use of individual biorhythms;
- maintaining and strengthening mental health;
- use of biologically active substances and geroprotectors;
- drug correction of diseases.

35.6. Personal hygiene, its content, meaning and bioethical aspects

Personal hygiene is a branch of hygiene that studies and develops the issues of maintaining and strengthening human health by maintaining a hygienic regimen in his personal life and professional activities.

Components of personal hygiene:

- body and oral hygiene;
- physical education;
- hardening;
- hygiene of clothes and shoes;
- hygiene of rest and sleep;
- hygiene of individual food;
- mental work hygiene;
- prevention of bad habits.

The following section is devoted to the meaning and prevention of bad habits.

36 CHAPTER HARMFUL HABITS AS A THREAT TO HUMAN HEALTH, THEIR PREVENTION

Ye. M. Anisimov

36.1. Habit, stages of habit development

Habit — a special form of human behavior, which is manifested in the tendency to repeat the same type of action in such situations.

There are the following stages of habit development:

I. You made a decision. An important stage, but without reinforcement, you are still at the zero stage of developing a habit.

II. You did it at least once. (Getting started is the most important thing).

III. You did it two days in a row. (One day to get up at any time — it's easy, but two days in a row — it requires effort. Taking a shower, you can tell yourself that from that moment you started to make a habit, but whether it really is, the next day will show).

IV. You did it for a week. (Overcome the social factor — do something all week, INCLUDING the weekend).

V. 21 days. (The minimum time to develop a habit, confirmed experimentally, used in the works of Brian Tracy).

VI. 40 days. (The time after which the habit will be 100 % developed until an opposite one is made).

Questions to the audience. At what stage (0–IV) are you now? What useful habit do you intend to develop soon?

That is why it is important to form good habits, but bad habits can be formed, which are risk factors and which are a threat to human health.

36.2. Risk factors, classification of risk factors

Risk factors are potentially harmful behavioral, biological, genetic, ecological, social, environmental, and industrial factors that increase the likelihood of disease development, progression, and adverse effects.

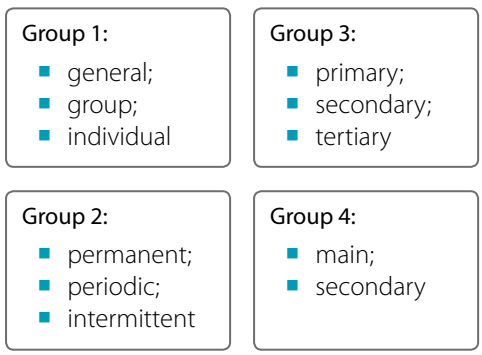


Fig. 36.1. Hierarchical distribution of risk factors

The hierarchical distribution of risk factors is shown in Figure 36.1.

36.3. Bad habits and their prevention

Drug addiction (Greek *narke* — numbness, stupor; *mania* — madness) — an irresistible and painful human urge to use drugs (opium, morphine, cocaine, etc.) for the purpose of excitement, intoxication, which leads to mental disorders, profound personality changes and dysfunction of internal organs. Drugs cause a pleasant psychological state even with a single use, and with repeated use — mental and physical dependence (Fig. 36.2).

Toxicomany (Greek *toxicon* — poisonous; *mania* — madness) — a disease caused by the usual abuse of any substance that causes a short-term subjectively attractive mental state (Fig. 36.3). The essence of drug addiction is poisoning and the urge to poisoning. Substances of different chemical structure and pharmacological activity are used for intoxication, which have a general psychophysical effect — euphoria and change of consciousness, behavioral disorders and social degradation. The term covers all forms of drug and non-drug abuse.



Fig. 36.2. Drug addiction. Photo source: *nbcphiladelphia.com*



Fig. 36.3. Toxicomany. Photo source: *telemundodallas.com*

Smoking is the inhalation with smoke of substances that cause a pleasant mental state together with intoxication of the body (Fig. 36.4). During smoking, tobacco is dry distilled with the formation of some new substances. Tobacco smoke contains about 1.200 different components, half of which have a toxic effect. These are substances such as nicotine and its derivatives, ammonia, carbon monoxide, hydrocyanic, acetic and formic acids, phenols, formaldehyde, hydrogen sulfide, carcinogens, soot. The main poisonous substance of tobacco smoke is



Fig. 36.4. Smoking. Photo source: *archyworldys.com*

nicotine. Its content depends on the variety and dryness of tobacco. One drop of nicotine kills a dog, and a leech that has sucked the blood of a heavy smoker drops dead.

Smokers annually "smoke" to the atmosphere 720 tons of hydrocyanic acid, 384.000 tons of ammonia, 108.000 tons of nicotine, 600.000 tons of tar, 550.000 tons of carbon monoxide.

Specialists of the Marzieiev Institute for Public Health of the National Academy of Medical Sciences of Ukraine conducted sociological research in Kyiv, Lviv and Lviv region, which showed that the average age of onset (attempts) of smoking is:

1. Kyiv: boys — 10.3 years, girls — 11.5 years.
2. Lviv: boys — 9.8 years, girls — 10.2 years.
3. Lviv region (rural area):
   - boys — 10.0 years;
   - girls — 12.2 years.

At the same time, 67% of teenagers see billboards advertising cigarettes, but only 49% of teenagers see warnings about the dangers of smoking on these billboards. 86% of boys said that classes on the dangers of smoking are held at school. Typically, 33% of students see teachers smoking at school and 17% see teachers smoking near school.

Table 36.2 shows the "tobacco" statistics of Ukraine.

According to the main effect, harmful substances contained in tobacco smoke and affecting the body are divided into 4 groups:

1. Carcinogenic substances.
2. Irritant substances.
3. Toxic gases.
4. Toxic alkaloids.

Carcinogenic substances: aromatic hydrocarbons, benzpyrene, phenols, organic compounds (nitrosamine, hydrazine, vinyl chloride, toluidine, etc.), inorganic compounds of arsenic and cadmium, radioactive polonium, tin and bismuth-210.

Irritant substances: unsaturated aldehyde — propenal (acrolein), carbon monoxide (II).

Toxic gases: carbon monoxide, hydrogen sulfide, hydrogen cyanide, etc.

Toxic alkaloids: only 12 (nicotine, nornicotine, nicotyrin, nicotine, nicotimine, etc.).

For people who do not smoke, but may experience the effects of smoking by others, the term "passive smoking" is used (Fig. 36.5).

Passive smoking (tobacco smoke in the atmosphere) is an involuntary inhalation of secondary tobacco smoke that a smoker exhales while smoking. According to WHO, approximately 40% of all children in the world, 33% of

Table 36.2. "Tobacco" statistics of Ukraine

- In Ukraine, 45 % of adult men and 9 % of adult women smoke daily; among young people, 45 % of boys and 35 % of girls smoke.
- 68 % of smokers say they are interested in quitting, and among those who have ever smoked every day, 26 % are already ex-smokers.
- More than 90 % of Ukraine's population supports a ban on smoking in all workplaces.
- Support for a total ban on tobacco advertising among the population — 70 %.
- In total, there are about 9 million active smokers in Ukraine, which is a third of the total working population.
- Ukraine ranks 17th in the list of leading countries in the number of smokers.
- Every year at least 100.000 Ukrainians join the number of smokers.
- Every fourth teenager in Ukraine smokes the first cigarette at the age of 10.
- Ukraine is the second country in the world (after Chile), where over 30 % of boys and girls smoke at the age of 13–15.
- Ukraine ranks second in the number of cigarettes smoked per capita. Every Ukrainian has more than 2.500 cigarettes — almost 7 a day.
- The World Bank estimates that Ukraine's economic losses from tobacco are about $ 2 billion annually.
- According to official statistics, 120.000 people die each year from smoking-related diseases in Ukraine



Fig. 36.5. "Active" and "passive" smoking. Photo source: *gdz4you.com*

men and 35 % of non-smoking women are regularly exposed to secondhand smoke. According to a study conducted by the World Health Organization, inhalation of second-hand tobacco smoke leads to 600.000 premature deaths per year (31 % of deaths are children, 47 % are women).

Smoking also has social significance. Harm of smoking regarding the occurrence and course of some diseases in smokers:

- 8–10 times more likely to suffer from pulmonary emphysema;
- 3–5 times — gastric ulcer;

- 3–4 times — coronary sclerosis;
- one in seven suffers from obliterating mendarteritis;
- 2 times more often — myocardial infarction;
- 3 times more often — sudden deaths due to CVS disorders;
- 20 times more likely to suffer from cancer of the respiratory tract, esophagus, stomach, kidneys (Fig. 36.6);
- mortality among smokers aged 40–49 years is 3 times higher, and at the age of 60–65 years — 19 times higher than among non-smokers (Fig. 36.7).

Every 20th bed in the hospital is occupied by a person who has health problems related to smoking. Statistics show that of the 460.000 people hospitalized with this pathology, 27 % had respiratory disorders, about 35 % — lung cancer, another 29 % — cardiovascular diseases caused by smoking.

Smoking prevention measures at the state level:

1. Increase in taxes and prices for tobacco products.
2. Prohibition of tobacco advertising.
3. Informing smokers about the dangers of smoking by placing warnings on the packaging of tobacco products.
4. Informing smokers and non-smokers about the dangers of smoking.
5. Assisting smokers to quit smoking.
6. Protection of the population from the effects of tobacco smoke.
7. Restriction of illegal trade.

Alcoholism (Fig. 36.8). Studies of Christian Rus' clearly emphasize that sobriety is a national trait of the Ukrainian people. Origins — family and Christian upbringing. In the first, and so far the only, detailed study



Fig. 36.6. Consequences of smoking

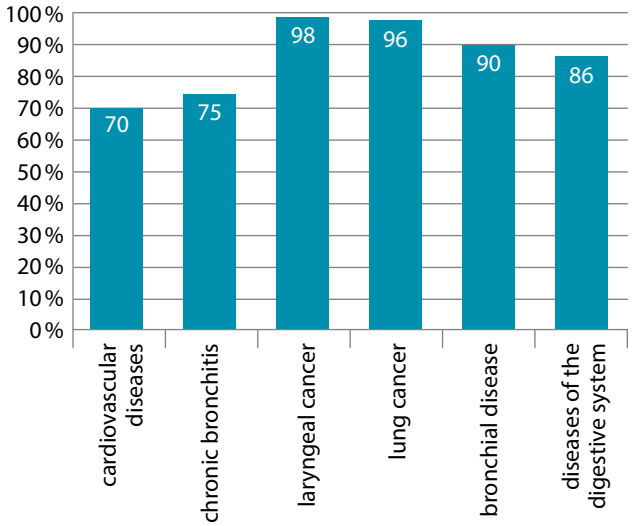


Fig. 36.7. Smoking mortality statistics, %



Fig. 36.8. Alcoholism. Photo source: *wikisara.com*

of I. Prizhov on the history of drinking business and alcoholism in Ukraine, Russia and Belarus since the end of the first millennium AD and by the mid-1860s contained comprehensive summaries of information on the study of drunkenness. According to him, Ruthenians drank brew, honey, beer, kvass (1–5 %), intoxication of which lasts a short time. Imported wine from Byzantium has been known in Rus' since the 10th century. Until the 12th century, wine in Rus' "was consumed only diluted with water, just as it was drunk in Greece and Byzantium". The Greeks diluted wine with water in a ratio of 1 : 3 or 2 : 5.

Every year, more than 55.000 young Europeans die from alcohol abuse. Alcohol intoxication accounts for 40–60 % of fatal injuries.

Alcohol consumption accounts for 9 % of the total burden of diseases, including liver cirrhosis, heart disease, stroke, malignant neoplasms of the digestive system.

Reducing alcohol consumption per capita by 10% will reduce alcohol-related deaths among men by 20% and reduce fatal accidents, suicides and homicides among the population by 5%.

WHO states: 40% of children in Ukraine consume alcohol. At the age of 11–12, they not only try alcohol, but also experience being intoxicated; one-sixth of 11-year-olds know what intoxication is.

Every year, Ukraine loses more than 40.000 of its citizens, whose deaths are caused by alcohol: 8.000 — poisonings, 8.000 — cardiopathy, other diseases, accidents. Plus 25–30% of cases of pediatric pathology of newborns are recorded. The level of alcohol consumption in Ukraine is 20 liters of absolute alcohol per capita per year. According to Honored Doctor of Ukraine Hennadiy Zilberblat, every tenth Ukrainian who consumes alcohol becomes an alcoholic.

Over the past 10 years, the number of people addicted to beer has increased 10–12 times, 30% of men aged 25 to 50 are addicted to alcohol. In Ukraine, 700.000 people have been officially registered and put on drug records.

Stages of alcoholism development: acquaintance with alcohol, regular consumption, obsession, chemically conditioned dependence.

Scientists have experimentally established what dose of alcohol is safe for the human body. The results of the research completely shattered the myth that daily consumption of a minimum amount of alcohol is good for the body, because a banal drinking bout threatens the "passive alcoholics". But French scientists are quite firm in their conclusions: drinking a glass of wine every day, a person increases the risk of developing cancer not only of the throat but also of the oral cavity. In turn, leading WHO experts say that a perfectly acceptable rate of consumption of beverages containing alcohol is a bottle of dry wine per week. According to experts, it is this amount and this type of alcohol which can benefit the human body. According to Eugene Brun, ex-chief narcologist of the Ministry of Health of the Russian Federation, even despite the proposed WHO recommendations, one bottle of wine a week is a very large amount of alcohol. One glass of dry wine a week will be enough for a healthy drink. He argues that this amount of alcohol contains a sufficient amount of pectin and other nutrients.

The world experience in combating this vice is unique: restrictions on production, selling, excise duties, monitoring the absence of harmful impurities. These measures were most consistently and expediently carried out in Sweden, where the so-called "Gothenburg system" emerged, which served as a model for combating alcoholism in other countries. In Sweden, from 1788, almost complete freedom of distilling and trade in alcohol was established; the result was that in 1829 there were up to 173.124 distilleries in the country. In 1865, in Gothenburg, on the initiative of the famous Swedish philanthropist, priest Wieselgren, the "Gothenburg Trust Public House" was founded, which gave its name to a new system of combating alcoholism. The society began to reduce the number of taverns, bringing it from 72 to 19 by 1885. The rest of these establishments were provided with good premises and vendors. The sale of beverages on credit and as collateral was prohibited, it was forbidden to sell to a drunk person under 18 years of age. There were large dining and reading rooms, a large selection of books, newspapers and magazines. The combination of all these measures has led to a reduction in alcohol consumption in Gothenburg by more than half. The company's experience has been used in Sweden, Norway and Finland. Currently, alcohol can be bought in Sweden only for a lot of money and out of town; there is a constant anti-alcohol propaganda.

Drug addiction (Gr. *narke* — numbness, sleep, and *mania* — madness, passion, attraction) — a group of diseases that occur as a result of systematic, increasing use of substances that are included in the officially approved list of drugs.

Manifestations of drug addiction are mental and physical dependence on these substances, as well as the development of abstinence due to cessation of their usage. There is a tendency to increase the use of drugs based on cannabis (hashish, marijuana), poppy (opium, morphine, heroin), coca (cocaine).

It should be borne in mind that primary narcotization often takes the form of "experiments" that reflect the age-specific psychological specifics of adolescents — active search for forms of self-affirmation through "special", "interesting" pastime ("unusual", "risky", "adult", etc.).

The main motives for this search are also curiosity, imitation (leaders, groups), subordination, the desire to find their place in the group, sometimes a protest against the "norms of adult behavior." This usually happens in the absence of real, emotionally colored interests, spiritual values, skills in the organization of leisure, clear positive social attitudes.

Among the risk group can be identified adolescents and slightly older people with a certain readiness for narcotization, which is caused by: low resistance to

mental "overload" (stress), reduced adaptability to new difficult situations, intolerance of conflicts; severe tension, anxiety, self-doubt, low self-esteem, difficulties in communication; impulsiveness, in particular with the desire to have fun, new sensations, pleasant and even unpleasant, as soon as possible and in any way; mental and social immaturity, insufficient assimilation of social norms of behavior, willingness to follow negative leaders, including willingness to engage in criminal behavior.

Reasons for drug use. The first acquaintance with drugs is facilitated by a number of non-specific factors, the largest share of which is the deviation of personality. The second place is occupied by the peculiarity of social orientation. The third place in importance belongs to a group of factors that reflect the negative attitude to work and study. Fourth — the peculiarity of education. Fifth — hyperprotection. Sixth — the influence of an informal group, a reference group for adolescents.

Ways to prevent addiction. In Ukraine at the present stage, the problem of combating drug addiction is gaining national importance. In 1992, Ukraine was admitted to Interpol. The most important measures for drug prevention are: organizational, economic, cultural, educational and legal.

Medical prevention of drug addiction includes: health education, control over the prescription of narcotic drugs (strict adherence, short duration, dose control, alternation of drugs to avoid addiction), timely detection of abuse (primary prevention), control of remission after treatment, relapse prevention (secondary prevention).

Here it is worth mentioning that one of the specific methods of hygiene is the method of sanitary education, which involves educational work among the population. Thus, the main and promising object of preventive work should be organized teams: kindergarten, school; college, institute and university; army; production teams.

Leading specialists who can organize and control preventive work should be: scientists of the departments of preventive medicine of medical universities; general practitioners and sanologists; family doctors; medical doctors of sanitary units.

In addition, a special system of incentives should be introduced to stimulate prevention: moral encouragement; use of the effect of collective influence on recovery; material incentives for both citizens and doctors.

36.4. Physical culture and its place in a healthy lifestyle

One of the signs of culture is the attitude of an individual citizen and the state as a whole to a healthy lifestyle!

Exercise is important for maintaining and strengthening everyone's health and for preventing hypodynamics. Exercise affects the cerebral cortex and subcortical centers, forms a balanced nervous and mental state, causes a feeling of vitality, stimulates the development of the muscular system of the body, the cardiovascular system.

Physical training includes: morning exercise to restore physical activity and efficiency after sleep; sports breaks during the working day at work to improve efficiency; physical exercises in free time from work (Fig. 36.9).

Consequences of low physical activity. Quantitative characteristics of physical health in people who exercise regularly are 1.3–2.4 times higher than in people who neglect it. The duration of treatment in hospitals of the most physically active men and women compared to the least physically active is lower by 36 % and 23 %, respectively. Successful control of hypodynamics will reduce the incidence of coronary heart disease by 15–39 %, stroke — by



Fig. 36.9. Physical culture. Photo source: *induced.info*

33 %, hypertension — by 12 %, diabetes — by 12–35 %, colon cancer — by 22–33 %, breast cancer — by 5–12 %, fractures on the background of osteoporosis.

Physical health indices: level of physical development; level of physical training; level of functional preparation of the body to perform physical activity; level and ability to mobilize the body's adaptive reserves, which ensure its adaptation to the effects of various environmental factors.

36.5. Hardening (tempering) of the body, its significance and basic principles

Hardening is an increase in the body's resistance to fluctuations in air and water temperature, humidity, atmospheric pressure, solar radiation and other physical environmental factors (Fig. 36.10).

Basic principles of hardening:

1. Graduality — a gradual increase in the intensity and duration of the impact of the hardening factor.
2. Systematicity — procedures should be performed regularly according to a certain system.
3. Complexity — a purposeful combination of participation of all organs and systems of the body in the hardening and the influence of several environmental factors.
4. Adequacy — the exact dosage of hardening factors.
5. Individual regimen, its compliance with the biological rhythms of the organism.

Hardening significance:

- increases the body's adaptive capacity to the effects of adverse factors;
- reduces susceptibility to respiratory and other infectious diseases;
- increases efficiency;
- promotes the formation of positive physiological reactions.

The main factors of hardening: air, water, solar radiation and corresponding to the body's capabilities, but with a gradual increase, physical activity and self-training of psychophysiological state.

36.6. Psychohygiene, sections and tasks of psychohygiene

Maintaining mental health paves the way for the health of our entire body. WHO provides a definition of mental health.

Mental health is a state of mental well-being that allows a person to realize his or her abilities, successfully



Fig. 36.10. Tempering (hardening). Photo source: *nl.lovetheteam.com*

overcome life's difficulties, problems and stresses, work productively and efficiently, and benefit society.

Psychohygiene (as a branch of modern hygiene) studies the state of neuro-mental health of a person, its dynamics in connection with the impact on his body of natural, industrial and social factors.

Sections of psychohygiene: age psychohygiene; psychohygiene of life; psychohygiene of family life; psychohygiene of work and study; psychohygiene of pedagogical process and mental work; extreme situations and catastrophes, military; sports; space.

The main tasks of psychohygiene: analysis of nervous-mental health of the population; development of age standards for the development of psychophysiological functions and personality traits; study of the nature of the influence of environmental factors on the body and their normalization, taking into account the dynamic changes of neurophysiological and psychophysiological parameters of the organism.

The mental state of the organism is a generalized picture of the mental functioning of the higher nervous activity of the organism in a limited period of time, the idea of which in the human mind is realized on the basis of self-assessment processes.

36.7. Leading psychohygienic principles of optimization of daily human activity

1. Carrying out of hygienic rationing of professional (educational) activity of a person.
2. Identification of factors that contribute to the breakdown of adaptation mechanisms and, above all, taking into account crisis periods in human life, which are based on the organizational restructuring of personality, psychophysiological and behavioral changes, changes in psychosocial orientation.
3. Rational organization of extracurricular human activity and activity after working hours, which involves the study of individual characteristics of temperament, character, motivational orientation and neuropsychological states of a person, taking into account the age patterns of changes, the use of active methods of psychophysiological influence on the formation of criteria.
4. Substantiation and differentiated introduction of measures of psychohygienic correction and rehabilitation.

CHAPTER 37

PECULIARITIES OF HYGIENIC PROVISION OF THE POPULATION IN TROPICAL REGIONS (ORGANIZATION OF PLACES FOR HABITATION)

A. V. Blagaia

37.1. Hygienic description of tropical regions

The life of humankind in ancient times was strictly focused and dependent on environmental conditions. Most anthropogenesis centers are associated with geographical locations refered to the so-called tropical regions or tropics.

Tropical regions are latitudes between 23°28′ from the equator to the north (northern tropics) and south (southern tropics). The tropics are as far apart from the equator as the polar circles are from the poles. In the tropics, the Sun stands at its zenith on a sunny afternoon for this hemisphere's summer solstice (Fig. 37.1).

The tropics (from Ancient Greek *Τροπικός κύκλος* — turning circle) are climatic zones of the Earth. Since the angle of 23°26′14″ is the angle of the Earth's axis of rotation, in a strictly geographical sense, the tropics are located between the Tropic of Capricorn (Southern Tropic) and the Tropic of Cancer (Northern Tropic) — the main parallels located at 23°26′14″ (or 23.43722°) south and north of the equator, determining the greatest latitude at which the Sun can rise at zenith at noon. In the Tropic of Cancer and the Tropic of Capricorn, the sun is at its zenith only once a year: on the day of the summer solstice and the day of the winter solstice, respectively. At all intermediate latitudes, the Sun appears at zenith at noon twice a year, once every year heading to the north and the second time — to the south. Tropical belts of the Earth can also be called tropics. A hot climate is typical for tropical regions.

From a medico-geographical point of view, the tropics are part of the Earth's surface, located in the equato-

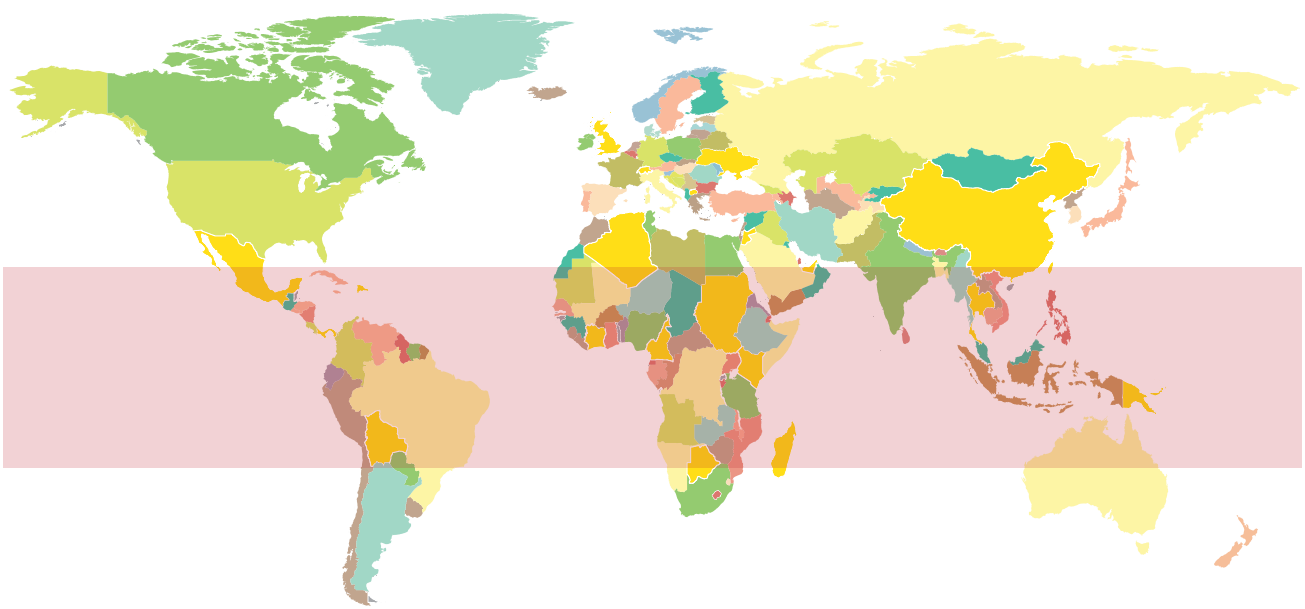


Fig. 37.1. Geographical location of tropical regions. Source: *en.wikipedia.org*

rial (from 10 north latitude to 10 south latitude), tropical (from 10 to 20 north latitude and 10 to 20 south latitude), and subtropical (from 20 to 30 northern latitudes and 20 to 30 southern latitudes) zones. However, taking into account climate change, which is associated, among other causes, with the accelerated pace of urbanization, the boundaries of the tropics in recent years have significantly eroded and changed their geographical location. It is also necessary to take into account the features of some geographical regions, which may depend on the circulation of air masses, local water supply, and so on.

To understand the peculiarities of certain tropical regions' impact, it is advisable to divide them into arid (dry) and humid (wet) tropics with a predominance of the appropriate climatic component (Fig. 37.2).

Tropical areas with an arid or desert climate (according to Köppen's climate classification — BWh and BWk, sometimes also BWn) include areas where the climate does not meet the criteria to be classified as a polar climate in which precipitations are too low to support vegetation, or the smallest shrub, at the same time the air temperature tends to high values with relatively large daily fluctuations.

Tropical areas with a humid (wet) climate include regions where the average temperature is above 18.0 °C (64.4 °F) for all twelve months. There are often only two seasons in a humid tropical climate: the wet season and the dry season. The humid type's tropical climate is free from frost, and changes in the solar angle are small. The air temperature remains relatively constant (hot) throughout the year, and sunlight's intensity is relatively high.

37.1.1. Disadvantages associated with urbanization in tropical regions of the world

Climate change and urbanization can change the distribution of nosologies in the population's morbidity structure in tropical regions. The tropics, as regions with the poorest stratum and the highest morbidity rates, are expected to become slightly hotter and significantly more urban. The mutual reinforcement of these factors in the future may increase morbidity rates or change its structure. Social managers need better data on current models of seasonal disease rates across the spectrum of climate, urbanization, and socioeconomic status. Interactions between climate change, urbanization, and health should be understood by health professionals, with the aim of proper strategic planning of prevention measures among the population of the respective regions.

The ecological consequence of urbanization in tropical regions with a negative aspect is significant tropical deforestation (disafforestment) rates in order to use these areas for construction or agro-industrial plantations. This aftermath changes the natural mechanisms of the rotation of substances and the utilization of car-

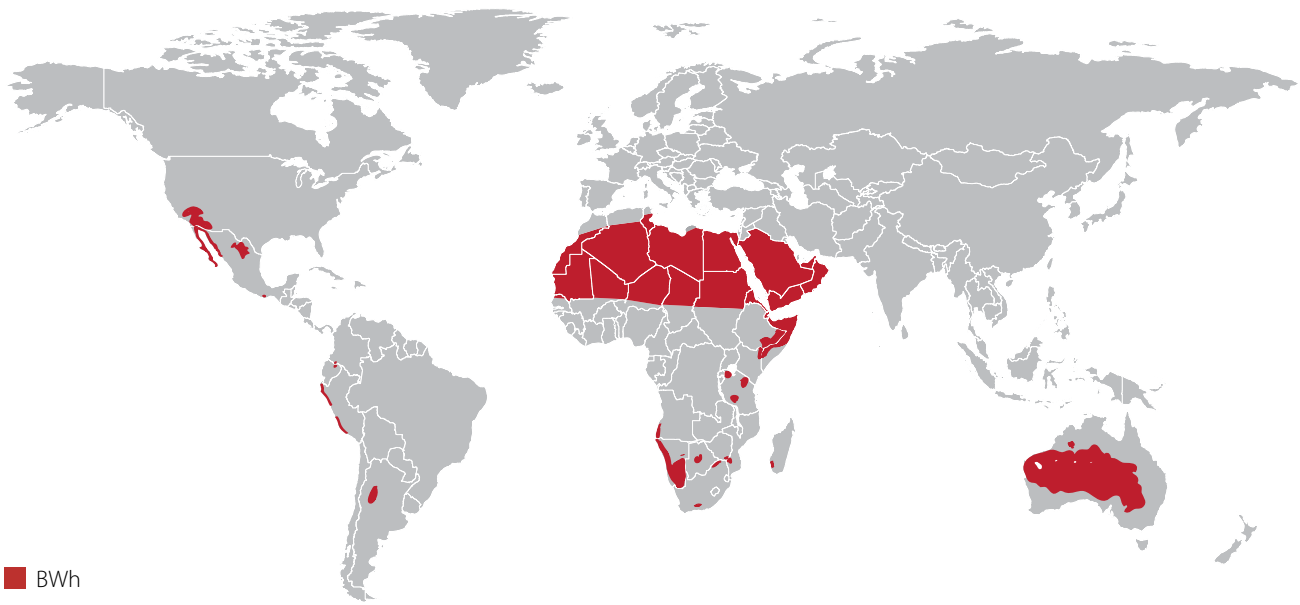


Fig. 37.2. Location of zones with arid climate type BWh. Source: *https://en.wikipedia.org*

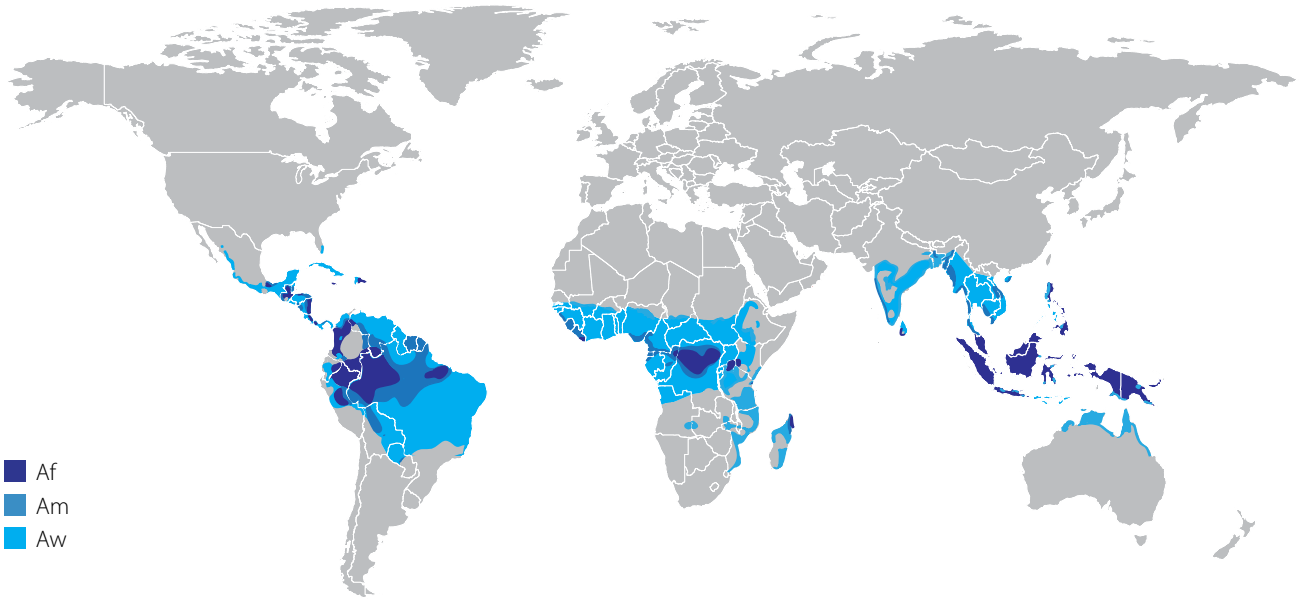


Fig. 37.3. Location of zones with humid climate types Af, Am, Aw. Source: *uk.wikipedia.org*

bon (carbon turnover) with increasing manifestations of global warming.

The following negative consequence of urbanization is a rapid increase in population in the cities of tropical regions (Fig. 37.4–37.5).

Levels of urbanization are rising in both developed and developing countries. The share of the world's urban population is expected to increase to 57 % by 2050 from 47 % in 2000. More than 90 % of future population growth will come from large cities in developing countries. Among developing countries, African countries have experienced the highest urban growth rates in the past two decades at 3.5 % per year, and this figure is expected by 2050. Forecasts also show that between 2010 and 2025, some African cities will account for up to 85 % of the country's population. In 2010, the African urban population's share was about 36 % and projected to increase to 50 % and 60 % by 2030 and 2050, respectively. Such rapid expansion has changed the demographic landscape of the continent. However, urbanization in Africa has failed to deliver inclusive growth, which has led to the spread of slums, urban poverty, and growing inequality. Inequality in African cities remains the second largest globally with an average Gini coefficient of about 0.58, well above the average of 0.4. Migration between rural and urban settlements and the natural rate of urban population growth are the main reasons for the growth rate of urban development and the spread of slums in Africa.

Southeast Asia is also steadily urbanizing. In 1950, only 15.5 % of its population lived in cities. In 2010, the figure was 41.8 % (or about 250 million people), and is expected to increase to 50 % by 2025.

Urbanization and economic development are often mutually reinforcing, and the most urbanized countries are usually the most economically developed. Such a statement also applies to Southeast Asia, although officially, the statistics may show different figures.

The living conditions of the population in tropical regions are also unsatisfactory — slums, favelas, in which 20–65 % of the population live, are not built in compliance with hygienic standards (Fig. 37.6).

The distribution of slum dwellers in the tropics is changing for the better in the context of improved housing. However, the proportion of people living in poor conditions continues to grow in the West Asian region (Fig. 37.7).

Also, unsatisfactory hygienic conditions associated with the urbanization of tropical regions are congestion of public transport: getting to work from the slums exhausts people; the death rate from road accidents is 4–6 times higher than from infections; traffic noise causes nervous and mental, cardiovascular disorders; air pollution from emissions of combustion products in vehicles causes chronic bronchitis.

And as a result of the transfer of production from developed countries to developing countries, which, for the most part, are in the tropics, air pollution occurs, fol-

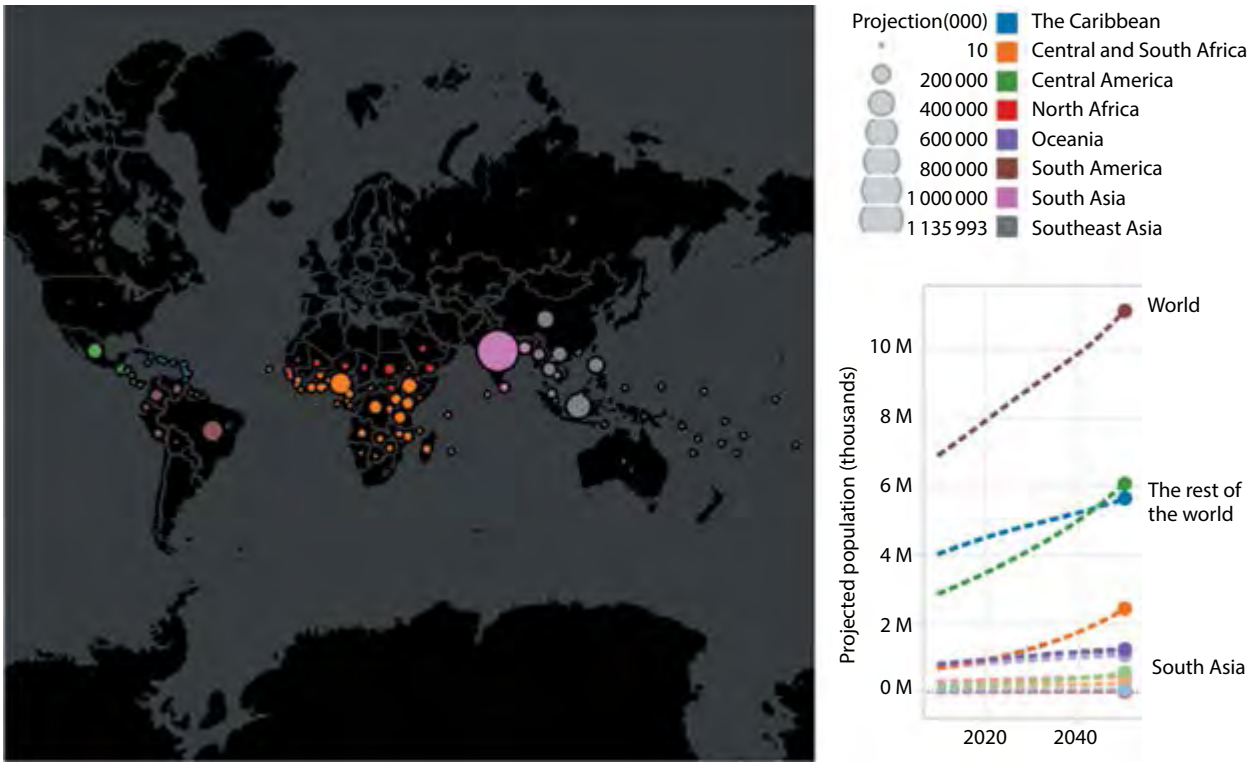


Fig. 37.4. Population density growth rates in the cities of tropical regions in 2010. Source: *un.org*

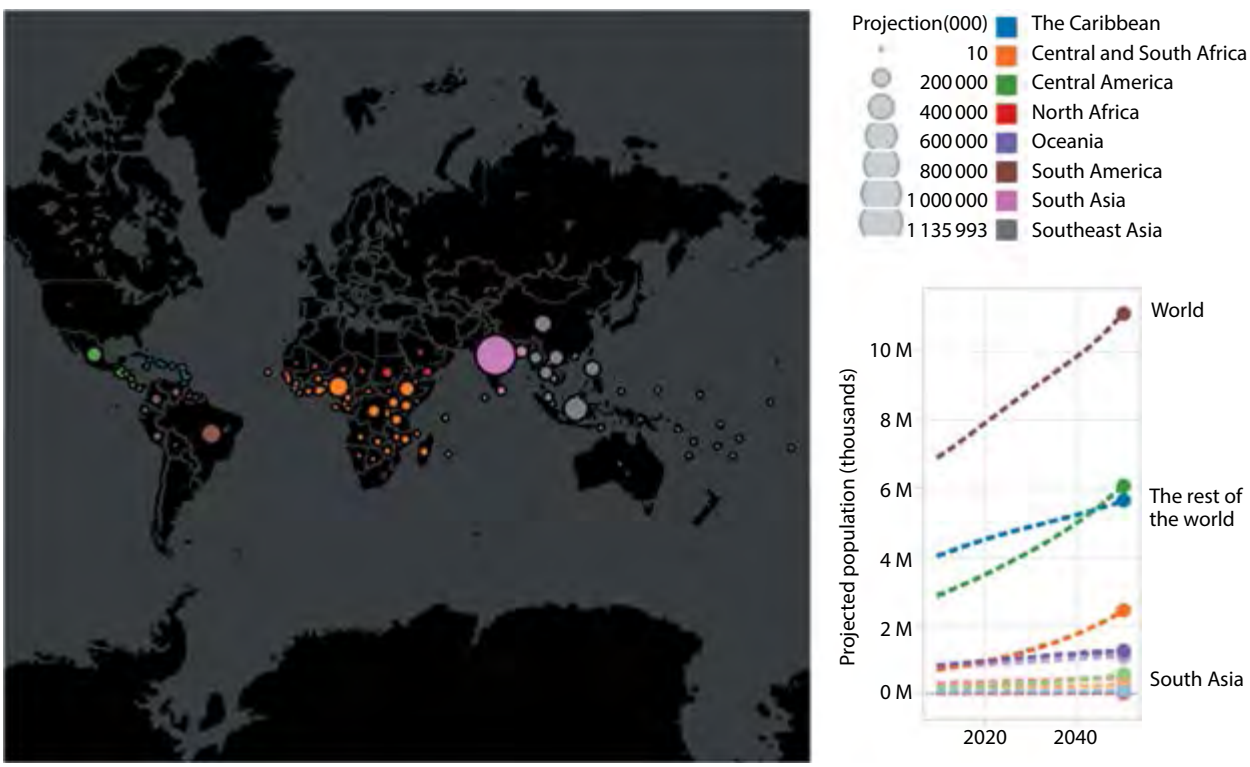


Fig. 37.5. Population density growth rates in the cities of tropical regions in 2015. Source: *un.org*



Fig. 37.6. Favelas in Trinidad and Tobago. Source: *i.imgur.com*

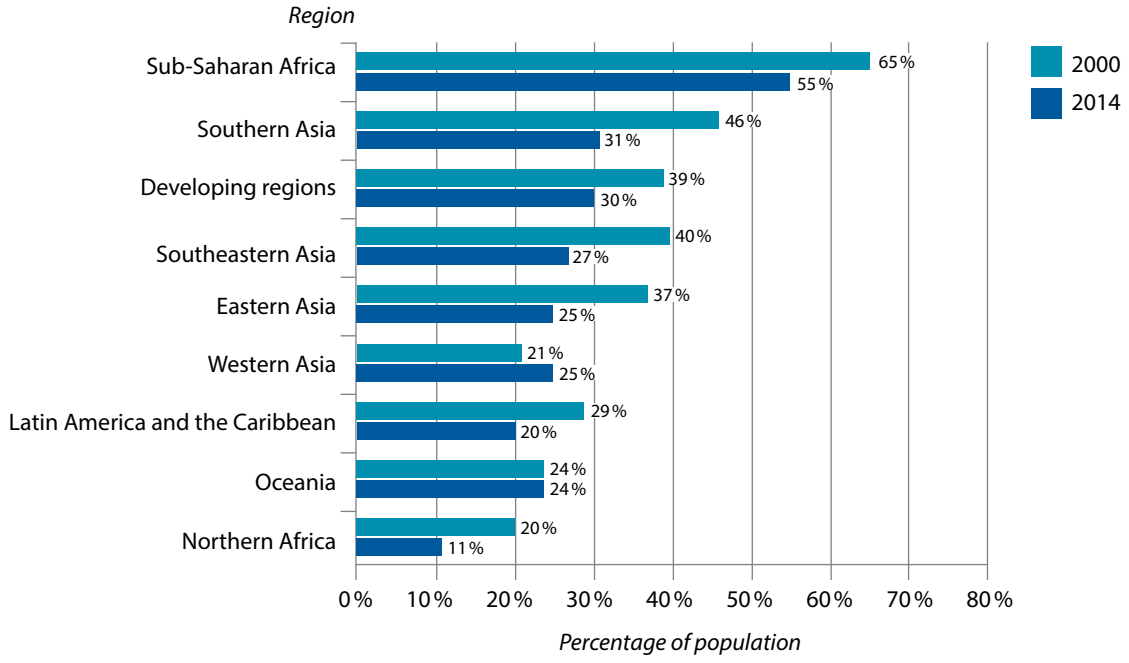


Fig. 37.7. The share of urban population living in the slums in 2000 and 2014, by region

lowed by medical manifestations in the form of chronic poisoning of the population (Fig. 37.8–37.10).

Along with industrial wastes, which pollute not only the air but also the soil, household wastes also accumulate in places of improper disposal.

For example, the Panamanian government wants to stimulate economic development along the Panama Canal banks, but due to the lack of waste disposal opportunities, this hinders significant investment. Squatters and garbage collectors now live on the largest landfill in the



Fig. 37.8. Illustration of air pollution from emissions of fuel combustion products in vehicles. Source: *medicaldaily.com*



Fig. 37.9. Illustration of soil and air pollution. Source: *politeka.net*



Fig. 37.10. Illustration of transport problems of tropical countries. Source: *previews.123rf.com*

area, and their living conditions pose serious health risks to the entire region.

The frequency of infectious diseases in large cities is twice as high as in rural areas (especially in the group of vector diseases), and there is a whole group of neglected diseases (helminthiasis: schistosomiasis, cysticercosis, filariasis; viral diseases: dengue fever, rabies, protozoan infections: leishmaniasis, trypanosomiasis, etc.).

Vector diseases include human diseases caused by parasites, viruses, and bacteria transmitted by vectors.

1. Mosquitoes:
   - Aedes (Chikungunya, dengue fever, lymphatic filariasis, Rift Valley fever, yellow fever, Zika fever);
   - Anopheles (malaria, lymphatic filariasis);
   - Culex (Japanese encephalitis, lymphatic filariasis, West Nile fever).
2. Sandflies (leishmaniasis, sandfly fever, phlebotomus fever).
3. Ticks (Crimean-Congo haemorrhagic fever, Lyme disease, relapsing fever (borreliosis), Rickettsial diseases (spotted fever and Q fever), tick-borne encephalitis, tularaemia).
4. Triatomine bugs (Chagas disease (American trypanosomiasis)).
5. Tsetse flies (sleeping sickness (African trypanosomiasis)).
6. Fleas (plague (transmitted by fleas from rats to humans), rickettsiosis).
7. Black flies (onchocerciasis (river blindness)).
8. Aquatic snails (schistosomiasis (bilharziasis)).
9. Lice (typhus and louse-borne relapsing fever).

Major vector diseases together account for 17% of all infectious diseases. The contribution of these diseases to the overall morbidity structure is the highest in the tropics and subtropics, and they disproportionately affect the poorest sections of the population. Since 2014, significant outbreaks of dengue, malaria, yellow fever, and Zika fever have threatened the population, claimed lives, and overloaded health systems in many countries (Fig. 37.11).

Changes in agricultural practice due to changes in temperature and rainfall may affect the transmission of vector-borne diseases (VBD). The growth of urban slums, which do not have a reliable water supply network for drinking water and in conditions of inadequate solid waste management, can expose large groups of people in cities to the spread of viral diseases caused by mosquitoes. Together, such factors affect the vector populations' proximity and patterns of transmission of pathogens.

Many of these diseases can be prevented through informed preventive measures of sanitary and hygienic direction.

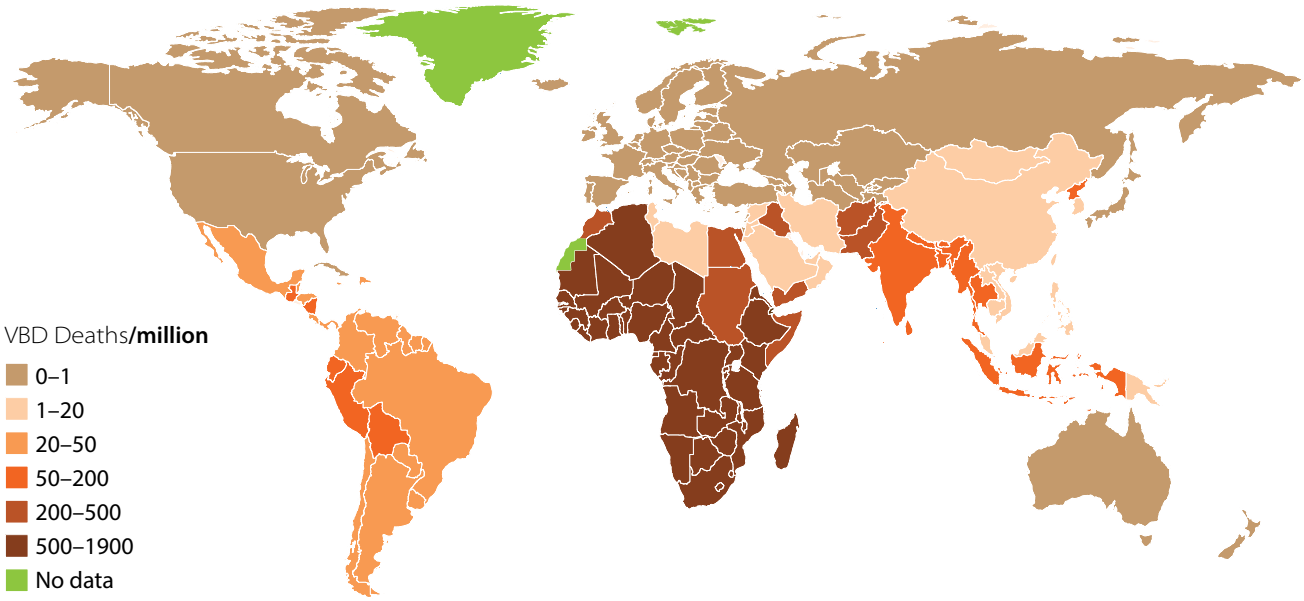


Fig. 37.11. Mortality from vector-borne diseases in the world as of 2002 *(WHO data)*

37.1.2. Hygienic peculiarities of urban development in tropical regions

Favorable measures of urban planning in tropical regions include the correct functional zoning of areas of the city with the following zones:

- residential area;
- industrial zone;
- utility depot area;
- transport communications;
- recreation area;
- waste collection and disposal areas, taking into account:
  - wind roses;
  - landscape peculiarities;
  - groundwater level.

In order to improve the sanitary and hygienic living conditions of the population in megalopolises and big cities, it is necessary to use forest areas, landscaping on the streets, flood prevention measures (even in arid climates, as an example, floods on the Sinai Peninsula (Egypt) in 2011, 2014).

At the same time, the creation of open reservoirs with running water and fountains in recreation areas has a positive effect on the microclimate of the surrounding areas, serves as water reservoirs, etc. (like in Masdar city, the United Arab Emirates).

Housing construction in Africa's tropical countries (for example, Nigeria) still does not have its own scientific and regulatory framework, which does not allow in the design process taking into consideration specific aspects of climatic conditions and national characteristics. In recent decades, mass construction of buildings and structures has become one of the main sectors of the economy in many countries. The introduction of effective climatology in housing construction methods has created a basis for the successful solutions of tasks for improving the efficiency and quality of construction, making the most favorable conditions for the most efficient use of material and energy resources.

The urgency of this problem is exacerbated by the significant increase in housing construction associated with the prospects for the development of the industrial sector. At the same time, the lack of free territories suitable for the construction of new settlements determines the need to use desert and steppe areas.

An important factor in the construction of housing and communal services, which must be taken into account in a humid tropical climate, is the location (the place should be protected from cyclones and tropical hurricanes and be out of reach of tsunami; be not in the ravines, in which mudflows and volcanic ash flows can pass; on ridges or plateaus, away from areas where downpours and earthquakes may cause rockslides or landslides, away from coastal sands that are subject to severe erosion.

In places with hot and humid climates, the main task is to avoid direct sunlight on the building and dissipate

the hot air generated in the building (the result of human life, cooking, household appliances). Thus, first of all it is necessary to provide shading and such orientation of buildings to have access to a cooling wind. It is required to determine the place where, preferably, a cooling wind has the opportunity to blow; also, the forest or a deep ravine helps to shade the house and give it coolness. In a region with high winds, it is necessary to find a place where the structures will be protected by forests, earth mounds, or surrounded by appropriate areas inaccessible to the wind.

In order to create comfortable microclimatic conditions in residential and industrial premises in tropical regions, the following factors must be taken into account:

- location of windows:
  - in the equatorial zone — to the north and south
  - (long rooms — parallel to the equator to reduce direct insolation);
  - in the subtropical zones of the northern hemisphere — southeast-southwest;
  - (the length of the premises should be oriented along the heliothermal axis);
  - it is necessary to install canopies over windows, screens (louvres), blinds, to arrange through ventilation by double-sided windows, natural and artificial ventilation, air conditioning (but it is necessary to anticipate the possibility of power outages due to overload on city grid and not to take electric air conditioning as the main factor in the microclimate regulation in the absence of backup power).

The walls' thickness should be increased to 0.5 m or more, using bricks, highly porous concrete, clay; it is also advisable to equip galleries and balconies.

Rooftops should be made of heat-insulating materials and designed 2–3 m above the walls with the installation of heat-insulating "technical" floor, or be arranged with double or insulated ceilings, and the floor should be made of concrete or stone slabs.

37.1.3. The mechanism of heat exchange and heat balance in tropical conditions

Air temperature and solar radiation temperature, heated soil surface and other hard surfaces' (walls, metal cars, etc.) temperature can often be higher than the human body temperature in tropical climate, so the human body cannot lose heat by radiation, convection or conduction, and vice versa due to these mechanisms, a person can get extra heat.

The only mechanism of heat exchange and heat balance is heat dissipation through evaporation. In tropical regions with an arid climate (relative humidity ≤ 40 % and the presence of wind), this mechanism works quite effectively. Under high humidity and lack of wind in a humid climate, this mechanism does not work correctly: sweat is released and drains without evaporation. This can cause overheating, heat- or sunstroke, and dehydration. A significant amount of salts, microelements, and vitamins are excreted in sweat. And the body requires extra water (5–12 liters or more per day).

Water loss can lead to the following changes in the state of the body:



Fig. 37.12. Venetian blinds. Source: *fg.wfcdn.com*



Fig. 37.13. Wind catchers in Iran. Source: *previews.123rf.com*

- Thirst, malaise, decreased mobility, loss of appetite, skin redness, irritability, and drowsiness if water loss is 1–5 % of body weight.
- Dizziness, shortness of breath, slurred speech, decreased salivation, fever, decreased blood volume, numbness of the extremities, difficulty in movement coordination are noted if the water loss is 6–10 % of body weight.
- Loss of water by 11–20 % of body weight causes difficulty in swallowing, delirium, deafness, blurred vision, painful urination, anuria, swelling of the tongue, numbness of the skin.
- Further dehydration causes DEATH.

Preventive measures to avert the development of the above conditions, in addition to a proper drinking regimen and the creation of comfortable microclimatic conditions, should include the correct selection of clothing and footwear.

37.2. Hygienic requirements for clothing, fabrics, and footwear in tropical regions

Textiles have the primary purpose of protecting the human body, and in the tropics, especially from harmful ultraviolet rays, creating a shield around human skin. Clothing makes a microclimate between the textile inner surface and human skin. These microclimatic conditions are a decisive factor that controls the feeling of comfort of the human body. Hot and humid microclimatic conditions are not desirable in the summer. Therefore, it is necessary to maintain the microclimate at the desired level. In summer, heat and moisture in the microclimatic space under the textile must be dissipated through the fabric's structure. Therefore, the textile characteristics determine comfort by controlling the heat and moisture transfer rate through it. Knitted fabrics are very popular as summer and active clothing due to their high stretch, permeability, and comfort.

Hygienic requirements for fabrics and clothing in tropical conditions should include indicators such as:

- high (for summer clothes) thermal conductivity;
- porosity;
- lightness;
- low hygroscopic property, water retention property, water permeability, high vapor conductivity, and evaporation;
- durability, wear resistance;
- low absorption properties in relation to chemical compounds;
- anti-electrostatic properties;
- color spectrum.

These qualities depend on the origin of the fiber (cotton, flax, hemp, wool, silk, synthetic fabrics), the thickness of the materials, their shrinkage and compression during soaking, washing, impregnation when worn with dust, sebum, technical oils, calcium, and magnesium salts if washed with detergents (including the soap) in hard water.

Linen and cotton knitted fabrics are popular for summer clothes and outerwear due to their comfort.

The typical porous structure of knitted fabrics, however, increases the risk of exposure to UV rays on human skin, which can lead to skin cancer. However, for cotton, in the tropical climate, it is necessary to find a balance between comfort when wearing clothes made of cotton and the resistance of the fabric to UV rays.

Thus, it is recommended to add other materials that have protective properties against UV to the structure of cotton fabrics.

The best choice in tropical climates is fabrics made of flax (linen) and silk with the right type of microfiber twist in the whole fiber structure.

Concerning footwear used in the tropics, it should be borne in mind that it should protect the feet from mechanical injury, dirt; by design to meet all physiological and anatomical features and sizes of the foot, to maintain depreciation, the functions of spring feet; be comfortable, light, with good vapor permeability, waterproof; must meet working conditions, lifestyle.

Wearing shoes with synthetic polymeric materials, which are widely used today, can lead to increased hyperhidrosis of the feet and the development of fungal infections (epidermophytosis), to the accumulation of significant levels of static electricity (up to 500–2000 V/cm), and chemicals derived from polymeric materials, can affect the skin with the appearance of dermatitis, allergic reactions.

Hygienic parameters to be considered when evaluating shoes include the type of waterproof leather, thickness (mm), tensile strength (N/mm^2); tensile load — bilateral cut (N); chromium (VI) content (mg/kg) should not be detected (< 10); water permeability (g) after 60 minutes; water absorption rate (%) after 60 minutes, vapor permeability ($mg/(cm^2 \cdot h)$), water vapor ratio.

CHAPTER 38

HYGIENIC REQUIREMENTS FOR WATER AND WATER SUPPLY AND NUTRITION RELATED TO THE PECULIARITIES OF TROPICAL REGIONS

A. V. Blagaia

38.1. Hygienic requirements for water and water supply in tropical conditions and its peculiarities in humid and arid tropical regions

Under conditions of water loss in the tropical climate, the following changes in the state of the organism can be observed:

- thirst, malaise, decreased mobility, loss of appetite, skin redness, irritability and drowsiness, if water loss is 1–5 % of body weight;
- dizziness, shortness of breath, slurred speech, decreased salivation, fever, decreased blood volume, numbness of the extremities, difficulty in movements coordination are noted if the water loss is 6–10 % of body weight;
- loss of water by 11–20 % of body weight causes difficulty in swallowing, delirium, deafness, blurred vision, painful urination, anuria, swelling of the tongue, numbness of the skin, and subsequent dehydration causes DEATH.

The primary preventive measure to avert the development of the above conditions is the organization of a proper drinking regimen.

However, the quality and quantity of water in the tropics varies greatly, which in turn can lead to endemic and epidemic diseases among the population consuming such water. The above conditions also require an individual approach to the methods of water intake, water treatment, etc.

Table 38.1. Predominant soil types of humid tropics

Soil	Total area (10^6 ha)	Regional distribution		
		America	*Africa*	*Asia*
Oxisols	525 (35.3 %)	332	179	14
Ultisols	413 (27.7 %)	213	69	131
Inceptisols	226 (15.2 %)	61	75	90
Entisols	212 (14.2 %)	3 1	91	90
Alfisols	53 (3.6 %)	18	20	15
Histosols	27 (1.8 %)	—	4	23
Spodosols	19 (1.3 %)	10	3	6
Mollisols	7 (0.5 %)	—	—	7
Vertisols	5 (0.3 %)	1	2	2
Aridisols	2 (0.1 %)	—	1	1
Total:	1489	666 (44.7 %)	444 (29.8 %)	379 (25.5 %)

(Listed from NRC, 1993a)

38.1.1. Endemic diseases related to water consumption in humid and arid tropical regions

Water quality in tropical regions and other parts of our planet is also connected to and dependable on the composition of the soil. Like vegetation, the soils of the humid tropics are also diverse and highly variable (Sanchez and Buol, 1975; Van Vambeke, 1992). The preferred soil types are: oxizoles, ultizols, inseptisols and others.

Soil constraints associated with crop production for different soil types are presented in Table 38.2.

Oxisols and ultisols together cover about 63 % of the total land area of the humid tropics. These soils have high

Table 38.2. Soil peculiarities in the humid tropics

Soil	Nutrient deficiency	Toxic substances	Erosion / landslides
Oxisols & Ultisols	N, P, Ca, Zn	Al, Mn	Site/arable land erosion
Inceptisols	P	—	Ravine erosion
Entisols	P	—	Ravine erosion
Alfisols	P	—	Accelerated erosion
Histosols	—	—	—
Spodosols	N, P	Al	Erosion of the site
Mollisols	—	—	—
Vertisols	P	—	Strong erosion of the site

acidity (pH 4 to 5), often contain toxic concentrations of Al and Mn, and are usually deficient in plant nutrients (e.g., N, P, Ca). Liming and frequent addition of phosphorus are essential to improve agronomic productivity. Once nutrition restrictions are reduced, soil degradation can also be a problem in intensive mechanized agriculture.

Although these soils are less prone to physical and nutritional soil problems, poor management and inadequate land-use systems can lead to compaction, erosion, and nutrient depletion.

At the same time, the soils of tropical xerophytic forests, dry savannas, semi-deserts and deserts have another properties.

Brown-red soils are formed in tropical xerophytic-forest areas under dry tropical sparse forests and shrubs with 1000–1300 mm of precipitation per year and dry season lasting 4–5 months at constantly high temperatures. Large tracts of brownish-red soils are common in southern Africa and eastern Brazil (Brazilian Plateau). Small arrays of these soils are in the Paraguay River's middle reaches and the Ethiopian Highlands (Kenya, Somalia, Ethiopia).

The soil mass is dominated by minerals of the kaolinite group, so the grain composition of the soil is clayey.

Red-brown soils of dry savannas are formed in the tropics with an annual precipitation of 800–1000 mm with a dry season of 6 months or more, in the rainy season 0.6–0.9 in the dry — 0.3–0.4. Vegetation is represented by a kind of formation, called the dry savannah. Areas of reddish-brown soils are clearly defined in Africa between 15° and 30° N. and in the south on the foothill plains of the Dragon Mountains. Small arrays of these soils are in Mexico, Brazil, India, Southeast Asia, Australia. Red-brown soils have a ferritic (kaolinite-illite-montmorillonite) composition.

The above peculiarities of soils have a significant impact on the composition of groundwater and surface water sources, causing the possible emergence of endemic diseases.

Due to heavy rainfalls, water resources are poorly mineralized in the humid tropics, which causes tooth decay (fluoride content is often less than 0.5 mg/l), endemic goiter (goiter endemy due to lowered content of iodine), etc. Soft water causes cardiovascular diseases, sudden death due to myocardial infarction: a significant lack of Ca, Mg, K adversely affects the heart's proper function.

Characteristics of water resources of arid tropical regions: high mineralization — 3000–5000 mg/l of salts. Due to the intensive evaporation of water, the concentrations of Ca, Mg, Na, K, Fe, HCO, Cl, SO, NO ions are much higher, and the water has a mountain-salt taste, dyspepsia is possible, children suffer from water-nitrate methemoglobinemia (blue baby syndrome).

High water hardness — more than 7, and sometimes even 14 mg-eq/l can cause diarrhea (laxative effect of Mg), provoke the appearance of kidney stones and gallstones (Ca). There are many disadvantages to using hard water for domestic purposes. Meat and beans are poorly boiled, insoluble Ca and Mg soaps, which permeate the fabric's pores during washing, reduce their ventilation and evaporation capacity, contribute to limescale on kitchen utensils, spoil the technical characteristics of steam boilers, washing machines, and more.

High content of microelements characterizes this water: fluoride (more than 1.5 mg/l), which promotes the development of fluorosis, molybdenum (causes sheep molybdenosis or molybdenum gout), arsenic, cadmium, chromium.

Saturation of surface waters with nitrates and other agrochemicals, including fertilizers (widely used in tropical areas), contributes to water mineralization (increased salinity of water), which has a negative impact on public health: pesticides accumulate in the aquatic fauna of fish, mollusks, and other organisms used in the nutrition of the population.

38.1.2. Epidemic diseases related to water consumption in humid and arid tropical regions

From the epidemiological standpoints, water resources of tropical regions are characterized by the following facts:

Nearly 1 billion people do not have safe drinking water without access to water; Diarrheal diseases — 2 million annual deaths due to dangerous water consumption, lack of proper sanitation and hygiene (contaminated water can transmit diseases such as diarrhea of different microbial origin, cholera, dysentery, typhoid fever and polio. It is estimated that contaminated drinking water causes 502 000 deaths from diarrhea); cholera — more than 50 countries still report cases of the disease to WHO; schistosomiasis — there are data on approximately 260 million infected people.

And one of the new challenges is that increasing the use of wastewater in agriculture is important for maintaining livelihoods and poses serious risks to public health.

844 million people lack even essential drinking water, including 159 million people who depend on surface water.

Worldwide, at least 2 billion people use drinking water sources contaminated with feces (and most of them live in the tropics).

By 2025, half of the world's population will live in areas affected by water shortages.

In low- and middle-income countries, 38 % of health facilities do not have improved water supply, 19 % do not have improved sanitation, and 35 % do not have water and soap for handwashing. Among these countries, the vast majority are located in tropical regions.



Fig. 38.1. Illustration of the lack of proper sanitary and hygienic conditions of water supply. Source: *i.pinimg.com*

Leading infectious diseases in tropical countries are typhoid fever, A and B, paratyphoid fever, cholera, bacterial and amoebic dysentery. Among children, there are 14–30 % of carriers of amoebic dysentery.

Salmonella, Shigella, rotaviruses, pathogenic strains of bacilli, campylobacter, enterocolitis-causing pathogens, neonatal diarrhea viruses, polio, epidemic conjunctivitis, and trachoma are also common. In general, there are 100+ types of viruses in the tropics that retain their virulence for up to 200 days in warm water and can multiply there.

There is a widespread prevalence of zoonotic infections, such as leptospirosis, brucellosis, tularemia, Q-fever, which result from drinking water, washing and bathing in water contaminated with the products of animals, rodents' vital activity (feces, urine, and so on). There are common fungal skin diseases such as epidermophytosis, scabies, and the like.

Helminth infestations are also common among the population: giardiasis, ascariasis, trichocephaly, hookworm, fasciolosis, drancunculosis, diphyllobothriasis, opisthorchiasis, angiostrongylosis, clonorchiasis. Helminthiasis is more common among the rural population, and especially among children.

Moreover, some of the pathogens transmitted through water have the ability from moderate to high resistance to chlorine (Table 38.3).

At the same time, there are opportunities to improve this situation: implementation of good water management practices.

4 % of diseases from the global contribution to the structure of morbidity can be prevented by improving water supply and introducing good sanitary and hygienic practices; better tools and procedures to improve and protect drinking water quality at the community and city levels, for example, through water security plans; availability of inexpensive and straightforward approaches to water treatment and safe water storage at the household level.

38.1.3. Characteristics of water supply sources and peculiarities of hygienic requirements for water quality in tropical conditions

There is no water problem in the humid tropics: the area is covered with forests, jungles, frequent rains, tropical storms constantly replenish surface and groundwater.

There is a significant shortage of water in arid areas, especially in deserts; seasonal precipitation changes to

Table 38.3. Pathogens transmitted through drinking water

Pathogen	Type of species / genus / group	Health significance	Persistence in water supply networks	Resistance to chlorine	Relative infectivity	Important animal source
Bacteria						
Burkholderia	*B. pseudomallei*	High	May multiply	Low	Low	No
Campylobacter	*C coli C. jejuni*	High	Moderate	Low	Moderate	Yes
Escherichia coli — Diarrhoeagenic	*E. coli O157*	High	Moderate	Low	Low	Yes
E. coli — entero-hemorrhagic		High	Moderate	Low	High	Yes
Francisella	*F. tularensis*	High	Long	Moderate	High	Yes
Legionella	*L. pneumophila*	High	May multiply	Low	Moderate	No
Mycobacteria (non-tuberculous)	*Mycobacterium avium* complex	Low	May multiply	High	Low	No
Salmonella	*S. typhi*	High	Moderate	Low	Low	No
Other salmonella	*S. enterica, S. bongori*	High	May multiply	Low	Low	Yes
Shigella	*S. dysenteriae*	High	Short	Low	High	No
Vibrio	*V. cholerae* O1 and O139	High	Short to long[h]	Low	Low	No
Viruses						
Adenoviridae	Adenoviruses	Moderate	Long	Moderate	High	No
Astroviridae	Astroviruses	Moderate	Long	Moderate	High	No
Caliciviridae	Noroviruses, sapoviruses	High	Long	Moderate	High	Potentially
Hepaviridae	Hepatitis E virus	High	Long	Moderate	High	Potentially
Picornaviridae	Enteroviruses, parechoviruses, hepatitis A virus	High	Long	Moderate	High	No
Reoviridae	Rotaviruses	High	Long	Moderate	High	No
Protozoa						
Acanthamoeba	*A. culbertsoni*	High	May multiply	High	High	No
Cryptosporidium	*C. hominis / parvum*	High	Long	High	High	Yes
Cyclospores	*C. cayetanensis*	High	Long	High	High	No
Entamoeba	*E. histolytica*	High	Moderate	High	High	No
Giardia	*G. intestinalis*	High	Moderate	High	High	Yes
Naegleria	*N. fowleri*	High	May multiply	Low	Moderate	No
Helminths						
Dracunculus	D. medinensis	High	Moderate	Moderate	High	No

drought or lack of rain and creates harsh living conditions for living organisms or makes life impossible.

There is a tradition of collecting rainwater during rainy periods and preserving it during the dry season. Rainwater is traditionally collected from the roofs of buildings. Such water is weakly mineralized (up to 30–50 mg/l) and contains a dust component of pollution, leaves of trees, bird excrements. Water is stored in barrels or concrete or clay tanks dug into the ground, provided with ventilation ducts to prevent putrefaction/rotting. Water from such tanks is taken using pumps with a hose or tube with a tap installed 15–20 cm above the bottom. There is a tube for settling, which is located on the lower level and is aimed at releasing water. Millponds are also used, but water can be stored there only for a short time because the water is filtered into the soil, evaporates, loses its quality, and therefore is not used for drinking, but only for domestic purposes.

Open reservoirs (rivers, streams, lakes) can be heavily polluted and become a source of infections, invasions, zoonotic diseases, fungal infections, and due to intense evaporation, the water in ponds and lakes may become highly mineralized.

In some cases, export waters, artificial wells, and reservoirs are used.

Groundwater, underground and artesian waters in arid areas are usually deep underground, highly mineralized, transparent, and non-epidemically hazardous. But such water is not enough in arid regions, i.e., quantitative needs for water supply are not met.

Seawater is a possible source of water supply in areas close to the water resources of the seas, bays, and oceans. Still, water treatment of such water for drinking requires significant investment in the sector.

Peculiarities of drinking water requirements in tropical regions are indicators of qualitative and quantitative compliance with the population's needs, taking into account the diversity of the composition and discharge (output) of water supply sources.

Quantitative requirements for drinking water supply should ideally meet 600–750 liters per day for one person. But in an arid climate, this amount of water of acceptable quality is often unattainable.

Regarding the hygienic requirements for water quality, the "classic" include: good organoleptic properties: to be transparent, colorless, without inclusions of suspended materials left on the surface, odorless and with no aftertaste, have a pleasant fresh taste (which also depends on water temperature, dissolved salts, and gases); optimal physiologically available composition; without toxic substances in toxic concentrations; without infectious agents and other organisms.

Regarding the peculiarities of hygienic requirements for water quality, it should be noted that in the Water Quality Guidelines (WHO, 2017), there are concentrations of harmful substances, expressed in mg/l, taking into account the average water consumption of 3 liters. Still, it is necessary to calculate values for different substances, both toxic and physiologically essential, taking into account the fact of increased water demand (sometimes up to 10–12 or more liters per day).

The above Guidelines, which contain sections on safe drinking water conditions, microbiological aspects, water disinfection, chemical, and radiological aspects, and acceptability aspects (taste, odor and appearance), pay considerable attention to water treatment.

In the case of centralized water supply, water from open reservoirs must be treated at water pumping stations: by precipitation and filtration through slow English filters (with biological film) and subsequent stabilization at small stations; at large water treatment plants, water must be purified by coagulation, desalination, and filtration through fast (American) filters. These methods do not differ significantly from those used at pumping stations in moderate climatic zones.

The water supply system in the UAE may serve as an example.

Drinking water in Dubai is provided by seawater desalination from the Arabian/Persian Gulf. Today, the most effective desalination tools use reverse osmosis in combination with preheating water with waste heat from a power plant. The old low-pressure distillation process is rapidly dying out because it is energy inefficient. The water is then filtered, disinfected to prevent bacteria's growth, and little minerals are added to make it fit for human consumption, washing, and industrial use. Today's cost of desalination is only 50 cents/m^3, which is cheaper than transporting/pumping water over long distances. The by-product is concentrated saltwater, which is then pumped back to the bay. Initially, seawater is used in the Dubai Aluminum Plant (Jebel Ali) to cool aluminum smelters until the final water treatment at the DEWA (Jebel Ali) plant. All wastewaters (bath, toilet, etc.) from buildings and industry are collected by the fleet of vehicles, as Dubai does not have a sewage system. It is sent to a processing plant in Al-Aweer (Al Aweer Sewage Treatment Plant (STP)), where solids are removed (and safely treated), the water component is then treated and used as gray/non-potable water — it is allocated to the municipality of Dubai and used for watering greenery in

municipal areas of Dubai, including roads and numerous parks etc.).

Methods of water disinfection in tropical regions are identical to traditional ones.

The most widely used method is chlorination according to chlorine consumption, superchlorination, double chlorination with preammonization, the use of chlorine gas, chlorinated lime, calcium hypochlorite; ozonation, and ultraviolet radiation are also possible.

In the case of a decentralized water supply, water purification from open sources is achieved almost only by settling/sedimentation.

As for disinfection, one of the simplest and most reliable methods is boiling, but it allows you to disinfect small amounts of water, and in deserts, due to lack of fuel may not be available.

Solar water disinfection: the ultraviolet part of sunlight can also kill pathogens in water (Fig. 38.2). The SODIS method uses a combination of ultraviolet light and elevated temperature (solar heat) to disinfect water using only sunlight and PET plastic bottles. SODIS is a free and effective water treatment method for decentralized water supply, which is commonly used at the household level and recommended by the World Health Organization as a viable way to purify water for home and safe storage.

The destruction of pathogenic microorganisms is significant and very often involves the use of reactive chemical agents such as chlorine.

Disinfection is an effective barrier to many pathogens (mainly bacteria) during drinking water treatment and should be used for surface water and groundwater which are the subject to faecal contamination. Residual disinfection is used to provide partial protection against low contamination levels and growth in the distribution system.

Chemical disinfection of drinking water that is faecally contaminated will reduce the overall risk of disease but does not necessarily make the water supply safe. For example, chlorine disinfection has restrictions against protozoa pathogens, i.e., Cryptosporidium, and some viruses. The effectiveness of disinfection may also be unsatisfactory against pathogens present in the composition of particles or inclusions that protect them from disinfectants' action. High levels of turbidity can protect microorganisms from the effects of disinfection, stimulate the growth of bacteria. It is important that an overall management strategy be implemented in which multiple barriers, including water source protection and appropriate treatment processes and protection during storage and distribution, are used in conjunction with disinfection to prevent or eliminate microbial contamination.



Fig. 38.2. SODIS project. Source: *sodis.ch, rainsaucers.com*

Tablets with chloramine, containing a higher concentration of chlorine (water is disinfected by chlorination) and sodium hyposulfite, which is released from the soluble plastic capsule after exposure to chlorination, are used of the chemical methods for disinfecting water for individual water supplies in the tropical climate; then the water is dechlorinated. If the water is of doubtful quality, 2–3 tablets are used.

In many countries of the tropical zone, portable bacterial filters are widely used, where water is filtered through replaceable ceramic fine-pore filters, so-called Berkefeld and Chamberland filters (candles)/Pasteur — Chamberland filters, which are mounted in a vessel. The water is filtered under pressure from a hand pump or connected to a water tap.

Deodorization (elimination of tastes and odors of water/odor and taste removal) is achieved by ozonation or filtration through activated carbon or other specific actions. Deferrization is carried out by aeration, spraying water in cooling towers. Ferrous iron is oxidized to insoluble oxidative, which is then retained on the filters.

Desalination and decontamination of water is carried out by distillation or filtration through ion exchange filters — cation exchange resins, which retain cations, and hydrogen ion is released into the water, and anion exchangers, which retain anions, and OH-ion is released into the water.

Sanitary supervision of centralized and local water supply is carried out by sanitary inspection of water supply sources and distribution network with sampling, laboratory analysis of water, and evaluation of its results and differs almost little from the classical ones.

38.2. Hygienic requirements for food in tropical conditions, peculiarities in humid and arid tropical regions

38.2.1. Rational nutrition and its hygienic provision in tropical regions

The conditions of a balanced diet are:

- energy value of the diet, i.e., its compliance with the energy expenditure of the body, taking into account the indigestible part of the food (in moderate climate this part is about 10%, in tropical — significantly more);
- qualitative completeness of the food ration — the presence of all nutrients in sufficient quantities and ratio (balance);
- rational diet — compliance of meals with biological rhythms of the body, i.e., determined by the intake at certain hours of the day, the number of meals, the intervals between them, the percentage distribution of the diet for individual meals;
- enzymatic constellation — compliance of products and ready meals quality with enzymatic possibilities of the digestive system of an individual (quality of culinary processing, conditions of food intake, presence and quality of spices, etc. which provide easy digestibility and absorbency of food);
- food safety from epidemiological and toxicological standpoints, i.e., the absence of pathogens of infectious diseases, helminths, and toxic substances in toxic concentrations.

Concerning the first and second conditions, according to WHO, the energy and quality value of the diets of some developing countries does not meet physiological needs, partial, and in some cases, complete starvation is quite common (Table 38.4).

When energy and protein deficiency in the tropics develops, as a rule, an edematous form of starvation occurs — kwashiorkor, which primarily affects children. The muscles atrophy, but the body, especially the lower extremities, swell to such an extent that the toes are hidden under the feet' swelling. The person loses physical strength, ability to work, there is anemia.

With general starvation, the predominance of energy deficiency, insanity (cachexia) develops, which is characterized by growth retardation, severe atrophy of muscles and subcutaneous tissue. The contours of the skeleton emerge under the skin, the head looks disproportionately large.

The incidence of sprue, alimentary dwarfism, postpartum diarrhea, anemia, liver cirrhosis, and dementia is typical for developing tropical countries.

Among hypo-, avitaminoses, there are observed:

- scurvy;
- xerophthalmia;
- keratomalacia;
- beriberi;
- pellagra;
- ariboflavinosis;
- rickets;
- malignant anemia and others .

In some areas, a specific soil and water composition leads to endemic diseases of mineral deficiency or excess of micronutrients due to consumption of mainly local products: endemic goiter, caries, dental fluorosis, rickets, iron deficiency, microcytic hypochromic anemia, selenium-deficient myopathy, myocardial infarction, etc.

Another problem that can occur due to nutrition in the tropics is the lack of digestive function. This condition is often associated with appetite suppression and is one of the peculiarities of a hot climate that leads to

Table 38.4. World and regional data on food consumption (kcal per person per day)

Region	Years					
	1964–1966	*1974–1976*	*1984–1986*	*1997–1999*	*2015*	*2030*
Sub-Saharan Africa	2058	2079	2057	2195	2360	2540
South Asia	2017	1986	2205	2403	2700	2900
Developing countries	2054	2152	2450	2681	2850	2980
WORLD	2358	2435	2655	2803	2940	3050
Latin America and the Caribbean	2393	2546	2689	2824	2980	3140
Countries with economies in transition	3222	3385	3379	2906	3060	3180
East Asia	1957	2105	2559	2921	3060	3190
Middle East and North Africa	2290	2591	2953	3006	3090	3170
World's major economies	2947	3065	3206	3380	3440	3500

digestive disorders. Suppressed appetite and digestion are peculiar for a hot climate. Therefore, spicy dishes with pepper and other stimulants of the digestive system are used in the local diet.

People change their eating time by eating in the evening and in the morning instead of during the day when the heat leads to overheating of the body and reduced activity of the enzyme systems of the digestive system.

1. *Body temperature:*
   - For every 0.5 °C increase in the internal temperature of the human body, their basic metabolism increases by about 7 %. Chemical reactions in the human body occur faster at higher temperatures.
2. *Outdoor temperature:*
   - Temperature outside the human body can also affect the level of basal metabolism. Cold temperatures can cause an increase in human basal metabolism, although the short-term effects of elevated temperatures have little impact on the body's metabolism. Prolonged exposure to heat can increase a person's basal metabolism (if temperatures are significantly elevated, the body must work harder to maintain its normal temperature and thus increases the rate of metabolism).

Extreme heat can aggravate the manifestations of gastrointestinal disorders.

Outbreaks of inflammatory bowel disease and "gastric disorders" may be more common during and immediately after heat waves.

38.2.2. Hygienic characteristics of common food products of tropical regions

Among the plant products of arid and humid zones of the tropical zone, an important place is occupied by cereals — wheat containing from 10 to 20 % protein in the form of gluten, which causes the porosity of bread, rice — up to 12 % protein, but gluten less than 1 %, and therefore used for cooking cereals, not for baking bread, corn (maize) contains up to 7 % protein, millet, sorghum (up to 10–13 % protein), etc. Grain impurities, such as weed seeds, can be harmful to health. The development of fungi (ergot, smuts, aspergillus, etc.) on grains (especially with large precipitation), frequently leads to mycotoxicosis.

Cultivation of legumes rich in protein (15–17 %), fats (up to 6 %), rough fibers, and soy (18–20 % fat), peas, lentils, chickpeas, rank, mash, and others, is also widespread.

Cultivation of oilseeds — peanuts, coconut, rape/colza, canola, mustard, olives, sesame, safflower, cocoa, aleurites, cotton is common for tropical regions. These crops are characterized by a significant content of PUFA — linoleic (33–50 %), oleic (29–44 %). In Africa, ricin is also cultivated, the oil of which (50 %) is characterized by a laxative effect.

Among the vegetables grown in tropical countries, the leading place is occupied by cassava, especially in



Fig. 38.3. Clinical manifestations of different types of hypovitaminosis in tropical regions. Source: *larajuan775.wordpress.com, trove.nla.gov.au, thetrentonline.com, ars.els-cdn.com, res.cloudinary.com*

the humid tropics, savannas. The weight of cassava tubers is 0.8–2 kg. It contains up to 24% carbohydrates, 1% protein, 0.5% fat, 3% fiber. Some cassava varieties contain up to 80 mg/kg of toxic cyanogenic glucoside so that they can be dangerous to health.

The second vegetable crop, widespread in the tropics and subtropics, is sweet potatoes or Ipomoea batatas. The weight of sweet potato tubers reaches 4–5 kg. It contains up to 24% carbohydrates, 2% protein, 1.5% fat, 3% fiber. In Southeast Asia and Oceania, yams are grown, which contain up to 29% carbohydrates, 2% protein, 0.03% fat, and 1% fiber. In Indonesia and Malaysia, a sago palm is cultivated from the core wood of which sago starch is made. Sago contains 80% starch, 3% protein, 0.25% fat. In areas with hot climates, melons and gourds are widely cultivated — pumpkins, watermelons.

Citruses, such as oranges, tangerines, grapefruits, lemons, limes, kumquats, are widespread fruits in the tropics. Their fruits are rich in sugars, organic acids and have beneficial dietary properties.

An important place in the diet of the tropical population is occupied by bananas — fruits rich in sugar, vitamins. The carbohydrates' content in them is 22–27%, proteins 1.3–1.5%, fats 0.1–0.6%.

In the arid regions of Asia and Africa, date palms are cultivated. Dates are a highly nutritious product called desert bread. They contain up to 72% carbohydrates, 7% protein, 2.5% fat, 3–6% fiber, B vitamins.

Breadfruit, jackfruit, which are rich in starch (19%) and sugar (12%), contain 1.5% protein, 0.2–0.5% fat, grow in Indonesia, Polynesia. Mango, mangosteen, tamarind, durian, loquat are widely used in South Asia, as well as pineapples, guava, granadillo, sapodilla, sapota, avocado, tuna (Barbary fig or cactus pear) — in Central America. All these plants have a fairly high nutritional and taste qualities.

A significant disadvantage of all farming cultures is the lack of complete proteins. All of them, except for soybeans, partly legumes, contain insufficient amounts and an irrational ratio of essential aminoacids. Therefore, with a monotonous diet — when only plant products are consumed and without a sufficient foodstuffs assortment — this can lead to partial protein deficiency, anemia (lack of heme iron from animal products (i.e., meat).

38.2.3. Methods and measures for the prevention of foodborne illnesses of microbial and non-microbial origin, and food infections and invasions

Elements of sanitary culture, sanitary and educational activities among the population, and preventive vaccinations are among those measures that help reduce the incidence of diseases associated with poor nutrition/malnutrition.

Also, no less important factor of any country's strategy in measures to prevent such diseases is the observance of food security policy, which includes actions to ensure quantitative and qualitative compliance of nutrition with the population's needs. Control measures to ensure safety and quality in the food industry should include:

1. Hygienic production safety practices (GMP — good manufacture practice).

GMP covers the basic principles, procedures, and tools needed to develop an appropriate environment for the production of acceptable quality. GMP codes and the hygienic requirements they contain are appropriate conditions for the hygienic production of food.

GMP is an essential requirement for obtaining an operating license (LTO — a License to Operate) by food-producing establishments. Manufacturers in the food industry are obliged to comply with hygienic standards, also known as current good manufacturing practices (cGMP), and the company's established standard operating procedures.

The above applies to the compliance of the following elements with sanitary and hygienic requirements:

- Building and playgrounds.
- Equipment and other facilities.
- Sanitary facilities and control.
- Sanitary operations.
- Processes and management.
- Personnel.

Currently (especially in tropical developing countries), some food producers have encountered difficulties in complying with GMP, especially small and medium-sized enterprises, since compliance with GMP requires capital to address structural deficiencies, technical assistance to support their own in-house knowledge, and commitment to change attitudes and values at the management and employee levels.

In addition, an essential element of food safety is introducing the HACCP system (Hazard Analysis and Critical Control Point) — a system of analysis of risks, hazards, and control of critical points. The HACCP system is scientifically proven and substantiated, thus guarantees the production of safe products by identifying and controlling hazards.

LIST OF REFERENCES

References to Chapter 1. Preventive medicine. Hygiene as a science. Sanitation

1. Бардов В. Г., Москаленко В. Ф., Омельчук С. Т. та інші. Гігієна та екологія. — Вінниця : Нова Книга, 2006. — С. 14–34.
2. Габович Р. Д., Познанський С. С., Шахбазян Г. Х. Гигиена. — Київ, 1983. — С. 3–25.
3. Гончарук Є. Г., Бардов В. Г., Рум'янцев Г. І. та інші. Общая гигиена. — Київ, 1991. — С. 3–25.
4. Гончарук Є. Г., Кундієв Ю. І., Бардов В. Г. та інші. Загальна гігієна. — Київ, 1995. С. 6–47.
5. Даценко І. І., Габович Р. Д. Основи загальної і тропічної гігієни. — Київ, 1995. — С. 3–11.
6. Закони України про охорону природи.
7. Закон України "Про забезпечення санітарного та епідемічного благополуччя населення" (1994 р.).
8. Конституція України (1996 р.).
9. Навчальні посібники з загальної гігієни.
10. Основи законодавства України про охорону здоров'я (1993).
11. Рум'янцев Г. І., Вишневська О. П., Козлова Т. А. та інші. Общая гигиена. — М., 1985. — С. 3–23.
12. Рум'янцев Г. І., Воронцов М. П., Гончарук Є. Г. та інші. Общая гигиена. — М., 1990. — С. 3–57.

References to Chapter 2. Ecology as a science. Biosphere

1. Гігієна та екологія. Підручник / За ред. В. Г. Бардова. — Вінниця : Нова Книга, 2006. — С. 178–209.
2. Загальна гігієна: пропедевтика гігієни: Підручник /Гончарук Є. Г., Кундієв Ю. І., Бардов В. Г. та ін.; За ред. Є. Г. Гончарука. — К. : Вища шк., 1995. — С.157–162; С.488–490.
3. Комунальна гігієна / Є. Г. Гончарук, В. Г. Бардов, С. І. Гаркавий, О. П. Яворовський та ін.; За ред. Є. Г. Гончарука. — К. : Здоров'я, 2003. — С. 36–326.
4. Общая гигиена. Пропедевтика гигиены. / Е. И. Гончарук, Ю. И. Кундиев, В. Г. Бардов и др. — К. : Вища школа, 2000. — С. 242–254.
5. Основи екології: підручник для студ. вищих навч. закладів / [В. Г. Бардов, В. І. Федоренко, Е. М. Білецька та ін.]; за ред. В. Г. Бардова, В. І. Федоренко. — Вінниця : Нова Книга, 2013. — 424 с.
6. Профілактична медицина / Даценко І. І., Габович Р. Д. — К. : Здоров'я, 2004. — 792 с.

References to Chapter 3. Advances in science and technology and their impact on the Earth's biosphere

1. Environments should improve not harm our health — 2016. Електронний ресурс — Режим доступу: http://www.who.int/mediacentre/commentaries/environments-should-improve-our-health/ru/
2. Geneva, WHO: 2014. Електронний ресурс — Режим доступу: http://www.who.int/mediacentre/news/releases/2014/air-pollution/ru/
3. http://www.who.int/mediacentre/news/releases/2015/reducing-climate-pollutants/ru/
4. New report identifies four ways to reduce health risks from climate pollutants — 2015. Електронний ресурс — Режим доступу:
5. WHO: Ambient (outdoor) air quality and health: Fact sheet / Updated September 2016 Електронний ресурс — Режим доступу: http://www.who.int/mediacentre/factsheets/fs313/ru/
6. Гігієна та екологія. Підручник / За ред. В. Г. Бардова. — Вінниця : Нова Книга, 2006. — С. 178–209.
7. Загальна гігієна: пропедевтика гігієни: Підручник / Гончарук Є. Г., Кундієв Ю. І., Бардов В. Г. та ін.; За ред. Є. Г. Гончарука. — К. : Вища шк., 1995. — С.157–162; С. 488–490.
8. Комунальна гігієна / Є. Г. Гончарук, В. Г. Бардов, С. І. Гаркавий, О. П. Яворовський та ін.; За ред. Є. Г. Гончарука. — К. : Здоров'я, 2003. — С. 36–326.
9. Общая гигиена. Пропедевтика гигиены. / Е. И. Гончарук, Ю. И. Кундиев, В. Г. Бардов и др. — К. : Вища школа, 2000. — С. 242–254.
10. Основи екології: підручник для студ. вищих навч. закладів / [В. Г. Бардов, В. І. Федоренко, Е. М. Білецька та ін.]; за ред. В. Г. Бардова, В. І. Федоренко. — Вінниця : Нова Книга, 2013. — 424 с.
11. Профілактична медицина / Даценко І. І., Габович Р. Д. — К. : Здоров'я, 2004. — 792 с.

References to Chapter 4. Air pollution and its health effect. Protection against pollution

1. Environments should improve not harm our health — 2016. Електронний ресурс — Режим доступу: http://www.who.int/mediacentre/commentaries/environments-should-improve-our-health/ru/
2. Geneva, WHO: 2014. Електронний ресурс — Режим доступу: http://www.who.int/mediacentre/news/releases/2014/air-pollution/ru/
3. http://www.who.int/mediacentre/news/releases/2015/reducing-climate-pollutants/ru/
4. New report identifies four ways to reduce health risks from climate pollutants — 2015. Електронний ресурс. — Режим доступу: http://www.who.int/news-room/detail/22–10–2015-new-report-identifies-four-ways-to-reduce-health-risks-from-climate-pollutants
5. WHO: Ambient (outdoor) air quality and health: Fact sheet / Updated September 2016. Електронний ресурс — Режим доступу: http://www.who.int/mediacentre/factsheets/fs313/ru/
6. Гігієна та екологія. Підручник / За ред. В. Г. Бардова. — Вінниця : Нова Книга, 2006. — С. 178–209.
7. Загальна гігієна: пропедевтика гігієни: Підручник / Гончарук Є.Г., Кундієв Ю.І., Бардов В.Г. та ін.; За ред. Є. Г. Гончарука. — К. : Вища шк., 1995. — С.157–162; С.488–490.
8. Комунальна гігієна / Є. Г. Гончарук, В. Г. Бардов, С. І. Гаркавий, О. П. Яворовський та ін.; За ред. Є. Г. Гончарука. — К. : Здоров'я, 2003. — С. 36–326.
9. Общая гигиена. Пропедевтика гигиены. / Е.И.Гончарук, Ю.И.Кундиев, В. Г. Бардов и др. — К. : Вища школа, 2000. — С. 242–254.
10. Основи екології: підручник для студ. вищих навч. закладів / [В. Г. Бардов, В. І. Федоренко, Е. М. Білецька та ін.]; за ред. В. Г. Бардова, В. І. Федоренко. — Вінниця : Нова Книга, 2013. — 424 с.
11. Профілактична медицина / Даценко І. І., Габович Р. Д. — К. : Здоров'я, 2004. — 792 с.

References to Chapter 5. Water pollution and its health effect. Protection against pollution

1. Водний кодекс України, затверджений Постановою Верховної Ради України від 06.06.1995 р.
2. Гігієна та екологія. Підручник. / За редакцією В. Г. Бардова. — Вінниця : Нова Книга, 2006. — с. 14–15.
3. ДСанПіН 2.2.4–400–10 "Гігієнічні вимоги до води питної, призначеної для споживання людиною". Затв. Наказом МОЗ України за № 400 від 12.05.2010. Зареєстровано в Міністерстві юстиції України за № 452/17747 від 1 липня 2010 р.
4. ДСТУ 3041–95 "Система стандартів у галузі охорони навколишнього середовища та раціонального використання ресурсів. Гідросфера. Використання й охорона води. Терміни та визначення".
5. Загальна гігієна. Пропедевтика гігієни. /Є. Г. Гончарук, Ю.І. Кундієв, В. Г. Бардов та ін./За ред. Є. Г. Гончарука. — К. : Вища школа, 1995. — с. 8–23, 48–87, 118–137.
6. Загальнодержавна програма "Питна вода України" на 2006–2020 роки Затв. Законом України за № 2455-IV від 3 березня 2005 р.
7. Закон України "Про забезпечення санітарного та епідемічного благополуччя населення", затверджений Постановою Верховної Ради України № 4004-XII від 24.02.1994 р.
8. Закон України "Про охорону навколишнього природного середовища", затверджений Постановою Верховної Ради України від 25.06.1991 р.
9. Закон України "Про питну воду та питне водопостачання", затверджений Постановою Верховної Ради України № 2918-III від 01.01.2002 р.
10. Комунальна гігієна /Є. Г. Гончарук, В. Г. Бардов, С. І. Гаркавий, О. П. Яворовський та ін./За ред. Є. Г. Гончарука. — К. : Здоров'я, 2003. — с. 5–15, 37–57, 327–378, 420–501.
11. Конституція України, прийнята на п'ятій сесії Верховної Ради України 28.06.1996 р.
12. Основи законодавства України про охорону здоров'я, затверджені Постановою Верховної Ради України № 2801-XII від 19.11.1992 р.
13. Питна вода України: медико-екологічні та санітарно-гігієнічні аспекти: монографія / В. О. Прокопов; за ред.. А. М. Сердюка. — К. : ВСВ "Медицина", 2016. — 400 с.
14. Правила охорони поверхневих вод від забруднення зворотними водами, затверджені Постановою Кабінету Міністрів України № 465 від 25.03.1999 р.
15. Профілактична медицина. Загальна гігієна з основами екології. /І. І. Даценко, Р. Д. Габович. — Київ, Здоров'я, 2004. — с. 11–43.
16. Основи екології: підручник для студ. вищих навч. закладів / [В. Г. Бардов, В. І. Федоренко, Е. М. Білецька та ін.]; за ред. В. Г. Бардова, В. І. Федоренко. — Вінниця : Нова Книга, 2013. — с.10–26, 39–44, 114–159.

References to Chapter 6. Soil pollution and its health effect. Protection against pollutioМенаєв

В. Переробка відходів в розвинених країнах світу. Електронний ресурс — Режим доступу: http://www.biowatt.com.ua/analitika/pererobka-vidhodiv-v-rozvinenih-krayinah-svitu/

1. Гігієна та екологія. Підручник / За редакцією В. Г. Бардова. — Вінниця : Нова Книга, 2006. — с. 14–15.
2. ДСТУ 3041–95 "Система стандартів у галузі охорони навколишнього середовища та раціонального використання ресурсів. Гідросфера. Використання й охорона води. Терміни та визначення".
3. Загальна гігієна. Пропедевтика гігієни /Є. Г. Гончарук, Ю.І. Кундієв, В. Г. Бардов та ін./За ред. Є. Г. Гончарука. — К. : Вища школа, 1995. — с. 8–23, 48–87, 118–137.
4. Закон України "Про забезпечення санітарного та епідемічного благополуччя населення", затверджений Постановою Верховної Ради України № 4004-XII від 24.02.1994 р.

5. Закон України "Про охорону навколишнього природного середовища", затверджений Постановою Верховної Ради України від 25.06.1991 р.
6. Комунальна гігієна. /Є. Г. Гончарук, В. Г. Бардов, С. І. Гаркавий, О. П. Яворовський та ін./За ред. Є. Г. Гончарука. — К. : Здоров'я, 2003. — с. 5–15, 37–57, 327–378, 420–501.
7. Конституція України, прийнята на п'ятій сесії Верховної Ради України 28.06.1996 р.
8. Основи екології: підручник для студ. вищих навч. закладів / [В. Г. Бардов, В. І. Федоренко, Е. М. Білецька та ін.]; за ред. В. Г. Бардова, В. І. Федоренко. — Вінниця : Нова Книга, 2013. — с.10–26, 39–44, 114–159.
9. Основи законодавства України про охорону здоров'я, затверджені Постановою Верховної Ради України № 2801-XII від 19.11.1992 р.
10. Питна вода України: медико-екологічні та санітарно-гігієнічні аспекти: монографія / В.О. Прокопов; за ред. А. М. Сердюка. — К. : ВСВ "Медицина", 2016. — 400 с.
11. Правила охорони поверхневих вод від забруднення зворотними водами, затверджені Постановою Кабінету Міністрів України № 465 від 25.03.1999 р.
12. Профілактична медицина. Загальна гігієна з основами екології. /І.І. Даценко, Р.Д. Габович. — Київ, Здоров'я, 2004. — с. 11–43.
13. Ходарев О.В. Переробка твердих побутових відходів як фактор економічного розвитку України // Електронне наукове фахове видання "Ефективна економіка". 2011. № 11. Електронний ресурс — Режим доступу: http://www.rn.nayka.com.ua/?op=1&j=efektyvna-ekonomika&s=ua&z=1353.

References to Chapter 7. Solar radiation. Interaction with the magnetosphere and atmosphere of the Earth

1. Основи екології: підручник для студ. вищих навч. закладів / [В. Г. Бардов, В. І. Федоренко, Е. М. Білецька та ін.]; за ред. В. Г. Бардова, В. І. Федоренко. — Вінниця : Нова Книга, 2013. — с. 88–94.
2. Гігієна та екологія. Підручник / За ред. В. Г. Бардова. — Вінниця : Нова Книга, 2006. — с. 34–59.
3. Профілактична медицина / Даценко І. І., Габович Р.Д. — К. : Здоров'я, 2004. — с. 445.
4. Загальна гігієна: пропедевтика гігієни: Підручник /Гончарук Є.Г., Кундієв Ю.І., Бардов В.Г. та ін.; За ред. Є. Г. Гончарука. — К. : Вища шк., 1995. — с.144–157; С.193–239.
5. Korobchanskiy V.A., Vorontsov M.P., Musulbas A.A. Hygiene and Ecology. — Kharkov, 2006. — p. 16–22.
6. Hygiene and Ecology: textbook for students of higher medical educational establishment / under the editorship of corresponding member of NAMS of Ukraine, prof. Bardov V.G. — Vinnytsia: Nova Knyha, 2009. — p. 32–46.
7. Hygiene and Ecology: textbook for students of higher medical educational establishment / under the editorship of corresponding member of NAMS of Ukraine, prof. Bardov V.G. — Vinnytsia: Nova Knyha, 2018. — p. 32–46.

References to Chapter 8. Solar radiation. Interaction with the Earth's biosphere. Use of sun rays for disease prevention and air, water and objects sanation

1. Основи екології: підручник для студ. вищих навч. закладів / [В. Г. Бардов, В. І. Федоренко, Е. М. Білецька та ін.]; за ред. В. Г. Бардова, В. І. Федоренко. — Вінниця : Нова Книга, 2013. — с. 88–94.
2. Гігієна та екологія. Підручник / За ред. В. Г. Бардова. — Вінниця : Нова Книга, 2006. — с. 34–59.
3. Профілактична медицина / Даценко І. І., Габович Р.Д. — К. : Здоров'я, 2004. — с. 445.
4. Загальна гігієна: пропедевтика гігієни: Підручник /Гончарук Є.Г., Кундієв Ю.І., Бардов В.Г. та ін.; За ред. Є. Г. Гончарука. — К. : Вища шк., 1995. — с.144–157; С.193–239.
5. Korobchanskiy V.A., Vorontsov M.P., Musulbas A.A. Hygiene and Ecology. — Kharkov, 2006. — p. 16–22.
6. Hygiene and Ecology: textbook for students of higher medical educational establishment / under the editorship of corresponding member of NAMS of Ukraine, prof. Bardov V.G. — Vinnytsia: Nova Knyha, 2009. — p. 32–46.
7. Hygiene and Ecology: textbook for students of higher medical educational establishment / under the editorship of corresponding member of NAMS of Ukraine, prof. Bardov V.G. — Vinnytsia: Nova Knyha, 2018. — p. 32–46.

References to Chapter 9. Hygienic importance of weather. Hygienic aspects of heliometeorotropic reactions prevention

1. Загальна гігієна: пропедевтика гігієни. Підручник / Є. Г. Гончарук, Ю. І. Кундієв, В. Г. Бардов та ін.; За ред. Є. Г. Гончарука. — К. : Вища школа, 1995. — С. 143–192.
2. Гелиометеотропные реакции человека / Никберг И. И., Ревуцкий Е. Л., Сакали Л. И. — К. : Здоров'я, 1986. — 144 с.
3. Бокша В. Г. Справочник по климатотерапии. — К. : Здоровье, 1989. — 208 с., ил.
4. Гігієна та екологія. Підручник. / За редакцією В. Г. Бардова. — Вінниця : Нова Книга, 2006. — С.106–121.
5. Основи екології: підручник для студ. вищих навч. закладів / [В. Г. Бардов, В. І. Федоренко, Е. М. Білецька та ін.]; за ред.. В. Г. Бардова, В. І. Федоренко. — Вінниця : Нова Книга, 2013. — С. 85–88.

6. Общая гигиена: пропедевтика гигиены/ Е.И.Гончарук, Ю.И.Кундиев, В.Г.Бардов и др.. — 2-е изд. Перераб и доп. — К. : Вища школа, 2000. — С. 177–217.
7. Даценко І. І., Габович Р. Д. Профілактична медицина. Загальна гігієна з основами екології. — 2-ге вид.: К. : Здоров'я, 2004. — С.124–140.

References to Chapter 10. Hygienic importance of climate. Acclimatization

1. Загальна гігієна: пропедевтика гігієни. Підручник / Є. Г. Гончарук, Ю. І. Кундієв, В. Г. Бардов та ін.; За ред. Є. Г. Гончарука. — К. : Вища школа, 1995. — С. 143–192.
2. Гелиометеотропные реакции человека / Никберг И.И., Ревуцкий Е.Л., Сакали Л.И. — К. : Здоров'я, 1986. — 144 с.
3. Бокша В.Г. Справочник по климатотерапии. — К. : Здоровье, 1989. — 208 с., ил.
4. Основи екології: підручник для студ. вищих навч. закладів / [В. Г. Бардов, В. І. Федоренко, Е. М. Білецька та ін.]; за ред.. В. Г. Бардова, В. І. Федоренко. — Вінниця : Нова Книга, 2013. — С. 85–88.
5. Общая гигиена: пропедевтика гигиены/ Е.И.Гончарук, Ю.И.Кундиев, В.Г.Бардов и др.. — 2-е изд. Перераб. и доп. — К. : Вища школа, 2000. — С. 177–217.
6. Даценко І. І., Габович Р.Д. Профілактична медицина. Загальна гігієна з основами екології. — 2-ге вид.: — К. : Здоров'я, 2004. — С.124–140.

References to Chapter 11. Hygienic significance of natural and artificial illumination, noise, electromagnetic radiation in the conditions of populated localities

1. Основи екології: підручник для студ. вищих навч. закладів / [В. Г. Бардов, В. І. Федоренко, Е. М. Білецька та ін..]; за ред. В. Г. Бардова, В. І. Федоренко. — Вінниця : Нова Книга, 2013. — 424 с.
2. Гігієна та екологія. Підручник / За ред. В. Г. Бардова. — Вінниця : Нова Книга, 2006. — С.178–209.
3. Профілактична медицина / Даценко І. І., Габович Р.Д. — К. : Здоров'я, 2004. — 792 с.
4. Комунальна гігієна / Є. Г. Гончарук, В. Г. Бардов, С. І. Гаркавий, О. П. Яворовський та ін.; За ред. Є. Г. Гончарука. — К. : Здоров'я, 2003. — С. 36–326.
5. Загальна гігієна: пропедевтика гігієни: Підручник /Гончарук Є.Г., Кундієв Ю.І., Бардов В.Г. та ін.; За ред. Є. Г. Гончарука. — К. : Вища шк., 1995. — С.157–162; С.488–490.
6. Общая гигиена. Пропедевтика гигиены. / Е.И.Гончарук, Ю.И.Кундиев, В.Г.Бардов и др. — К. : Вища школа, 2000. — С. 242–254.
7. Державні будівельні норми України "Природне і штучне освітлення" ДБН В.2.5–28–2006. Мінбуд України. — Київ, 2006. — с. 80.
8. Федотова Т.А., Масич Д.А., Шепель Т.О. Вплив освітлення на продуктивність праці // Вісник Черкаського університету. 2016. № 4. С. 13–22.
9. Вплив електромагнітних полів (мобільні телефони, Wi-Fi мережі) на здоров'я людини. — 2014. Електронний ресурс — Режим доступу: https://www.bsmu.edu.ua/uk/news/digest/1930-vplyv-electromagnitnyh-poliv
10. billion people at risk of hearing loss WHO highlights serious threat posed by exposure to recreational noise. — 2015. Електронний ресурс — Режим доступу: http://www.who.int/mediacentre/news/releases/2015/ear-care
11. Environmental Health. From global to local / Under Howard Frumkin edition. — Third edition. — San-Francisco, 2016. — P. 219–220, 608–609.
12. Korobchanskiy V.A., Vorontsov M.P., Musulbas A.A. Hygiene and Ecology. — Kharkov, 2006. — P. 16–21.

References to Chapter 12. Microclimate and its health effect. Indoor microclimate improvement ways and resources

1. Основи екології: підручник для студ. вищих навч. закладів / [В. Г. Бардов, В. І. Федоренко, Е. М. Білецька та ін..]; за ред. В. Г. Бардова, В. І. Федоренко. — Вінниця : Нова Книга, 2013. — 424 с.
2. Гігієна та екологія. Підручник / За ред. В. Г. Бардова. — Вінниця : Нова Книга, 2006. — С. 71–105.
3. Комунальна гігієна / Є. Г. Гончарук, В. Г. Бардов, С. І. Гаркавий, О. П. Яворовський та ін.; За ред. Є. Г. Гончарука. — К. : Здоров'я, 2003. — С. 578–583.
4. Общая гигиена: пропедевтика гигиены /Е.И.Гончарук, Ю.И.Кундиев, В.Г.Бардов и др. — 2-е изд. Перераб. и доп.– К. : Вища шк., 1999. — С. 217–236.
5. Профілактична медицина. Загальна гігієна з основами екології. / І.І. Даценко, Р.Д. Габович, 2-ге видання. — К., 2004. — С. 98–124.
6. Гигиена. Р.Д.Габович, С.С.Познанский, Г.Х.Шахбазян. — 3-е изд., перераб. и доп. — Киев: Вища школа, 1983. — С. 36–43.
7. Даценко І. І., Габович Р.Д. Основи загальної і тропічної гігієни. — К. : Здоров'я, 1995. — С. 22–36.
8. Санітарні норми мікроклімату виробничих приміщень. ДСН 3.3.6.042 — 99. Київ, 2000. — С.15.
9. Санітарні норми і правила СНиП 2.04.05–91 "Отопление, вентиляция и кондиционирование воздуха". — Киев — 1996. — 99 с.
10. Державні будівельні норми ДБН В.2.5–67:2013. Опалення, вентиляція та кондиціонування.
11. Візір В.А., Буряк В.В. Захворювання, викликані дією на організм термічних факторів (тепла та холоду) / Навчально-методичний посібник до практичних занять з внутріш-

ньої медицини (військова терапія) для студентів 5 курсу медичних факультетів Запоріжжя 2017. — 66 с.
12. Тимофеева Е.И., Федорович Г.В. Экологический мониторинг параметров микроклимата. 2005. — 68 с.
13. ГОСТ 30494–2011 Будівлі житлові і суспільні. Параметри мікроклімату в приміщеннях.
14. Environmental Health. From global to local / Under Howard Frumkin edition. — Third edition. — San-Francisco, 2016. — P. 550–562.
15. Korobchanskiy V.A., Vorontsov M.P., Musulbas A.A. Hygiene and Ecology. — Kharkov, 2006. — P. 26–29.

References to Chapter 13. Hygienic significance of atmospheric air, its denaturation, ways and means of preserving the natural composition

1. Основи екології: підручник для студ. вищих навч. закладів / [В.Г.Бардов, В.І.Федоренко, Е.М.Білецька та ін.]; за ред. В.Г.Бардова, В.І.Федоренко. — Вінниця: Нова Книга, 2013. — 424 с.
2. Гігієна та екологія. Підручник / За ред. В.Г.Бардова. — Вінниця : Нова Книга, 2006. — С.178–209.
3. Комунальна гігієна / Є.Г.Гончарук, В.Г.Бардов, С.І.Гаркавий, О.П.Яворовський та ін.; За ред. Є.Г.Гончарука. — К. : Здоров'я, 2003. — С. 36–326.
4. Профілактична медицина / Даценко І. І., Габович Р.Д. — К.: Здоров'я, 2004. — 792 с.
5. Загальна гігієна: пропедевтика гігієни: Підручник /Гончарук Є.Г., Кундієв Ю.І., Бардов В.Г. та ін.; За ред. Є.Г.Гончарука. — К. : Вища шк., 1995. — С.157–162; С. 488–490.
6. Общая гигиена. Пропедевтика гигиены. / Е.И.Гончарук, Ю.И.Кундиев, В.Г.Бардов и др. — К. : Вища школа, 2000. — С. 242–254.
7. New report identifies four ways to reduce health risks from climate pollutants — 2015. Електронний ресурс — Режим доступу: http://www.who.int/mediacentre/news/releases/2015/reducing-climate-pollutants/ru/
8. Environments should improve not harm our health — 2016. Електронний ресурс — Режим доступу: http://www.who.int/mediacentre/commentaries/ environments-should-improve-our-health/ru/
9. Geneva, WHO: 2014. Електронний ресурс — Режим доступу: http://www.who.int/mediacentre/news/releases/2014/air-pollution/ru/
10. WHO: Ambient (outdoor) air quality and health: Fact sheet / Updated September 2016 Електронний ресурс — Режим доступу: http://www.who.int/mediacentre/factsheets/fs313/ru/
11. Environmental Health. From global to local / Under Howard Frumkin edition. — Third edition. — San-Francisco, 2016. — P. 552–557.
12. Korobchanskiy V.A., Vorontsov M.P., Musulbas A.A. Hygiene and Ecology. — Kharkov, 2006. — P. 36–40.

References to Chapter 14. Soil hygiene and purification of settlements. Problems of urbanization

1. Основи екології: підручник для студ. вищих навч. закладів / [В.Г.Бардов, В.І.Федоренко, Е.М.Білецька та ін..]; за ред. В.Г.Бардова, В.І.Федоренко. — Вінниця: Нова Книга, 2013. — 424 с.
2. Комунальна гігієна / Є.Г.Гончарук, В.Г.Бардов, С.І.Гаркавий, О.П.Яворовський та ін.; За ред. Є.Г.Гончарука. — К. : Здоров'я, 2003. — С. 36–326.
3. Гігієна та екологія. Підручник / За ред. В.Г.Бардова. — Вінниця : Нова Книга, 2006. — С.178–209.
4. Профілактична медицина / Даценко І. І., Габович Р.Д. — К.: Здоров'я, 2004. — 792 с.
5. Загальна гігієна: пропедевтика гігієни: Підручник /Гончарук Є.Г., Кундієв Ю.І., Бардов В.Г. та ін.; За ред. Є.Г.Гончарука. — К. : Вища шк., 1995. — С.157–162; С. 488–490.
6. Общая гигиена. Пропедевтика гигиены. / Е.И.Гончарук, Ю.И.Кундиев, В.Г.Бардов и др. — К. : Вища школа, 2000. — с. 242–254.
7. Ходарев О.В. Переробка твердих побутових відходів як фактор економічного розвитку України // Електронне наукове фахове видання "Ефективна економіка". 2011. № 11. Електронний ресурс — Режим доступу: http://www.m.nayka.com.ua/?op=1&j=efektyvna-ekonomika&s=ua&z=1353.
8. Менаєв В. Переробка відходів в розвинених країнах світу Електронний ресурс — Режим доступу: http://www.biowatt.com.ua/analitika/pererobka-vidhodiv-v-rozvinenih-krayinah-svitu/
9. Environmental Health. From global to local / Under Howard Frumkin edition. — Third edition. — San-Francisco, 2016. — P. 454–472.
10. Korobchanskiy V.A., Vorontsov M.P., Musulbas A.A. Hygiene and Ecology. — Kharkov, 2006. — P. 82–87.

References to Chapter 15. Water and health. Hygienic significance of drinking water

1. Питна вода України: медико-екологічні та санітарно-гігієнічні аспекти: монографія / В.О. Прокопов; за ред.. А.М.Сердюка. — К.: ВСВ "Медицина", 2016. — 400 с.
2. Основи екології: підручник для студ. вищих навч. закладів / [В.Г.Бардов, В.І.Федоренко, Е.М.Білецька та ін..]; за ред. В.Г.Бардова, В.І.Федоренко. — Вінниця: Нова Книга, 2013. — 424 с.
3. Гігієна та екологія. Підручник / За ред. В.Г.Бардова. — Вінниця : Нова Книга, 2006. — С.178–209.
4. Комунальна гігієна / Є.Г.Гончарук, В.Г.Бардов, С.І.Гаркавий, О.П.Яворовський та ін.; За ред. Є.Г.Гончарука. — К. : Здоров'я, 2003. — С. 36–326.
5. Профілактична медицина / Даценко І. І., Габович Р.Д. — К.: Здоров'я, 2004. — 792 с.

6. ДСанПіН 2.2.4–400–10 "Гігієнічні вимоги до води питної, призначеної для споживання людиною". Затв. Наказом МОЗ України за № 400 від 12.05.2010. Зареєстровано в Міністерстві юстиції України за № 452/17747 від 1 липня 2010 р.
7. Закон України "Про питну воду та питне водопостачання". Затв. за № 16 від 2002 р.
8. Загальнодержавна програма "Питна вода України" на 2006–2020 роки Затв. Законом України за № 2455-IV від 3 березня 2005 р.
9. Environmental Health. From global to local / Under Howard Frumkin edition. — Third edition. — San-Francisco, 2016. — P. 287–289, 413–442.
10. Korobchanskiy V.A., Vorontsov M.P., Musulbas A.A. Hygiene and Ecology. — Kharkov, 2006. — P. 67–82.

References to Chapter 16. Problems of water supply of settlements. Hygienic requirements and methods for improving the quality of drinking water

1. Питна вода України: медико-екологічні та санітарно-гігієнічні аспекти: монографія / В.О. Прокопов; за ред.. А. М. Сердюка. — К. : ВСВ "Медицина", 2016. — 400 с.
2. Основи екології : підручник для студ. вищих навч. закладів / [В. Г. Бардов, В. І. Федоренко, Е. М. Білецька та ін..]; за ред. В. Г. Бардова, В. І. Федоренко. — Вінниця : Нова Книга, 2013. — 424 с.
3. Гігієна та екологія. Підручник / За ред. В. Г. Бардова. — Вінниця : Нова Книга, 2006. — С.178–209.
4. Комунальна гігієна / Є. Г. Гончарук, В. Г. Бардов, С. І. Гаркавий, О. П. Яворовський та ін.; За ред. Є. Г. Гончарука. — К. : Здоров'я, 2003. — С. 36–326.
5. Профілактична медицина / Даценко І. І., Габович Р.Д. — К. : Здоров'я, 2004. — 792 с.
6. ДСанПіН 2.2.4–400–10 "Гігієнічні вимоги до води питної, призначеної для споживання людиною". Затв. Наказом МОЗ України за № 400 від 12.05.2010. Зареєстровано в Міністерстві юстиції України за № 452/17747 від 1 липня 2010 р.
7. Закон України "Про питну воду та питне водопостачання". Затв. за № 16 від 2002 р.
8. Загальнодержавна програма "Питна вода України" на 2006–2020 роки. Затв. Законом України за № 2455-IV від 3 березня 2005 р.
9. Environmental Health. From global to local / Under Howard Frumkin edition. — Third edition. — San-Francisco, 2016. — P. 454–472.
10. Korobchanskiy V.A., Vorontsov M.P., Musulbas A.A. Hygiene and Ecology. — Kharkov, 2006. — P. 82–87.

References to Chapter 17. Hygiene of patient care institutions. Features of planning, improvement and equipment of medical facilities

Basic:

1. Гігієна та екологія/ За ред. В. Г. Бардова.- Вінниця : Нова Книга, 2006. — С.474–493.
2. Environmental Health. From global to local / Under Howard Frumkin edition. — Third edition. — San-Francisco, 2016. — P. 539–568.
3. Korobchanskiy V. A., Vorontsov M. P., Musulbas A. A. Hygiene and Ecology. — Kharkov, 2006. — P. 175–185.
4. Гончарук Є. Г., Бардов В. Г., Гаркавий С. І., Яворовський О. П. та ін. Комунальна гігієна/За ред. Є. Г. Гончарука. — К. : Здоров'я, 2003. — С. 615–657.
5. Габович Р.Д., Познанский С.С., Шахбазян Г.Х. Гигиена.- Киев. 1983. — С. 277–308.
6. Даценко І. І., Габович р.Д. Профілактична медицина. Загальна гігієна з основами екології. Навчальний посібник. К. : Здоров'я, 1999. — С. 466–608.
7. Загальна гігієна. Посібник до практичних занять. / І. І.Даценко, О.Б.Денисюк, С.Л.Долошицький та ін. / За ред. І. І. Даценко.- Львів, 1992. — С. 223–247.

Additional:

1. Никберг И. И. Гигиена больниц. — К. : Здоров'я, 2000. — 261 с.
2. СанПиН 5179–9 санітарні правила улаштування, обладнання і експлуатації лікарень, пологових будинків і інших лікувальних стаціонарів. — М., 1990.
3. Державні будівельні норми України. Будинки і споруди. Заклади охорони здоров'я. ДБН В.2.2.-10–2001. — Київ: Держбуд України, 2001. — 164 с.

References to Chapter 18. Nosocomial infections, preventive measures. Occupational hygiene of medical personnel

Basic:

1. Гігієна та екологія/ За ред. В. Г. Бардова. — Вінниця : Нова Книга, 2006. — С.474–493.
2. Environmental Health. From global to local / Under Howard Frumkin edition. — Third edition. — San-Francisco, 2016. — P. 539–568.

3. Korobchanskiy V.A., Vorontsov M.P., Musulbas A.A. Hygiene and Ecology. — Kharkov, 2006. — P. 175–185.
4. Гончарук Є.Г., Бардов В.Г., Гаркавий С.І., Яворовський О.П. та ін. Комунальна гігієна/За ред. Є.Г.Гончарука. — К. : Здоров'я, 2003. — С. 615–657.
5. Профилактика внутрибольничних инфекций/ Под ред.. С.И.Гаркавого, А.А.Шевченко. — Одесса: Пресс-курьер, 2015. — 240 с.
6. Габович Р.Д., Познанский С.С., Шахбазян Г.Х. Гигиена. — Киев. 1983. — С. 277–308.
7. Даценко І. І., Габович р.Д. Профілактична медицина. Загальна гігієна з основами екології. Навчальний посібник. — К. : Здоров'я, 1999. — С. 466–608.
8. Загальна гігієна. Посібник до практичних занять. / І.І.Даценко, О.Б.Денисюк, С.Л.Долошицький та ін. / За ред. І.І.Даценко. — Львів, 1992. — С. 223–247.

Additional:

1. Никберг И. И. Гигиена больниц. — К. : Здоров'я, 2000. — 261с.
2. СанПиН 5179–9. Санітарні правила улаштування, обладнання і експлуатації лікарень, пологових будинків і інших лікувальних стаціонарів. — М., 1990.
3. Державні будівельні норми України. Будинки і споруди. Заклади охорони здоров'я. ДБН В.2.2.-10–2001. — Київ : Держбуд України, 2001. — 164 с.

References to Chapter 19. Current issues of occupational hygiene

1. Гігієна та екологія. Підручник / За редакцією В.Г.Бардова. — Вінниця : Нова Книга, 2006. — 720 с.
2. Гігієна праці: Підручник / Ю.І.Кундієв, О.П.Яворовський, А.М.Шевченко та ін.: за ред. акад. НАН України, НАМН України, проф.. Ю.І.Кундієва, чл.-кор.НАМН України, проф. О.П.Яворовського. — К. : ВСВ "Медицина", 2011. — 904 с.
3. Основи екології: підручник для студ. вищих навч. закладів / [В.Г.Бардов, В.І.Федоренко, Е.М.Білецька та ін.]; за ред. В.Г.Бардова, В.І.Федоренко. — Вінниця : Нова Книга, 2013. — 424 с.
4. Environmental Health. From global to local / Under Howard Frumkin edition. — Third edition. — San-Francisco, 2016. — P. 582–598.
5. Korobchanskiy V.A., Vorontsov M.P., Musulbas A.A. Hygiene and Ecology. — Kharkov, 2006. — P. 148–151, 162–165.

References to Chapter 20. Harmful and dangerous ocuupational factors, prevention of their influence

1. Гігієна та екологія. Підручник / За редакцією В.Г.Бардова. — Вінниця : Нова Книга, 2006. — 720 с.
2. Гігієна праці: Підручник / Ю.І.Кундієв, О.П.Яворовський, А.М.Шевченко та ін.: за ред. акад. НАН України, НАМН України, проф.. Ю.І.Кундієва, чл.-кор.НАМН України, проф. О.П.Яворовського. — К. : ВСВ "Медицина", 2011. — 904 с.
3. Основи екології: підручник для студ. вищих навч. закладів / [В.Г.Бардов, В.І.Федоренко, Е.М.Білецька та ін.]; за ред. В.Г.Бардова, В.І.Федоренко. — Вінниця : Нова Книга, 2013. — 424 с.
4. Environmental Health. From global to local / Under Howard Frumkin edition. — Third edition. — San-Francisco, 2016. — P. 182–196.
5. Environmental Health. From global to local / Under Howard Frumkin edition. — Third edition. — San-Francisco, 2016. — P. 123–146.
6. Environmental Health. From global to local / Under Howard Frumkin edition. — Third edition. — San-Francisco, 2016. — P. 582–598.

References to Chapter 21. The importance of hygiene in solving problems of protection and promotion of child and adolescent health

Basic:

1. Гігієна та екологія/ За ред. В.Г.Бардова. — Вінниця : Нова Книга, 2006. — С. 391–413.
2. Korobchanskiy V.A., Vorontsov M.P., Musulbas A.A. Hygiene and Ecology. — Kharkov, 2006. — P. 131–141.
3. Загальна гігієна. Пропедевтика гігієни / Є.Г.Гончарук, Ю.І.Кундієв, В.Г.Бардов та ін. / За ред. Є.Г.Гончарука. — К. : Вища шк., 1995. — С. 458–479.
4. Общая гигиена. Пропедевтика гигиены / Е.И.Гончарук, Ю.И.Кундиев, В.Г.Бардов и др. — К. : Вища шк., 2000. — С. 538–560.
5. Гігієна дітей та підлітків. Навчальний посібник/ За ред. М.М.Надворного. — Одеса: Прес-кур'єр, 2014. — 264 с.
6. Гігієна дітей та підлітків. / За ред. В.І.Берзіня. — К. : "Асканія", 2012. — 304 с.
7. Даценко І. І., Габович Р.Д. Профілактична медицина. Загальна гігієна з основами екології. — К. : Здоров'я, 1999. — С. 568–578, 605–607.
8. Даценко І. І., Габович Р.Д. Профілактична медицина. Загальна гігієна з основами екології. — К. : Здоров'я, 2004. — С. 524–534, 555–557.
9. Габович Р.Д., Познанский С.С., Шахбазян Г.Х. Гигиена. — К. : Вища школа. 1983. — С. 243–252, 275–276.
10. Загальна гігієна. Посібник до практичних занять / І.І.Даценко, О.Б.Денисюк, С.Л.Долошицький та ін. / За ред. І.І.Даценко. — Львів : Світ, 2001. — С. 221–236.

Additional:

1. Гигиена детей и подростков // Под ред. В.Н.Кардашенко. — М.: Медицина, 1988. — С. 41–114, 487–503.
2. Руководство к лабораторным занятиям по гигиене детей и подростков / В.И. Берзинь и др. — К. : Вища шк., 1989. — С. 20–69.
3. Сергета І.В, Бардов В.Г. Організація вільного часу та здоров'я школярів. — Вінниця : РВВ ВАТ "Віноблдрукарня", 1997. — 292 с.
4. Державні санітарні правила і норми по устаткуванню, утриманню загальноосвітніх навчальних закладів та організації навчально-виховного процесу. ДСанПіН 5.5.2.008–01. — К., 2001. — 54 с.
5. Гігієна та екологія людини: навчальний посібник до практичних занять. /За ред. В. Я. Уманського. — Донецьк: "НОРД Комп'ютер", 2004. — С. 143–173.

References to Chapter 22. Hygiene of children's institutions. Requirements for planning, improvement and equipment of children's institutions

Basic:

1. Гігієна та екологія/ За ред. В.Г.Бардова.- Вінниця : Нова Книга, 2006. — С.413–433.
2. Korobchanskiy V.A., Vorontsov M.P., Musulbas A.A. Hygiene and Ecology. — Kharkov, 2006. — P. 131–141.
3. Загальна гігієна. Пропедевтика гігієни / Є.Г.Гончарук, Ю.І.Кундієв, В.Г.Бардов та ін. / За ред. Є.Г.Гончарука. — К. : Вища шк., 1995. — С. 458–479.
4. Общая гигиена. Пропедевтика гигиены / Е.И.Гончарук, Ю.И.Кундиев, В.Г.Бардов и др. — К. : Вища шк., 2000. — С. 538–560.
5. Гігієна дітей та підлітків. Навчальний посібник/ За ред. М.М.Надворного. — Одеса: Прес-кур'єр, 2014. — 264 с.
6. Гігієна дітей та підлітків. / За ред. В.І. Берзіня. — К. : Асканія, 2012. — 304 с.
7. Даценко І. І., Габович Р.Д. Профілактична медицина. Загальна гігієна з основами екології. — К. : Здоров'я, 1999. — С. 568–578, 605–607.
8. Даценко І. І., Габович Р.Д. Профілактична медицина. Загальна гігієна з основами екології. — К. : Здоров'я, 2004. — С. 524–534, 555–557.
9. Габович Р.Д., Познанский С.С., Шахбазян Г.Х. Гигиена. — К. : Вища школа. 1983. — С. 243–252, 275–276.
10. Загальна гігієна. Посібник до практичних занять / І.І. Даценко, О.Б.Денисюк, С.Л.Долошицький та ін. / За ред. І.І.Даценко. — Львів : Світ, 2001. — С. 221–236.

Additional:

1. Гигиена детей и подростков // Под ред. В. Н. Кардашенко. — М. : Медицина, 1988. — С. 41–114, 487–503.
2. Руководство к лабораторным занятиям по гигиене детей и подростков / В.И.Берзинь и др. — К. : Вища шк., 1989. — С. 20–69.
3. Сергета І.В, Бардов В.Г. Організація вільного часу та здоров'я школярів. — Вінниця : РВВ ВАТ "Віноблдрукарня", 1997. — 292 с.
4. Державні санітарні правила і норми по устаткуванню, утриманню загальноосвітніх навчальних закладів та організації навчально-виховного процесу. ДСанПіН 5.5.2.008–01. — К., 2001. — 54 с.
5. Гігієна та екологія людини: навчальний посібник до практичних занять. /За ред. В.Я. Уманського. — Донецьк: "НОРД Комп'ютер", 2004. — С. 143–173.

References to Chapter 23. Nutrition as a factor of health, scientific fundamentals of rational nutrition

1. Гігієна та екологія: підручник для студентів вищих медичних навчальних закладів. — Вінниця : Нова Книга, 2008. — 720 с.
2. Hygiene and ecology: textbook for students of higher medical educational establishments / under the editorship of corresponding member of NAMS of Ukraine, prof. Bardov V.G. — Vinnytsia: Nova Knyha, 2009. — 688 p.
3. General nutrition: Study guide for the 4th accreditation level Medical School Students / edited by S.T. Omelchuk, O.V. Kuzminska. — Kyiv, 2016. — 146 p.
4. Гигиена и экология: учебник для студентов высших медицинских учебных заведений. — Винница : Нова Книга, 2008. — 720 с.
5. Гігієна харчування з основами нутриціології: підручник / Т.І. Аністратенко, Т.М. Білко, О.В. Благодарова, В.І. Ципріян. — Кн.1 — 528 с.
6. Гігієна харчування з основами нутриціології: підручник / Т.І. Аністратенко, Т.М. Білко, О.В. Благодарова, В. І. Ципріян. — Кн.2 — 544 с.
7. Зубар Н. М. Основи фізіології та гігієни харчування: Підручник. — К. : Центр учбової літератури, 2010. — 336 с.
8. Fundamentals of Human Nutrition: for Students and Practitioners in the Health Sciences, 12th Edition /Catherine Geissler, Hilary Powers, — 2011, p. 47–177.
9. Nutrition at a Glance 1st Edition / Mary Barasi — 2014, p. 18–22.
10. Nutrition Counseling and Education Skills: A Guide for Professionals 7th Edition /Judith Beto, Betsy Holli, –2018, p. 3–24.
11. Clinical Nutrition Basics for Medical Students Paperback / Amanda Velazquez — 2014, 304 p.
12. Textbook of Clinical Nutrition and Functional Medicine, Vol. 1: Essential Knowledge for Safe Action and Effective Treat-

ment (Inflammation Mastery & Functional Inflammology)/ Alex Vasqeuz — 2016, p. 50–64.
13. Nutrition in Public Health 4th Edition /Sari Edelstein, –2018.- p.183–225
14. Advanced Human Nutrition 3rd Edition / Denis M Medeiros, Robert E.C. Wildman, — 2010, 280 p.

References to Chapter 24. Functions of food substances. Hygienic problems of undernutrition and overnutrition

1. Гігієна та екологія: підручник для студентів вищих медичних навчальних закладів. — Вінниця : Нова Книга, 2008. — 720 с.
2. Hygiene and ecology: textbook for students of higher medical educational establishments / under the editorship of corresponding member of NAMS of Ukraine, prof. Bardov V.G. — Vinnytsia: Nova Knyha, 2009. — 688 p.
3. General nutrition: Study guide for the 4th accreditation level Medical School Students / edited by S.T. Omelchuk, O.V. Kuzminska. — Kyiv, 2016. — 146 p.
4. Гигиена и экология: учебник для студентов высших медицинских учебных заведений. — Винница : Нова Книга, 2008. — 720 с.
5. Гігієна харчування з основами нутриціології: підручник / Т.І. Аністратенко, Т.М. Білко, О.В. Благодарова, В.І. Ципріян. — Кн.1 — 528 с.
6. Гігієна харчування з основами нутриціології: підручник / Т.І. Аністратенко, Т.М. Білко, О.В. Благодарова, В.І. Ципріян. — Кн.2 — 544 с.
7. Зубар Н. М. Основи фізіології та гігієни харчування: Підручник. — К. : Центр учбової літератури, 2010. — 336 с.
8. Fundamentals of Human Nutrition: for Students and Practitioners in the Health Sciences, 12th Edition /Catherine Geissler, Hilary Powers, — 2011, p. 47–177.
9. Nutrition at a Glance 1st Edition / Mary Barasi — 2014, p. 18–22.
10. Nutrition Counseling and Education Skills: A Guide for Professionals 7th Edition /Judith Beto, Betsy Holli, — 2018, p. 3–24.
11. Clinical Nutrition Basics for Medical Students Paperback / Amanda Velazquez — 2014, 304 p.
12. Textbook of Clinical Nutrition and Functional Medicine, Vol. 1: Essential Knowledge for Safe Action and Effective Treatment (Inflammation Mastery & Functional Inflammology) / Alex Vasqeuz — 2016, p. 50–64.
13. Nutrition in Public Health 4th Edition /Sari Edelstein, –2018.- p.183–225
14. Advanced Human Nutrition 3rd Edition / Denis M Medeiros, Robert E.C. Wildman, –2010, 280 p.

References to Chapter 25. Diseases related to violation of the basics of rational nutrition and the consumption of substandard products

1. Гігієна та екологія: підручник для студентів вищих медичних навчальних закладів. — Вінниця : Нова Книга, 2008. — 720 с.
2. Hygiene and ecology: textbook for students of higher medical educational establishments / under the editorship of corresponding member of NAMS of Ukraine, prof. Bardov V.G. — Vinnytsia: Nova Knyha, 2009. — 688 p.
3. General nutrition: Study guide for the 4th accreditation level Medical School Students / edited by S.T. Omelchuk, O.V. Kuzminska. — Kyiv, 2016. — 146 p.
4. Гигиена и экология: учебник для студентов высших медицинских учебных заведений. — Винница : Нова Книга, 2008. — 720 с.
5. Гігієна харчування з основами нутриціології: підручник / Т.І. Аністратенко, Т.М. Білко, О.В. Благодарова, В.І. Ципріян. — Кн.1. — 528 с.
6. Гігієна харчування з основами нутриціології: підручник / Т.І. Аністратенко, Т.М. Білко, О.В. Благодарова, В.І. Ципріян. — Кн.2. — 544 с.
7. Зубар Н. М. Основи фізіології та гігієни харчування: Підручник. — К. : Центр учбової літератури, 2010. — 336 с.
8. Fundamentals of Human Nutrition: for Students and Practitioners in the Health Sciences, 12th Edition /Catherine Geissler, Hilary Powers, –2011, p. 47–177.
9. Nutrition at a Glance 1st Edition / Mary Barasi — 2014, p. 18–22.
10. Nutrition Counseling and Education Skills: A Guide for Professionals 7th Edition /Judith Beto, Betsy Holli, — 2018, p. 3–24.
11. Clinical Nutrition Basics for Medical Students Paperback / Amanda Velazquez– 2014, 304 p.
12. Textbook of Clinical Nutrition and Functional Medicine, Vol. 1: Essential Knowledge for Safe Action and Effective Treatment (Inflammation Mastery & Functional Inflammology)/ Alex Vasqeuz — 2016, p. 50–64.
13. Nutrition in Public Health 4th Edition /Sari Edelstein, –2018.- p.183–225
14. Advanced Human Nutrition 3rd Edition / Denis M Medeiros, Robert E.C. Wildman, –2010, 280 p.

References to Chapter 26. Hygienic importance of vitamins and microelements

1. Гігієна та екологія: підручник для студентів вищих медичних навчальних закладів. — Вінниця : Нова Книга, 2008. — 720 с.
2. Hygiene and ecology: textbook for students of higher medical educational establishments / under the editorship of corresponding member of NAMS of Ukraine, prof. Bardov V.G. — Vinnytsia: Nova Knyha, 2009. — 688 p.

3. General nutrition: Study guide for the 4th accreditation level Medical School Students / edited by S.T. Omelchuk, O.V. Kuzminska. — Kyiv, 2016. — 146 p.
4. Гигиена и экология: учебник для студентов высших медицинских учебных заведений. — Винница : Нова Книга, 2008. — 720 с.
5. Гігієна харчування з основами нутриціології: підручник / Т.І. Аністратенко, Т.М. Білко, О.В. Благодарова, В.І. Ципріян. — Кн.1. — 528 с.
6. Гігієна харчування з основами нутриціології: підручник / Т.І. Аністратенко, Т.М. Білко, О.В. Благодарова, В.І. Ципріян. — Кн.2. — 544 с.
7. Зубар Н. М. Основи фізіології та гігієни харчування: Підручник. — К. : Центр учбової літератури, 2010. — 336 с.
8. Fundamentals of Human Nutrition: for Students and Practitioners in the Health Sciences, 12th Edition /Catherine Geissler, Hilary Powers. — 2011, p. 47–177.
9. Nutrition at a Glance 1st Edition / Mary Barasi. — 2014, p. 18–22.
10. Nutrition Counseling and Education Skills: A Guide for Professionals 7th Edition /Judith Beto, Betsy Holli, –2018, p. 3–24.
11. Clinical Nutrition Basics for Medical Students Paperback / Amanda Velazquez– 2014, 304 p.
12. Textbook of Clinical Nutrition and Functional Medicine, Vol. 1: Essential Knowledge for Safe Action and Effective Treatment (Inflammation Mastery & Functional Inflammology) / Alex Vasqeuz — 2016, p. 50–64.
13. Nutrition in Public Health 4th Edition /Sari Edelstein, –2018.- p.183–225
14. Advanced Human Nutrition 3rd Edition / Denis M Medeiros, Robert E.C. Wildman, –2010, 280 p.

References to Chapter 27. Ionizing radiation as an environmental factor and occupational hazards

1. Радіаційна гігієна: підручник для лікарів-інтернів та лікарів-слухачів Мурашко В. О., Мечев Д. С., Бардов В. Г. та ін.. Вінниця : Нова Книга, 2013. — 376 с.
2. Гігієна та екологія. Підручник / За ред. В. Г. Бардова. — Вінниця : Нова Книга, 2006. — С.493–535.
3. Профілактична медицина / Даценко І. І., Габович Р.Д. — К. : Здоров'я, 2004. — 639–650 с.
4. Радіаційна гігієна: Підручник /За редакцією В.Я.Уманського, С.Т. Омельчука. — Донецьк, 2009. — 143 с.
5. Ключников О.О., Носовський А.В. Основи дозиметрії іонізуючих випромінювань.Навчальний посібник. Київ — 2007. — 255 с.
6. Мечев Д.С., Мурашко В.О., Коваленко Ю.М.. Застосування джерел іонізуючих випромінювань у медицині та попередження надмірного опромінення персоналу і пацієнтів. Навчальний посібник.– Київ, 2010.
7. Мащенко Н.П., Мурашко В.А. Радиационное воздействие и радиационная защита населения при ядерных авариях на атомных электростанциях. — Киев, 1992.
8. Норми радіаційної безпеки України (НРБУ-97). Державні гігієнічні нормативи ДГН 6.6.1.-6.5.001–98. Київ ,1998.
9. Норми радіаційної безпеки України, доповнення: Радіаційний захист від джерел потенційного опромінення (НРБУ-97/Д-2000).
10. Основні санітарні правила забезпечення радіаційної безпеки України. Державні санітарні правила 6.177–205–09–02. Київ-2005.
11. Гігієнічні вимоги до влаштування та експлуатації рентгенівських кабінетів і проведення рентгенологічних процедур. Державні санітарні норми і правила. ДСанПіН 6.6.3–150–2007. Київ-2007.
12. Допустимі рівні вмісту радіонуклідів 137Cs і 90Sr у продуктах харчування та питній воді. Гігієнічний норматив. ГН 6.6.1.1–130–2006. Київ-2006.
13. Гігієнічний норматив питомої активності радіонуклідів 137Cs та 90Sr у рослинній лікарській сировині (субстанції), що використовується для виготовлення лікарських засобів". Затверджено Наказом МОЗ України № 240 від 08.-5.2008.
14. Radiation Protection and Safety of Radiation Sourses: International Basic Safety Standards //IAEA Safety Standards Series No. GSR — IAEA. Vienna — 2011/ — 303 p.
15. ICRP Publication 101. The optimisation of radiological protection: broadening the process. — New York: Pergamon Press.- 2006. — p.104 (Annals of ICRP. — 2006. — V.37/2–3).
16. ISRP Publication 103. Recommendation of the ICRP. — New York: Pergamon Press.- 2008. — p.104 (Annals of ICRP. — 2006. — V.37/2–4).
17. ICRP Publication 105. Radiological Protection in medicine. — New York: Pergamon Press.- 2008. — p.108 (Annals of ICRP. — 2006. — V.37/6).

References to Chapter 28. Fundamentals of hygienic regulation of ionizing radiation

1. Радіаційна гігієна: Підручник / [Мурашко В. О., Мечев Д. С., Бардов В. Г. та ін.] — Вінниця : Нова Книга. 2009, — 376 с.
2. Радіаційна гігієна: Підручник /За редакцією В.Я.Уманського, С.Т. Омельчука. — Донецьк, 2013. — 143 с.
3. Норми радіаційної безпеки України (НРБУ-97). Державні гігієнічні нормативи ДГН 6.6.1.-6.5.001–98. Київ-1998.
4. Норми радіаційної безпеки України, доповнення: Радіаційний захист від джерел потенційного опромінення (НРБУ-97/Д-2000).
5. НРБУ-97 Відповіді на запитання практики. Тлумачний та методичний посібник. Під ред. чл.-кор.АМН України, професора А.М.Сердюка. — Київ, 2004. — 160 с.
6. Основні санітарні правила забезпечення радіаційної безпеки України. Державні санітарні правила 6.177–205–09–02. Київ- 2005.
7. ICRP Publication 101. The optimisation of radiological protection: broadening the process. — New York: Pergamon Press. — 2006. — p.104 (Annals of ICRP. — 2006. — V.37/2–3).

8. ICRP Publication 103. Recommendation of the ICRP. — New York: Pergamon Press, 2008. — P. 104 (Annals of ICRP. — 2006. — V.37/2–4).
9. ICRP Publication 105. Radiological Protection in medicine. — New York: Pergamon Press, 2008. — P. 108 (Annals of ICRP. — 2006. — V.37/6).
10. ICRP Publication 60. Radiation protection 1990: Recommendations of the International Commission on Radiological Protection (ICRP) — New York: Pergamon Press, 1991. — 197 p. (МКРЗ Публікація N 60 — Рекомендації Міжнародної комісії з радіологічного захисту 1990 р.).
11. МКРЗ Публикация N 65. Защита от радона-222 в жилых помещениях и на рабочих местах. — М.: Энергоатомиздат, 1995. — 78 с.
12. Международные основные нормы безопасности для защиты от ионизирующих излучений и безопасного обращения с источниками излучения. Серия изданий по безопасности N 115. — Вена : МАГАТЭ, 1997. — 382 с.

References to Chapter 29. Sanitary protection of the environment from radioactive contamination as a hygienic problem

1. Радіаційна гігієна: Підручник / [Мурашко В. О., Мечев Д. С., Бардов В. Г. та ін.] — Вінниця : Нова Книга, 2009. — 376 с.
2. Радіаційна гігієна: Підручник / За редакцією В. Я.Уманського, С. Т. Омельчука. — Донецьк, 2013. — 143 с.
3. Норми радіаційної безпеки України (НРБУ-97). Державні гігієнічні нормативи ДГН 6.6.1.-6.5.001–98. Київ-1998.
4. Норми радіаційної безпеки України, доповнення: Радіаційний захист від джерел потенційного опромінення (НРБУ-97/Д-2000).
5. НРБУ-97 Відповіді на запитання практики. Тлумачний та методичний посібник. Під ред. чл.-кор.АМН України, професора А.М.Сердюка. Київ 2004. — 160 с.
6. Основні санітарні правила забезпечення радіаційної безпеки України. Державні санітарні правила 6.177–205–09–02. Київ- 2005.
7. ЕнергоАтом. Сучасний стан атомної енергетики. Перспективи. "Тиждень Відкритої Енергетики": Матеріали Міжнародного енергетичного форуму (м. Київ, 10 жовтня 2017 р.). URL.: https://vse.energy/docs/OEW-tarakanov.pdf.
8. "Енергоатом" у 2018 році збільшив дохід від реалізації електроенергії на 14% (за даними Інформаційного агенства УНІАН). URL.: https://economics.unian.ua/energetics/10407489-energoatom-u-2018-roci-zbilshiv-dohid-vid-realizaciji-elektroenergiji-na-14.html.
9. Международные основные нормы безопасности для защиты от ионизирующих излучений и безопасного обращения с источниками излучения. Серия изданий по безопасности N 115. — Вена: МАГАТЭ, 1997. — 382 с.

References to Chapter 30. Medical consequences of the Chornobyl disaster for the population of Ukraine

1. Радіаційна гігієна: підручник для лікарів-інтернів та лікарів-слухачів. Мурашко В. О., Мечев Д. С., Бардов В. Г. та ін.. — Вінниця : Нова Книга, 2013. — 376 с.
2. Гігієна та екологія. Підручник / За ред. В. Г. Бардова. — Вінниця : Нова Книга, 2006. — С. 493–535.
3. Профілактична медицина / Даценко І. І., Габович Р.Д. — К. : Здоров'я, 2004. — 639–650 с.
4. Радіаційна гігієна: Підручник /За редакцією В. Я. Уманського, С. Т. Омельчука. — Донецьк, 2009. — 143 с.
5. Ключников О. О., Носовський А. В. Основи дозиметрії іонізуючих випромінювань.Навчальний посібник. — Київ, 2007. — 255 с.
6. Мечев Д.С., Мурашко В.О., Коваленко Ю.М.. Застосування джерел іонізуючих випромінювань у медицині та попередження надмірного опромінення персоналу і пацієнтів. Навчальний посібник. — Київ, 2010.
7. Мащенко Н.П., Мурашко В.А. Радиационное воздействие и радиационная защита населения при ядерных авариях на атомных электростанциях. — Киев, 1992.
8. Норми радіаційної безпеки України (НРБУ-97). Державні гігієнічні нормативи ДГН 6.6.1.-6.5.001–98. Київ-1998.
9. Норми радіаційної безпеки України, доповнення: Радіаційний захист від джерел потенційного опромінення (НРБУ-97/Д-2000).
10. Основні санітарні правила забезпечення радіаційної безпеки України. Державні санітарні правила 6.177–205–09–02. Київ-2005.
11. Гігієнічні вимоги до влаштування та експлуатації рентгенівських кабінетів і проведення рентгенологічних процедур. Державні санітарні норми і правила. ДСанПіН 6.6.3–150–2007. Київ-2007.
12. Допустимі рівні вмісту радіонуклідів 137Cs і 90Sr у продуктах харчування та питній воді. Гігієнічний норматив. ГН 6.6.1.1–130–2006. Київ-2006.
13. Гігієнічний норматив питомої активності радіонуклідів 137Cs та 90Sr у рослинній лікарській сировині (субстанції), що використовується для виготовлення лікарських засобів". Затверджено Наказом МОЗ України № 240 від 08.05.2008.
14. Radiation Protection and Safety of Radiation Sourses: International Basic Safety Standards // IAEA Safety Standards Series No. GSR — IAEA. Vienna — 2011/ — 303 p.
15. ICRP Publication 101. The optimisation of radiological protection: broadening the process. — New York: Pergamon Press. — 2006. — p.104 (Annals of ICRP. — 2006. — V.37/2–3).
16. ISRP Publication 103. Recommendation of the ICRP. — New York: Pergamon Press.- 2008. — p. 104 (Annals of ICRP. — 2006. — V.37/2–4).
17. ICRP Publication 105. Radiological Protection in medicine. — New York: Pergamon Press.- 2008. — p. 108 (Annals of ICRP. — 2006. — V.37/6).

References to Chapter 30. Hygienic fundamentals of temporary location of military and civilian units in emergencies

1. Гігієна та екологія: Підручник / За редакцією В.Г.Бардова. — Вінниця : Нова Книга, 2006. — 720 с.
2. Hygiene and ecology. Manual/under the edit. of V. G. Bardov. — Vinnytsya: Nova Knyha, 2018. — C. 688.
3. Військова гігієна з гігієною при надзвичайних ситуаціях: Підручник / За редакцією К.О.Пашка. — Тернопіль: Укрмедкнига, 2005. — 312 с.
4. Військова гігієна (загальні питання): підручник М. І. Хижняк, Л. І. Біденко, В.М. Якимець [та ін.]; за ред. проф. М. І. Хижняка — К. : УВМА, 2011. — 528 с.
5. Військова гігієна (гігієна праці в окремих видах та родах військ): підручник М. І. Хижняк, Л. І. Біденко, В.М. Якимець [та ін.]; за ред. проф. М. І. Хижняка. — К. : УВМА, 2011. — 402 с.
6. Загальна гігієна: Посібник для практичних занять / За загальною ред. Даценко І. І. — Львів : Світ, 2001. — 472 с., іл.
7. Беляков В.Д., Жук Е.Г. Военная гигиена и эпидемиология. — М., 1988. — 320 с.
8. Medicine of emergency situations [Text] : a textbook for students of higher medical educational establishments of IV level of accreditation / V. V. Chaplyk, P. V. Oliynyk, S. T. Omelchuk, V. V. Humenyuk. — Vinnytsia : Nova Knyha, 2012. — 343 p.
9. http://intranet.tdmu.edu.ua/data/books/Gig_ns.pdf

References to Chapter 32. Hygienic peculiarities of water supply of military and civilian units in emergencies and in exceptional periods

1. http://eprints.kname.edu.ua/48445/1/2017%2088%D0%9B%20%D0%A2%D0%9E%D0%9F%D0%92%2C%20%D0%A1%D0%9E%D0%92%28%D0%9C3%29.pdf
2. http://intranet.tdmu.edu.ua/data/books/Gig_ns.pdf
3. http://intranet.tdmu.edu.ua/data/books/Gig_ns.pdf
4. Hygiene and ecology. Manual/under the edit. of V. G. Bardov. –Vinnytsya: Nova Knyha, 2018. — C. 688.
5. Medicine of emergency situations [Text] : a textbook for students of higher medical educational establishments of IV level of accreditation / V. V. Chaplyk, P. V. Oliynyk, S. T. Omelchuk, V. V. Humenyuk. — Vinnytsia : Nova Knyha, 2012. — 343 p.
6. Беляков В.Д., Жук Е.Г. Военная гигиена и эпидемиология. — М. — 1988. — 320 с.
7. Військова гігієна (гігієна праці в окремих видах та родах військ): підручник М. І. Хижняк, Л. І. Біденко, В.М. Якимець [та ін.]; за ред. проф. М. І. Хижняка — К. : УВМА, 2011. — 402 с.
8. Військова гігієна (загальні питання): підручник М. І. Хижняк, Л. І. Біденко, В. М. Якимець [та ін.]; за ред. проф. М. І. Хижняка — К. : УВМА, 2011. — 528 с.
9. Військова гігієна з гігієною при надзвичайних ситуаціях: Підручник / За редакцією К. О. Пашка. — Тернопіль : Укрмедкнига, 2005. — 312 с.
10. Гігієна та екологія: Підручник / За редакцією В.Г.Бардова. — Вінниця : Нова Книга, 2006. — С.591–663.
11. Загальна гігієна: Посібник для практичних занять / За загальною ред. Даценко І. І. — Львів : Світ, 2001. — 472 с., іл.

References to Chapter 33. Nutrition hygiene in the field conditions in emergencies

1. Гігієна та екологія: Підручник / За редакцією В.Г.Бардова. — Вінниця : Нова Книга, 2006. — 720 с.
2. Hygiene and ecology. Manual/under the edit. of V. G. Bardov. –Vinnytsya: Nova Knyha, 2018. — C. 688.
3. Військова гігієна з гігієною при надзвичайних ситуаціях: Підручник / За редакцією К. О. Пашка. — Тернопіль : Укрмедкнига, 2005. — 312 с.
4. Військова гігієна (загальні питання): підручник М. І. Хижняк, Л. І. Біденко, В.М. Якимець [та ін.]; за ред. проф. М. І. Хижняка — К. : УВМА, 2011. — 528 с.
5. Військова гігієна (гігієна праці в окремих видах та родах військ): підручник М. І. Хижняк, Л. І. Біденко, В.М. Якимець [та ін.]; за ред. проф. М. І. Хижняка — К. : УВМА, 2011. — 402 с.
6. Загальна гігієна: Посібник для практичних занять / За загальною ред. Даценко І. І. — Львів : Світ, 2001. — 472 с., іл.
7. Беляков В.Д., Жук Е.Г. Военная гигиена и эпидемиология. — М. — 1988. — 320 с.
8. Medicine of emergency situations [Text] : a textbook for students of higher medical educational establishments of IV level of accreditation / V. V. Chaplyk, P. V. Oliynyk, S. T. Omelchuk, V. V. Humenyuk. — Vinnytsia : Nova Knyha, 2012. — 343 p.
9. http://intranet.tdmu.edu.ua/data/books/Gig_ns.pdf

References to Chapter 34. Occupational hygiene within the rectification of the consequences of emergencies

1. http://intranet.tdmu.edu.ua/data/books/Gig_ns.pdf
2. Hygiene and ecology. Manual/under the edit. of V. G. Bardov. — Vinnytsya: Nova Knyha, 2018. — C. 688.
3. Medicine of emergency situations [Text] : a textbook for students of higher medical educational establishments of IV level of accreditation / V. V. Chaplyk, P. V. Oliynyk, S. T. Omelchuk, V. V. Humenyuk. — Vinnytsia : Nova Knyha, 2012. — 343 p.

4. Беляков В.Д., Жук Е.Г. Военная гигиена и эпидемиология. — М. — 1988. — 320 с.
5. Військова гігієна (гігієна праці в окремих видах та родах військ): підручник М. І. Хижняк, Л. І. Біденко, В.М. Якимець [та ін.]; за ред. проф. М. І. Хижняка — К. : УВМА, 2011. — 402 с.
6. Військова гігієна (загальні питання): підручник М. І. Хижняк, Л. І. Біденко, В.М. Якимець [та ін.]; за ред. проф. М. І. Хижняка. — К. : УВМА, 2011. — 528 с.
7. Військова гігієна з гігієною при надзвичайних ситуаціях: Підручник / За редакцією К. О. Пашка. — Тернопіль : Укрмедкнига, 2005. — 312 с.
8. Гігієна та екологія: Підручник / За редакцією В. Г. Бардова. — Вінниця : Нова Книга, 2006. — С.591 — 663.
9. Загальна гігієна: Посібник для практичних занять / За загальною ред. Даценко І. І. — Львів : Світ, 2001. — 472 с., іл.

References to Chapter 35. Healthy lifestyle and personal hygiene

1. Environmental Health. From global to local / Under Howard Frumkin edition. — Third edition. — San-Francisco, 2016. — P. 729–735.
2. Korobchanskiy V.A., Vorontsov M.P., Musulbas A.A. Hygiene and Ecology. — Kharkov, 2006. — P. 143–147.
3. Гігієна та екологія. Підручник / За редакцією В. Г. Бардова. — Вінниця : Нова Книга, 2006. — 720 с.
4. Основи екології: підручник для студ. вищих навч. закладів / [В. Г. Бардов, В. І. Федоренко, Е. М. Білецька та ін.]; за ред. В. Г. Бардова, В. І. Федоренко. — Вінниця : Нова Книга, 2013. — 424 с.

References to Chapter 36. Harmful habits as a threat to human health, their prevention

1. Environmental Health. From global to local / Under Howard Frumkin edition. — Third edition. — San-Francisco, 2016. — P. 729–735.
2. Korobchanskiy V.A., Vorontsov M.P., Musulbas A.A. Hygiene and Ecology. — Kharkov, 2006. — P. 16–21, 143–147.
3. Гігієна та екологія. Підручник / За редакцією В. Г. Бардова. — Вінниця : Нова Книга, 2006. — 720 с.

References to Chapter 37. Peculiarities of hygienic provision of the population in tropical regions (organization of places for habitation)

1. Dragcevic, Z., Vujasinovic, E., & Hursa Sajatovic, A. (2017). Multifunctional design of footwear for hot environment condition. IOP Conference Series: Materials Science and Engineering, 254, 232003. https://doi.org/10.1088/1757–899x/254/23/232003
2. Introduction to Permaculture. Bill Mollison and Reny Mia Slay. Tagari Publishers, Tyalgum, Australia.1991. 198pp
3. Koppen_World_Map_Hi-Res.png: Peel, M. C., Finlayson, B. L., and McMahon, T. A. (University of Melbourne) derivative work: Me ne frego [CC BY-SA 3.0 (https://creativecommons.org/licenses/by-sa/3.0)], via Wikimedia Commons.
4. Köppen World Map High Resolution.png: Peel, M. C., Finlayson, B. L., and McMahon, T. A.(University of Melbourne) derivative work: Me ne frego [CC BY-SA 3.0 (https://creativecommons.org/licenses/by-sa/3.0)], via Wikimedia Commons
5. Linowes, Richard & Brown Hupert, Mollie. (2006). The tropical waste dilemma: Waste management in Panama. International Journal of Emerging Markets. 1. 225–234. 10.1108/17468800610674453
6. P. Mal, A. Ghosh, A. Majumdar, and D. Banerjee, "Engineering of knitted cotton fabrics for optimum comfort in a hot climate," Fibres Textiles Eastern Eur., vol. 24, no. 2, pp. 102–106, 2016, doi: 10.5604/12303666.1191434
7. Reiner, R. C., Smith, D. L., & Gething, P. W. (2014). Climate change, urbanization and disease: summer in the city…. Transactions of the Royal Society of Tropical Medicine and Hygiene, 109(3), 171–2.
8. Urbanization in Africa // African Development Bank URL: https://www.afdb.org/en/blogs/afdb-championing-inclusive-growth-across-africa/post/urbanization-in-africa-10143/ (дата обращения: 12.02.2019).
9. World map torrid // URL: https://commons.wikimedia.org/wiki/File:World_map_torrid.svg#/media/File:World_map_torrid.svg (дата звернення: 12.02.2019).
10. Стратегія розвитку міст: молодь і майбутнє (інноваційний ліфт): матеріали Міжнародної науково-практичної конференції, 11 квітня 2018 року. — Харків, 2018
11. Ф.А.Брокгауз, И.А.Ефрон. Энциклопедический Словарь Ф.А.Брокгауза и И.А.Ефрона. — СПб., 1907.

References to Chapter 38. Hygienic requirements for water and water supply and nutrition related to the peculiarities of tropical regions

1. Disabled World. (2018/11/26). https://www.disabled-world.com/fitness/metabolism/ Human Metabolism: Facts and General Information. Retrieved 2019–03–06, from https://www.disabled-world.com/fitness/metabolism/
2. Drinking-water // World Health Organization URL: https://www.who.int/news-room/fact-sheets/detail/drinking-water (дата звернення: 15.03.2019).

3. Guidelines for Drinking-Water Quality: Fourth Edition Incorporating the First Addendum. Geneva: World Health Organization; 2017. Available from: https://www.ncbi.nlm.nih.gov/books/NBK442376/
4. Lal, R. (1995). Sustainable management of soil resources in the humid tropics. Tokyo: United Nations University Press.
5. Ubomba-Jaswa, E., Navntoft, C., Polo-López, M., Fernandez-Ibanez, P., & Mcguigan, K. (2009). Solar disinfection of drinking water (SODIS): An investigation of the effect of UV-A dose inactivation efficiency. Photochemical & photobiological sciences : Official journal of the European Photochemistry Association and the European Society for Photobiology (Vol. 8). https://doi.org/10.1039/b816593a
6. Water Safety Plans / Annette Davison, Guy Howard, Melita Stevens, Phil Callan, Jamie Bartram и др. — Geneva, Switzerland: Printing and Binding Service WHO, 2005.
7. WHO, Water Sanitation Health, Facts and Figures on Water Quality and Health. [Last cited on 2017 Jan 30]. Available from: http://www.who.int/water_sanitation_health/facts_figures/en/index.html
8. WHO | 3. Global and regional food consumption patterns and trends // World Health Organization URL: https://www.who.int/nutrition/topics/3_foodconsumption/en/#diet3.2 (дата звернення: 15.02.2019).
9. Гончарук Є.Г., Бардов В.Г., Гаркавий С.І., Яворовський О.П. та ін. Коммунальная гигиена/За ред. Є. Г. Гончарука. — К. : "Здоров'я", 2006. — С. 45–351
10. Назаренко І. І., Польчина С.М., Нікорич В.А. Грунтознавство. Підручник. — Чернівці : Книги-XXI, 2004. — 400 с.
11. Сирохман І. В. Товарознавство харчових продуктів функціонального призначення: навч. С 40 пос. [для студ. вищ. навч. закл.] / І. В. Сирохман, В. М. Завгородня. — К. : Центр учбової літератури, 2009. — 544 с.

Notes

Notes

Підручник підготовлено співробітниками кафедри гігієни та екології № 1, опорної кафедри МОЗ України з дисципліни "Загальна гігієна та екологія" і кафедри гігієни та екології № 4 Національного медичного університету імені О. О. Богомольця за загальною редакцією члена-кореспондента НАМН України професора В. Г. Бардова.

З урахуванням сучасних досягнень наук про здоров'я людини та біосферу у підручнику викладено теоретичні основи, методологія, мета і задачі, глобальні проблеми екології, структуру й характеристики сучасного стану атмосфери, гідросфери та літосфери Землі, вивчення закономірностей впливу фізичних, хімічних, біологічних та психологічних факторів на здоров'я людини і громадське здоров'я, використання встановлених закономірностей для розробки методів та систем профілактики впливу негативних градацій цих факторів.

У вигляді окремих 38 тем підручник включає всі розділи навчальної програми та всі основні розділи дисципліни "Загальна гігієна та екологія людини": пропедевтику гігієни, екологію людини, основи вчення про біосферу, глобальні проблеми забруднення біосфери, закономірності впливу природних та антропогенних компонентів біосфери на здоров'я людини та громадське здоров'я, основні положення комунальної гігієни, гігієни харчування, гігієни праці, гігієни дітей та підлітків, гігієни лікувально-профілактичних закладів, радіаційної гігієни, гігієни надзвичайних станів, військової гігієни, тропічної гігієни, особистої гігієни тощо.

Для студентів закладів вищої медичної освіти IV рівня акредитації, лікарів-інтернів, сімейних лікарів, практичних лікарів.

Навчальне видання

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