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Environmental Protection Strategies

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Methodological bases of ecological safety, its origins, essence, evolution are analyzed. The main problems of ecological safety of mankind are considered. Materials on the main branches of human production activity are presented. Their influence on the atmospheric air, hydrosphere, lithosphere is analyzed and ways of overcoming of negative consequences are suggested. The ecological bases of rational use of nature, methods of management of processes of use of nature, modern waste–free technologies and processes, development of means of waste utilization, integrated use of secondary raw materials are presented.

Проаналізовано методологічні засади екологічної безпеки, її витоки, суть, еволюція. Розглянуто основні проблеми екологічної безпеки людства. Представлено матеріали щодо основних галузей виробничої діяльності людини. Проаналізовано їх вплив на атмосферне повітря, гідросферу, літосферу та запропоновано шляхи подолання негативних наслідків. Представлені екологічні основи раціонального природокористування, методи управління процесами природокористування, сучасні безвідходні технології та процеси, розробка засобів утилізації відходів, комплексного використання вторинної сировини.

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CONTENT

INTRODUCTION

Today there is a deep environmental crisis in Ukraine, which is due to the high level of concentration of industrial production and agriculture, the irrational use of natural resources for decades.

In Ukraine, anthropogenic and technogenic impact on the environment is several times higher than in developed countries. To improve the ecological situation in Ukraine, it is necessary to change the priorities in the regulation of nature management and the ecological function of the state authorities.

The environmental protection strategy as a section of ecology puts forward a number of special requirements for the implementation of such regulation, as well as for the creation of modern industrial production:

– promoting sustainable development by ensuring environmental protection, life safety, and health protection of the citizens;

– development of new principles for the creation of technologically advanced industries that eliminate the negative impact on the biosphere;

– rational use of natural resources;

– assessment and calculation of environmental risk parameters for territories and water areas.

Thus, the scope of study of the discipline "Environmental Protection Strategy" is the process of defining the main strategies and concepts of society's interaction with the environment, the main preventive strategies for environmental protection, and the main activities to ensure the rational use of natural resources. The scope of competence in this area of ecology includes the determination of priority tasks of state policy in the environmental sphere.

The state's environmental policy provides for a set of measures aimed at environmental protection. At the national level, environmental policy is one of the most important areas of both domestic and foreign policy of the country, related to the reproduction of natural resources and ensuring the stability of the environmental system, as well as the dynamics of its development.

The experience of the advanced countries shows that effective management of environmental activities provides an opportunity for further socio–economic development with minimal impact on the environment.

Based on the above, the course book proposes to consider issues related to a wide range of environmental issues, as well as world experience in environmental protection to address today's environmental issues effectively.

The purpose of the discipline "Environmental Protection Strategy" is to develop the following competencies:

- to understand the priorities of state policy in the environmental sphere;
- to propose strategies for managing the environmental security of the Ukrainian regions;
- to provide a comprehensive assessment of threats and risks to the state of environmental security of the regions of the country;
- to choose the most effective and sound methods of environmental safety management that lead to the minimization of environmental risks;
- to take into account the environmental consequences when making management decisions.

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SECTION 1. THE PRIORITIES OF STATE POLICY IN THE ENVIRONMENTAL SPHERE

1.1. THE CONCEPT OF THE ENVIRONMENT AND ITS PROTECTION

1.1.1. Scope of study, methods, tasks, and structure of modern ecology

Modern ecology uses the methods and achievements of almost all sciences. It has become the most integrated science, as it combines knowledge of the exact, social, and human sciences. The reason for the great branching of ecology is the huge variety and complexity of the subjects of its study.

The distinctive feature of modern ecology is that it has evolved from a purely biological science into a cycle of knowledge, absorbing knowledge of geography, geology, chemistry, physics, sociology, cultural theory, economics, and even theology [1]. Some scholars believe that ecology is a social and natural science; it can be equally attributed to the biological and geographical disciplines and viewed as a completely independent science that has acquired fundamentalism and global nature. Ecology in a broad sense unites dozens of scientific areas. It has grown from traditional bioecology into an integrated complex multifaceted leading science and has become a philosophy of human survival (ecological philosophy).

Modern environmental science takes knowledge from almost all other sciences to study all components of modern environmental problems, establish direct and feedback links between the processes that determine environmental conditions, identify ways out of the ecological crisis, and develop specific plans and programs.

In fact, modern ecology is divided into four interconnected but to some extent independent sections that logically derive from each other and divide the ecology by the size of the subjects of study, namely:

- Autecology (ecology of organisms), which studies the relationships of species with their environment. This section of ecology is mainly concerned with determining the limits of species stability and its relationship to various environmental factors. Autecology also studies the influence of the environment on the morphology, physiology, and behavior of organisms.

- Demecology (ecology of population fluctuations), which describes fluctuations in the numbers of different species and identifies their causes. This section is also called population dynamics or population ecology.
- Synecology (ecology of groups), which analyzes the relationship between individuals belonging to different species of this group of organisms, as well as between them and the environment.
- Biospherology (global ecology), which studies the biosphere as a single planetary whole, finds out the laws of evolution of the biosphere.

There are other ways to divide ecology.

Thus, K. M. Sytnyk and M. I. Budyko (1990 – 1992) divide ecology into three parts:

- general ecology, which studies the basic laws of functioning of ecological systems;
- global ecology, which studies the biosphere as a whole;
- applied ecology, which studies the relationship of living organisms with the environment.

Today, the unifying center of ecology is the global ecology, which systematically studies and forecasts the state and changes of the Earth and its biosphere, recommends ways to harmonize the relationship between humanity and the environment. Other sections surround the central one and interact both with it and with each other, but they have narrower tasks and study different subjects, which is reflected in their names (Fig. 1.1).

Bioecology has the longest history. It studies the general patterns of relationships of organisms and their groups with the environment in natural conditions, forms an idea of ecology as a natural economy based on the study of flows of matter, energy, and information in biological systems. Bioecology is considered the mother substrate and the main component of modern ecology. It has dozens of disciplines (industries), both old (autecology, population ecology, synecology, etc.) and relatively new (bioecomonitoring, experimental ecology, bioindication, etc.). Thus, bioindication is a new branch of ecology that assesses the state of the natural environment and its individual components by the reactions of living organisms, i.e. it studies the effects of anthropogenic impact on the physiology and biochemistry of various organisms, population dynamics, and more.

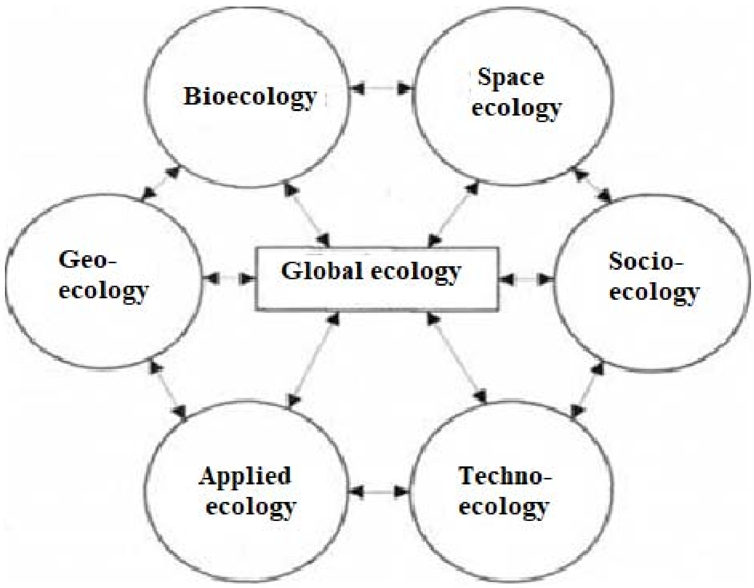

Fig. 1.1. **The main sections of global ecology**

Geoecology appeared when there was a need to study not only organisms and the relationship between them and the environment, but also their response to changes in environmental conditions, and to trace the reverse impact of human society on the biosphere as a habitat.

The term "geoecology" was introduced by the German geographer Carl Troll in 1939 and marked the birth of a new scientific field in the natural sciences [2]. He was the first to identify this direction at the junction of geography and ecology. According to modern extended interdisciplinary approaches, geoecology is considered as a scientific field that synthesizes the laws of ecology with the achievements of all sciences about the Earth: geography (ecological geography, ecological landscape science, ecological meteorology, ecological climatology, ecological paleogeography, etc.); geology (ecological geology, ecological geodynamics, ecological geochemistry, ecological geophysics, ecological mineralogy, etc.); soil science (ecological soil science, agroecology, ecological earth science, etc.).

From the ecological and geographical point of view, geoecology is an interdisciplinary scientific field that studies the ecosphere as an interconnected system of geospheres in the process of its integration with society. Geoecology studies the ecosphere (highest order ecosystem) but focuses on its changes under the influence of human activities. That is, the scope of study is not only natural but also anthropogenically modified systems, and the main purpose of research is to optimize the management of nature. The subjects of geoecology research are geoecosystems – territorial systems that are managed or controlled by man, areas of the landscape with their characteristic processes of heat and moisture exchange, biogeochemical cycles, certain economic activities and socio–cultural relations.

Thus, geoecology analyzes the various connection chains between nature, man (society) and the economy, suggests ways for the rational spatial organization of natural, social, and economic systems. Standards and criteria of environmental quality and the level of economic activity play a key role in geoecology. That is, geoecology is based mainly on the legal framework, which determines the different types of liability for environmental damage and misuse of resources, as well as on environmental assessments and forms of environmental protection incentives.

Technoecology is the largest section of applied environmental disciplines related to such spheres of human activity as energy, industry, agriculture, transport, military affairs, science, and space. This section of ecology determines the scope, mechanisms, and consequences of environmental impacts of various sectors of the economy, especially the use of natural resources, develops environmental regulations and engineering means of nature protection, takes care of waste disposal and reproduction of destroyed ecosystems, as well as creates conditions for making various industries more environmentally friendly.

Each section of technoecology – ecology of energy, industry, transport, agriculture (agroecology), etc. – has several subsections. Thus, the ecology of energy includes the ecology of nuclear, thermal, and hydroelectric power plants, as well as new unconventional energy sources.

Socioecology explores the specific role of man in the environment not as a biological species but as a social being, the differences between this role and the functions of other living beings, studies ways to optimize the relationship of human society with nature, forms environmental awareness, environmental culture through new methods and approaches to environmental education and training, formulates laws on ecological nature management, principles and criteria of ecological management, control and business activities, carries out social and ecological monitoring, lays the foundations of local, regional, and global environmental policy.

The subject of study of socioecology is the socio–ecosystem, i.e. the territorial socio–natural self–regulatory system, the dynamic balance of which must be ensured by human society. The scope of study is the processes and phenomena associated with the human population in different living conditions. The emergence of socioecology is not accidental. It is the reaction of the human mind to the real processes taking place on our planet and threatening the continued existence of mankind. The destruction of the biosphere by economic activity led to the emergence of the science of harmonizing the interaction of society and nature – socioecology. Human ecology is a joint scientific subsection of socioecology and medicine, which studies the medical and biological aspects of the relationship between society and nature. Human ecology considers the human body and its environment as an integral system in which not only the components but also the relationship between them are essential. The following subsections of socioecology are especially important nowadays: psychoecology, urban ecology, environmental legislation, etc.

Due to the expansion of human activity and the strengthening of its negative effects on nature in recent decades, various spheres are actively developing in the field of applied ecology. Applied ecology studies the mechanisms of biosphere destruction, develops methods to prevent it and ways of rational nature management. Applied ecology today is a large set of disciplines in various fields of human activity. Research in this field of ecology forms the ecological criteria for the economy, analyzes the mechanisms of anthropogenic impacts on nature, assesses the quality of the environment, substantiates standards for sustainable use of natural resources, provides environmental regulation of economic activity and environmental compliance of various plans and projects, develops technical means of environmental protection and to recreate natural systems affected by man.

Among the variety of subsections of applied ecology, the key ones are engineering ecology, agricultural ecology, bioresource ecology, ecology of settlements and communal ecology, medical ecology.

Engineering ecology aims to develop engineering standards and tools that meet environmental requirements in construction, industry, energy, and transport. It refers to the ecological safety of technological processes, constructions, vehicles, tools, and products; and also to optimization of branch structure of industrial complexes and operation of civil and economic objects.

Agricultural ecology studies the impact of agriculture on natural ecosystems, as well as the functioning nature of agroecosystems under man–made loads. To a large extent, it intersects with the biological foundations of agriculture (agroecology) and animal husbandry (ecology of farm animals).

Bioresource (industrial) ecology comprehensively studies the conditions under which the exploitation of biological resources of natural ecosystems does not lead to their depletion and disruption, loss of species, reduction of biodiversity. The tasks of this discipline include the development of methods of restoration and enrichment of bioresources, scientific substantiation of introduction and acclimatization of plants and animals, creation of nature reserves, etc.

Ecology of settlements and communal ecology are the subsections of applied ecology aimed at studying the impact of various factors of the artificially transformed living environment of people in settlements (cities, towns, villages, etc.).

Medical ecology studies primarily the ecological conditions of occurrence, spread, and development of human diseases, including chronic diseases caused by adverse man–made impacts on the environment. One of the subdivisions of medical ecology is recreational ecology, i.e. the ecology of recreation and rehabilitation of people.

Nature is a system capable of self–regulation and self–renewal. At a low level of development of productive forces, harmful consequences of anthropogenic influence have a local character. By the middle of the twentieth century, the contradictions between technological progress and the environment had become threatening.

A new system emerged – "nature – society" – which required the society to regulate the anthropogenic influence. It became clear that the existence of humans as a species depends on the existence of the natural environment – an environment in which man has originated, formed, and developed over millennia. Man needs the entire biosphere of the Earth, the one in which he grew up, which is not radically changed by industrial emissions, radioactive waste, and harmful effects.

Having the large number of negative consequences of human impact on nature that endangered its very existence, humanity has come to the conclusion that it is necessary to protect both individual natural objects and the biosphere as a whole.

The foundations for the proper interaction of society and the environment are laid in such activities as "nature protection" (environmental protection). The tasks of environmental protection are very complex because the relationship between man and nature is quite contradictory. On the one hand, humanity exists and develops due to the increasing use of natural resources. On the other hand, it faces the global problem of preserving the environment.

In order to manage natural processes and phenomena wisely, to restore the destroyed nature objects and return the lost ones, man must use all scientific knowledge and the power of technical means. In this regard, one shall remember that the biosphere, which consists of a huge number of constituent components, is a dialectical unity from which nothing can be taken away without consequences.

Self–assessment questions to subsection 1.1.1.

1. Define the concept of "ecology".
2. What sections is ecology divided into by the size of the subjects of study?
3. Describe bioecology as a component of modern ecology.
4. What is a "bioindication"?
5. Define the term geoecology.
6. Describe the essence of technoecology.
7. Describe the essence of socioecology.
8. What is the purpose of engineering ecology?
9. What does agricultural ecology study?
10. What does bioresource (industrial) ecology study?
11. What does the ecology of settlements study?
12. What does medical ecology study?
13. How can the system "nature–society" be characterized?
14. What is the essence of the concept of "environmental protection"?

1.1.2. Theoretical aspects of environmental security. Tasks facing engineers in the field of environmental protection

Considering nature protection within the historical aspect, we can identify a number of stages and aspects of this activity.

People's nature protection was aimed at preserving the basic means of subsistence in the territory of the family or tribe, such as game, fish, and others. As a result of controls and bans on extraction, as well as penalties for their violation, people's nature protection was highly effective.

Private nature protection is a system of measures, regulations, standards based on the relevant executive bodies and law enforcement agencies aimed at protecting the environment from the negative effects of economic activity.

Public nature protection is the activity of public organizations for the preservation of the natural environment.

International nature protection is an activity to protect the environment, to combat global problems at the international level.

The **classical nature protection concept** is based on the principle of nature conservation due to the lack of human impact on natural systems, i.e. nature develops without any changes due to anthropogenic activities. This approach can be implemented only on the basis of reserves, national parks, etc.

The **technological nature protection concept**, typical of most developed countries, is based on the regulation of anthropogenic impacts on the environment. It is aimed at reducing pollution and harmful effects to a minimum. For this purpose, the maximum allowable standards for emissions, discharges, waste dumping and disposal have been introduced. This approach does not take into account the possible accumulation of pollution in the biosphere. It is a compromise and a temporary approach.

An **anthropocentric** or a **hygienic approach** to environmental protection means that environmental pollution should not have a negative impact on human health. As in the previous case, the indicators of maximum allowable concentrations, emissions, discharges, etc. are used.

The **ecological approach** to environmental protection is based on the fact that the costs of environmental protection are compared with the averted environmental damage. The ecological approach is based on the fact that any anthropogenic impact on the environment should not cause changes in ecological systems. That is, allowable emissions and discharges into the environment are determined by normalizing the anthropogenic load on the environment. The key is to determine the "maximum allowable environmental load", the value of which is determined by the sustainability of the ecological system, or its individual parts and levels.

The year 1992 – the year of the United Nations Conference on Environment and Development in Rio de Janeiro (Brazil), which discussed the basic principles of sustainable development of human society – should be considered the beginning of the modern historical stage of environmental protection [3].

At the beginning of the rapid scientific and technological development (late 19th, early 20th century), manufacturers denied the harmful effects of production on the environment. Certain environmental protection measures were hygienic and related mainly to the protection of workers in the workplace. Subsequently, a way out was found in the assimilation potential of the planet and its ability to recover. However, the emergence and deepening of the global environmental crisis have clearly shown that the amount of emissions, discharges, solid waste and the magnitude of harmful effects in the 20th century significantly exceeded the assimilation threshold of the planet [4].

Starting from the 1970s and 1980s, attitudes toward environmental issues have changed radically. Society has been forced to take significant steps to protect the environment from harmful impacts and pollution. It was not just about the health of certain social groups, certain nations. The problems concerned the prospects for the existence of all mankind [1; 5].

As environmental problems became more complex, approaches to environmental protection were changing. In general, there are three stages in environmental protection based on the strategy of solving environmental problems, technical means, and organization levels.

Stage 1. The dilution strategy plays the main role. The method of dilution of gaseous emissions and wastewater, which is based on mixing toxic emissions with air and wastewater with natural waters, is used. To improve the dilution of gas emissions, high pipes were built for emissions of combustion products, gas emissions, and aerosol dispersion.

When wastewater is discharged, toxic effluents were often diluted with natural water both at the plant and when discharged into natural reservoirs.

Disadvantages of approaches:

- significant use of natural resources (water, air, etc.);
- accumulation of pollution in the environment;
- global changes in the atmosphere, hydrosphere, soil pollution.

Stage 2. Pollution isolation strategy (end–of–pipe approach).

The method of isolation and concentration of pollutants from gas emissions and wastewater is used. Concentrated waste is disposed of in specially designated landfills, purified gases are discharged into the atmosphere, and purified water is discharged into reservoirs. Disadvantages of approaches:

- accumulation of toxic waste;
- environmental pollution due to insufficient cleaning efficiency;
- high cost of equipment for gas and water purification.

Stage 3. Strategy for the use of secondary raw materials.

In this case, the method of waste separation, sorting, and recycling is used. For example, the use of scrap metal, waste paper, glass, etc. In general, this approach is possible for the processing of solid, liquid waste, and gaseous emissions. For example, when burning gas emissions, electricity or heat can be produced.

The strategy of secondary use is the use outside the main production. The disadvantages are that only waste that is easy to collect and recycle is used, as well as waste that meets the necessary quality requirements. For example, the industries are ready to use certain metals or scrap metal, but there is an acute problem with disposing of sludges containing metal hydroxides, including non–ferrous and heavy metals. Industries are generally reluctant to use waste as a raw material.

A common disadvantage for all three strategies is that none of them analyzes the production where waste is generated, does not consider methods of waste generation. Therefore, the possibility of reducing waste at the production stage is not considered.

The environmental strategies discussed here are not suitable for long–term use, primarily because their application does not reduce the amount of waste (or does not reduce it enough in the third case), and the assimilative capacity of natural systems is limited.

Another disadvantage is that existing approaches to environmental protection are unprofitable. The costs of processing and storing waste in accordance with the end–of–pipe approach are extremely significant, which is an obstacle to the further development of the industry. For example, the annual trade in technology and equipment for gas and wastewater treatment, recycling and waste disposal in the Organisation for Economic Co–operation and Development (OECD) in 1990 was about $ 200 billion. By 2000, this figure was projected to reach $ 300 billion, and in reality, in 1992 its value reached $ 295 billion, and in 1997 – $ 426 billion [4; 6].

The third reason for the ineffectiveness of the above approaches to environmental protection is the constant creation and use of new chemicals and reagents, the impact of which on the environment is unknown, as well as the impact of the products of their metabolism. The composition of pollutants is becoming more complex, which means the higher cost of recycling and increased toxicity of waste, which contains new compounds.

Another aspect is the tougher approaches of environmental authorities and the increased risk of being prosecuted for environmental pollution. It is often impossible to increase the efficiency of waste treatment just by modernizing existing technologies. Thus, the "end–of–pipe" concept is in conflict with the basic principle of business – the profitability of production.

The way to solve the problem is to apply the "cleaner production" approaches. This strategy allows you to treat the disease, rather than fight its consequences.

Self–assessment questions to subsection 1.1.2.

1. What is the purpose of people's nature protection?
2. What is the purpose of private nature protection?
3. What is the difference between public and international nature protection?
4. What are the differences between anthropocentric and ecological approaches to environmental protection?
6. What is the classic nature protection concept?
7. What is the essence of the technological nature protection concept?
8. What strategy is proposed in the first stage of environmental protection?
9. What strategy is proposed in the second stage of environmental protection?
10. What strategy is proposed in the third stage of environmental protection?

1.1.3. Environmental factors and their assessment as hazards of natural and man–made origin: physical, chemical, and biological components

As human society intensifies scientific and technological progress, there is an increasing environmental risk as a derivative of industrial and construction technogenesis. The most dangerous are the processes of degradation associated with the "matter–into–energy" transition. In particular, the consequence of such transitions is the greenhouse effect as a factor in the global ecological imbalance, local environmental deviations due to accidents, equipment failures, etc. The basis of man–made impact on the environment are monotonous and stepped (abrupt) quantitative transformations, which naturally lead to a qualitatively new state, mostly a lower–level state.

To some extent, the speed of anthropogenic changes in nature depends on the intensity and size of the areas of sources of man–made impact. The reaction of the components of nature is different with regard to the consequences of degradation. With some conventionality, we can assume that degradation processes are faster in the atmosphere than in soils. This circumstance is largely due to the physical density of the environment and the peculiarities of heat, mass, and energy exchange.

When assessing the effects of industrial impact on nature, it is important to determine the available scale of this impact, at which it would not cause harm to humans and nature.

Any impact on nature is characterized by a corresponding reaction of the environment, which is usually expressed in three forms:

- adaptive (with local, static balance shift);
- renewable (self–healing), characterized by the complete return of the ecosystem to its original state;
- partially renewable (or non–renewable), characterized by an irreversible shift of the ecosystem from its initial equilibrium.

Within the considered forms of man–made impact, there is an anthropogenic change in a natural landscape. Therefore, the regulation of anthropogenic environmental factors is a necessary condition for ensuring and maintaining the ecological balance in the "man – nature" system.

The following integral characteristics can be used to assess the impact of industrial technogenesis on the ecological balance in the natural environment:

- absolute environmental losses expressed in specific units of measurement of these biogeocenoses;
- compensatory capabilities of the ecosystem that characterize its rehabilitation in natural and forced modes;
- the danger of disturbing the natural balance, which determines the probability of irreversible losses and local environmental deviations;
- the level of concentration of environmental losses that characterizes the scale of the impact of industrial technogenesis on the environment.

The considered characteristics are marked by their functional variability over time. Therefore, it is advisable to consider them in three–dimensional coordinates.

From the standpoint of the considered physical and mathematical aspects of regional ecology, applied solutions are implemented technically by forming a **closed ecological system**. Closed–loop systems localize opposite processes in themselves, mutually excluding the negative effects of technogenesis.

The correlation aspect of the ecological relationship should be taken into account as a factor in the controlled or spontaneous development of a natural and technical geosystem. As a result, local anthropogenic pressures created in different regions of industrial development shape the environmental situation on a regional scale. Thus, we can talk about its large–scale development on a continental and planetary scale.

As follows from the consideration of two crisis states in the "man – biosphere" system, the processes that took place within it are developing in waves. For a long time, the former life support system of a man has been evolving due to internal mutations, as a result of which it acquired new qualities: increased size of the human population, increased diversity of population and individual needs, increased level of the household culture, reduced meat and plant resources, etc. Until a certain period of time, the life support system objectively becomes incapable of performing its functions. Therefore, even a small perturbation in the system is enough to start its destruction. For example, when a part of the tribe moved to the northern territories in search of new hunting grounds. Or when one of the tribes rose against the neighbors to take control over hunting and plant resources causing a war that led to a decrease in the population of Neolithic man by 70 %, and so on.

From this period of time, an instinctive, chaotic search for a new life support system has started, the essence of which is fundamentally impossible to determine or "to plan". As soon as a new system is established and stabilized, the processes are repeated: the slow evolution of the new system to a critical state → the explosion of the system and the onset of uncertainty (chaos) → the search for a new format of existence.

Self–assessment questions to subsection 1.1.3.

1. What environmental risks arise with the development of scientific and technological progress?

2. Describe the reaction of the environment to any impact on nature.

3. Give examples of characteristics of the assessment of the impact of industrial technogenesis on the ecological balance in nature.

4. Define the term "closed ecological system".

5. What is the nature of the development of crisis states in the "man – biosphere" system?

1.2. MAIN PROPERTIES OF THE BIOSPHERE, PRINCIPLES OF ITS DEVELOPMENT AND CONTRADICTIONS WITH TECHNOSPHERE OBJECTS

1.2.1. Principles of biosphere development as a dynamic system. Component features of the biosphere (technosphere and sociosphere). The place and responsibility of a man in the biosphere

The scientific and technological revolution (STR) has opened up unprecedented opportunities for human life support. At the same time, it also brought big dangers – the human impact on the biosphere has become both global and simultaneous. Thus, with the population "explosion", the mechanical impact of man on the biosphere has sharply increased due to increased extraction of resources, the alienation of new territories to create civilizational infrastructure, and so on.

And, perhaps most importantly, the STR has led to a sharp increase in anthropogenic chemical pressure on the biosphere, in other words, to chemical pollution of all geospheres of the Earth, including the atmosphere, hydrosphere, lithosphere. Pollution has become so significant that from the beginning of the second half of the twentieth century, the Earth's biosphere, i.e. its ecosystems, started facing difficulties in their functioning. Under the influence of chemical pollutants, new surface (on–land), water, and soil (lithosphere) ecosystems became unstable, degraded, and perished. And this process continues. According to some experts, in the next 25–30 years, the Earth's biodiversity may decrease by 25 % [7].

Simultaneously with the chemical pollution, there was intense physical (energy) pollution of the biosphere in the form of electromagnetic radiation (EMR) of the radio frequency range, ionizing and thermal radiation, and vibroacoustic effects. Within the evolutionary process, the emergence of intense EMRs, which are 2–5 times higher than the natural electromagnetic field, may be considered a sudden change with possible negative biological consequences [8].

The same can be said about other types of physical pollution. In addition, a qualitatively new level of biological pollution has formed in the conditions of STR, primarily related to the development of biotechnology and genetic engineering. It is possible, that the companies and laboratories in this field may release microorganisms and biological substances into the environment, which may contribute not only to chemical and physical pollution but also may have extremely harmful effects on flora and fauna, human health and gene pool. It should be added that the STR has led to rapid population growth in developing countries and the world as a whole. Thus, in 1900 and 1950, the ratio of the population of developing countries and developed countries was approximately the same (1,91 and 2,00 respectively), whereas in 2000 it was 4,13 with a total population of 1,630, 2,516 and 6,261 million people respectively [10]. This happened due to the collapse of the colonial system, progress in medicine and health care, the "green revolution" in agriculture, and other achievements of the STR.

On the one hand, this phenomenon is defined as a population "explosion" in real terms, on the other, it is a demographic crisis in social terms. It is characterized by an exacerbation of unemployment, inability to provide people with educational and health care services, a sharp increase in migration from developing countries to developed ones (today migrants make up more than 2,5 % of the world's population), difficulties in providing food for a rapidly growing population, etc [12].

In 1989 when the world population was 5,200 million people, food production allowed to feed 5,000 million people with the minimum amount of food necessary for survival or 3,900 million people with the moderate amount of food or 2,900 million people with the amount of food that corresponds to the modern level of European nutrition [11].

Today the growth rate of the Earth's population is slowing down. For example, by 2025–2030 the population is expected to be 8,5 billion. In 2011, the world's population exceeded 7 billion people [9]. And the main question is what resources will be needed in the future to ensure a decent life for such a large population.

The second half of the twentieth century is characterized by the increasing stratification of countries in terms of income. Thus, in 1984, low–income countries (total population was 611 million people without China and India), China and India

(1,778 million people), middle–income countries (1,188 million people), industrialized countries with market economies (733 million people) had the following per capita gross national product (GNP) in US dollars: USD 190, USD 290, USD 1,345 and USD 11,340, respectively [9; 13].

It is known that in 1990 the number of poor people (with income less than 2 dollars a day) was about 3 billion people [14]. There is a significant stratification with respect to the structure of consumption. More than 40 % of the population, especially in developing countries, is deprived of water and sanitation, health care services and medicines [14]. These countries have not even resolved the issue of primary education.

The main reasons are high unemployment, including due to production automation and informatization, moving the production to lower–cost labor countries, displacing locals from the usual workplaces with immigrants, as well as parasitism of some countries on world reserve currencies and virtualization of modern financial systems. These and many other similar phenomena characterizing the state of world civilization indicate its deep social crisis.

Finally, about the energy crisis. By maintaining the same growth rate of energy consumption, the biosphere will be exposed to such powerful negative consequences that are impossible to predict today. To prevent them successfully, revolutionary changes in saving energy and resource efficiency are needed, which require the transition to completely new devices in industry and everyday life.

Today, GDP per capita in developed countries is 10–15 times higher than in developing ones and 50–100 times higher than in the poorest countries [15]. Significant economic growth is needed to pull the developing countries out of poverty. Given the low level of resource efficiency in these countries, the increase in their consumption and, consequently, the exacerbation of environmental problems are inevitable.

The analysis of the energy crisis shows that the problems induced by the STR are interrelated: demography → population poverty → the need for economic growth → energy consumption growth → environmental degradation. Thus, the current global environmental crisis and the corresponding environmental revolution are as follows.

Crisis No. 7 (second half of the 20th century – beginning of the 21st century). Difficulties in the functioning of ecological systems. Demographic crisis. Social crisis. Energy crisis.

Revolution No. 7. Development of sustainable development concept and its implementation. Resource–ecological regulation of social progress.

Self–assessment questions to subsection 1.2.1.

1. What is the scientific and technological revolution?
2. What are the main consequences of the scientific and technological revolution?
3. What is the cause of the demographic crisis?
4. What are the ways to overcome the energy crisis?

1.2.2. Deterioration of the environment by the middle of the twentieth century. Noosphere concept development

The idea of the noosphere about the reasonable attitude of man to the processes taking place in the biosphere, which Vladimir Vernadsky developed in 1930–1940 almost alone, did not receive recognition from contemporaries. Thus, in 1948, the UN General Assembly, adopting the Universal Declaration of Human Rights, did not consider it appropriate to declare a human right to a favorable environment, because by this time the negative impact of the already polluted environment on human health has been relatively weak and non–systematic.

Although at this time and even earlier, some prominent scientists (Vladimir Vernadsky, Niels Bohr, etc.) noted that the "victorious" course of scientific and technological progress will inevitably lead to a catastrophic deterioration of human living conditions in the natural environment and to a resource crisis [22].

Meanwhile, in the period from 1950 to 1970, after the restoration of the economy destroyed by war, world industrial production and energy consumption increased three times, metal consumption increased almost four times, fertilizers use increased five times, grain production increased two times, annual ammonia consumption per capita increased four times, ethylene consumption increased almost seven times, chlorine increased three and half times [23].

In the 1950s, a sense of danger due to excessive stress on the environment first arose in a limited number of scientists – geographers, biologists, physicists, chemists, geologists, and physicians. The monitoring of the carbon dioxide concentration in the atmosphere and acid rains, the implementation of the international scientific program called The International Geophysical Year, smog in a number of industrialized countries, pollution of the Great Lakes in the United States, mercury poisoning in Japan, etc., played the key role. Some of these phenomena and events were subjected to in–depth analysis with practical implications. The other part did not receive publicity at first. It can be illustrated by many cases of occupational diseases due to exposure to chlorine–containing chemical compounds, which appeared as a result of accidents at chemical plants in 1949 in the United States, then in Japan and other countries.

The global environmental changes and local ecological catastrophes that were revealed as result have contributed to the realization of this problem primarily by industrialized countries, which were major consumers of energy and other resources and major polluters of the environment.

A precedent was needed after which premonitions about the impending trouble would turn into a systematic understanding of realities and active action to eliminate these trends. And the precedent in the form of the Great Smog of London (Fig. 1.2) in December 1952 did not take long to appear. According to official figures, during December 5–9, 1952, smog in London killed 4,000 people, primarily infants, old people, and people suffering from respiratory diseases. In fact, according to the authorities, the consequences of the smog were even more terrible: 12,000 died and 100,000 people fell ill during this period [2].

And the ice has been broken: the society began to realize the dramatic confrontation with the destructive industrial activities of man. This initiated systematic studies of industrial emissions, discharges, solid wastes, processes of pollutants distribution in the atmosphere, soil, surface and underground waters, their maximum admissible concentrations, research in the field of standardization of emissions and discharges, waste disposal, treatment facilities, low–waste technologies, formation of the regulatory and legal framework of environmental protection and nature management.

Fig. 1.2. Great Smog of London

With the constant increase in man–made pressure, attention to environmental issues shifted to the level of parliaments, governments, and international organizations. Thus, the Clean Air Act was adopted in Great Britain in 1956. In 1962, the UN General Assembly adopted a resolution on economic development and the conservation of nature, and in 1968 – on the crucial role of a favorable environment for human rights and proper economic and social development [16]. By the early 1970s, the first state bodies for environmental protection were introduced: in Sweden – in 1969, in the United States, Canada, Great Britain – in 1970, and in Japan – in 1971.

In 1968, the public figure, businessman and financier Aurelio Peccei (Fig. 1.3) founded the Club of Rome – an informal organization of prominent scientists, entrepreneurs, and statesmen. At the request of the Club of Rome, for the first time in history, under the direction of Professor Jay W. Forrester of the Massachusetts Institute of Technology, an attempt was made (1970–1972) to describe the dynamics of human society and its environment as a single integrated system with the assumption that the pace and nature of world economic development and the corresponding pollution and depletion of resources will preserve [17].

Numerous experiments have shown that while maintaining the current trends in the economy (sustainable economic growth) in a certain period of time (according to the authors, in the 2070s) one should expect a catastrophic decline in population and industrial capacity.

The work was a bombshell and became a bestseller in the early 1970s. In a certain aspect, it became a landmark event after the Great Smog of London in 1952, demonstrating the organic viciousness of the current system of economic development, in which in fact the only criterion for progress is economic growth [17].

Fig. 1.3. Aurelio Peccei

In the course of the study, the authors – outstanding experts in the field of system dynamics, modeling of large–scale social systems – concluded that "... it is possible to alter these [economic] growth trends and to establish a condition of ecological and economic stability that is sustainable far into the future. The state of global equilibrium could be designed so that the basic material needs of each person on earth are satisfied and each person has an equal opportunity to realize his individual human potential. If the world's people decide to strive for this second outcome rather than the first, the sooner they begin working to attain it, the greater will be their chances of success" [12].

The world's first report of the Club of Rome – the presentation of the book "The Limits to Growth" in March 1972 – received a huge resonance. And a series of subsequent reports to the Club of Rome influenced discussions and decisions in the field of environmental protection and economic development at the level of governments, intergovernmental meetings, and UN conferences on the environment and development.

In 1972, the United Nations Conference on the Human Environment held in Stockholm adopted the Declaration, which consists of principles for the attitude of the world community on environmental problems, and the Action Plan, which provides practical solutions to organizational, economic, political issues of environmental protection and relations between states and international organizations [18]. The Stockholm Conference first stated that an acceptable ecological regime of development could be ensured only with a reasonable solution to environmental issues by using natural resources in the most efficient way and minimizing the man–made impact of the technosphere on the biosphere. The Stockholm Conference accelerated the processes of studying the environment, monitoring its components, and establishing special bodies at the national and international levels that direct and coordinate activities for environmental protection and the development of resource–saving technologies. State bodies for environmental policy have emerged in many countries. Most of them began to provide statistics on the state of the environment in their countries and prepare annual reports on this topic.

Public awareness of the first troubles in the state of the environment, and later, in the middle of the twentieth century, the emergence and development of the global environmental crisis caused that a number of international environmental organizations was established. These organizations can be divided into three groups:

• Environmental ones: United Nations Environment Program (UNEP), 1972; International Union for Conservation of Nature (IUCN), 1947; GREENPEACE International Non–Governmental Organization, 1971;

• With an integrated nature protection profile: Food and Agriculture Organization of the United Nations (FAO), 1945; World Health Organization (WHO), 1946; World Meteorological Organization (WMO), 1946;

• With a special environmental profile: International Atomic Energy Agency (IAEA), 1957; International Register of Potentially Toxic Chemicals (IRPTC) that was established as part of UNESCO and collected information on more than 600 such substances, and other international organizations for the protection of the seas from pollution, fish stocks, migratory birds, etc.

The governments have started to develop environmental legislation intensively. For example, before the Stockholm Conference, only 32 environmental laws were adopted in all countries of the Organization for Economic Cooperation and Development (OECD), whereas by the end of 2010, their number had increased massively. The OECD consists of 34 countries, which account for 60 % of global GDP [9].

Many countries are developing targeted programs to solve environmental issues, create low–waste and resource–saving technologies, new water and gas treatment systems, and expand material recycling. Thus, since the beginning of the 21st century, European Union environmental authorities have been setting requirements for enterprises, facilitating their transition to the use of the best available techniques (BAT), which should ensure human safety in production and the environment and the highest efficiency use of energy and other resources. Today, these requirements are formulated for 26 industries and 7 general areas [26].

Serious articles on environmental protection began to appear in special literature and in the media only in the late 1960s – early 1970s. The anxiety that began to spread over the world community could not but affect the content of domestic ecological and environmental publications. However, the global surge of interest in environmental issues was reflected in our country only in the 1980s, which is partly due to the late establishment (in the late 1980s) of the Environmental Protection Agency.

After the Stockholm Conference, significant positive changes took place in the world: the remote sensing of environmental components based on aerospace means was introduced; a number of international programs for the study of the environment, such as "Man and the Biosphere" (since 1971), "World Ocean Research Program" (since the early 1950s), etc. were implemented; international conventions in the field of animal protection (on trade in rare animals, on the protection of Antarctic marine organisms), pollution of the seas (from ships and washing of oil tankers), air protection (Montreal Protocol on the Protection of the Ozone Layer, etc.) were signed. Actions taken at the regional level: Protocol for the Protection of the Mediterranean Sea against Pollution, signed by 12 states; coordinated environmental measures of OECD countries in the field of transboundary movement of sulfur dioxide and nitrogen oxides; multilateral agreements on international water bodies in Europe and other parts of the world, etc. [19].

These and other measures have led to a number of important achievements: the content of lead in the air has decreased, the condition of Lake Erie in the United States, the Rhine and Thames rivers in Europe has improved, and so on. These achievements of industrialized countries have shown that the affected nature can be treated successfully. However, during these years, developed and developing countries began to export polluting highly toxic industries. By the end of the 1970s, it became clear that the state of the environment was connected with other problems on a global scale: the growing gap in income levels of different social groups, demographic situation, political processes, etc.

Self–assessment questions to subsection 1.2.2.

1. What are the harmful effects of machinery and technology on the environment?

2. What is the history of human awareness of all the consequences of technological progress?

3. What is the purpose of the noosphere concept?

4. How did environmental activities develop in Ukraine?

SECTION 2. COMPREHENSIVE ASSESSMENT OF ENVIRONMENTAL SAFETY AT THE REGIONAL, STATE, AND GLOBAL LEVEL

2.1. GENERAL CHARACTERISTICS OF MODERN TECHNOLOGIES AND THEIR IMPACT ON THE ENVIRONMENT

2.1.1. Contradictions that arise between natural ecosystems and production

An **ecosystem** is a community of different species of plants, animals, and microbes that interact with each other and with the environment in such a way that the community can be preserved for an indefinite period of time.

It is known that depending on the geographical location, a specific landscape predominates in one or another part of the globe. Each of the landscapes is characterized by a special plant community, i.e. a certain group of plants. Each such community is characterized by a certain group of animals. Finally, any ecosystem is associated with an inconspicuous but distinctive group of microbes.

Such communities have existed long before the emergence of man and can exist indefinitely if they are not affected by man. Each such community is called an ecosystem.

Quite large terrestrial ecosystems are called **biomes**. Such systems include temperate forests, steppes, deserts, coniferous forests, tundra, savannah, and tropical forests.

Biomes include a number of smaller interconnected ecosystems. Some of them can be very large and occupy millions of square kilometers, whereas others may be the size of a small forest or field.

There are also a huge number of types of aquatic ecosystems – streams, rivers, lakes, ponds, swamps – each with its own group of plants, animals, and microorganisms. The oceans can also be divided into separate ecosystems, i.e. coral reefs, continental shelf, abyssal, etc.

The separation of various ecosystems in the landscape is quite conditional. Clear boundaries between them are rare. Usually, there is a transition zone between ecosystems or biomes with species and features inherent in both neighboring systems. Sometimes their contacts affect the specific characteristics of the environment that determine the existence of special species of plants and animals, which are characteristic only of this transition zone, which, therefore, can be considered as a separate ecosystem itself.

Ecosystems are not isolated from each other. Many species of plants and animals can be found in two or more different ecosystems. Some species, such as migratory birds, migrate between ecosystems depending on the season. Processes that take place in one ecosystem inevitably affect another. Thus, soil particles and nutrients washed out from land affect life in water bodies. That is, all ecosystems are interconnected and interdependent.

Humans, along with their cultivated plants and domestic animals, also form a group of organisms that interact with each other and with the environment. It is a human ecosystem that interacts with all ecosystems on the Earth. All Earth's ecosystems are interconnected and together form a single whole – the biosphere. For each organism, there is an optimum, stress zones and limits of stability to every abiotic factor. If the optimums and limits of stability of different species differ, their common ranges of stability may overlap.

With optimal values of all abiotic factors, if the value of at least one factor differs from the optimal one or is outside the range of stability, the organism falls into a state of stress or dies. This factor is called a **limiting factor**.

A limiting factor can be any abiotic factor that affects the growth and development of the organism. The law of limiting factors – the law of the minimum – was first formulated by Justus von Liebig (1840) [30].

Thus, the dependence of organisms on abiotic and biotic factors, the optimums of which are different for different organisms, led to the formation of different ecological systems. The main reason for the differences in ecosystems is the uniqueness of the abiotic conditions of each region. The population density of any species will be highest where the parameters of the environment are optimal for it. The population density will decrease where the values of one or more parameters of the environment will be stressful for this species. Where the value of at least one abiotic factor is beyond the stability of this species, such species is absent.

Two abiotic factors – temperature and precipitation – largely determine the location on the earth's surface of major terrestrial biomes. The temperature and precipitation regime in a certain area that is held for a long time is called **climate**.

Many abiotic factors, including relief, wind, soil type, etc., are manifested indirectly – through temperature and humidity. They affect local conditions in a particular climate zone. Such local conditions are called **microclimate**. Due to species competition, biotic factors may also be a limiting factor.

The main advantage in the organization of natural ecosystems is the ability to maintain its stable state for an indefinite period, without suffering from resource depletion and pollution by its own waste.

The main biogenic substances for natural ecosystems are carbon, hydrogen, oxygen, nitrogen, phosphorus, and sulfur. Potassium, calcium, and magnesium are also present in living organisms. In addition to these elements, a number of trace elements – iron, manganese, boron, zinc, copper, molybdenum, and chlorine – are found in living organisms.

All ecosystems function by exchanging *substances* and *energy*. A substance consumes space and has mass. The smallest particles of a substance are elementary particles (protons, neutrons, electrons, etc.). Energy is the ability to do work. It has no mass and does not consume space.

The main principle of ecosystem stability is the species diversity of these systems. In other words, the species diversity ensures ecosystem stability.

Primitive people lived in small tribes by hunting and gathering fruits and seeds. Hunter–gatherers did not differ much from other consumers of the 2nd–4th levels. However, about 10 000 years ago, a revolutionary event took place – agriculture emerged. With its development, people began to create their own human ecosystem, which was different from natural ecosystems. Guaranteed food supply and division of labor made it possible to create permanent settlements which were villages at first and then to establish natural cities. People were able to engage in the production of additional material goods.

In terms of "capacity", the ability to reproduce, grow and spread, the human ecosystem is an exception to other ecosystems. This has allowed people to increase their numbers from several hundred thousand to more than 7 billion and to settle all over the planet. To some extent, human abilities have allowed people to overcome or weaken the usual limiting factors, such as the availability of food, water, temperature level, danger from predators and parasites, to win the competition with other species, at least temporarily. That is, by overcoming the natural limiting factors to some extent, a man was able to extend his ecosystem to the entire known world on Earth.

People were able to weaken or reduce the effect of limiting factors by:

- producing sufficient food, albeit with uneven distribution;
- creating water supply systems, reservoirs, irrigation and reclamation systems;
- creating protection means against parasites, diseases, killing or neutralizing predators;
- building houses and regulating temperature in them;
- winning the competition with other species.

The growth of the human ecosystem to gigantic proportions has taken place and continues to progress due to the destruction and ruining of natural ecosystems with deforestation, forest burning, plowing, and housing development of huge areas in the struggle for space. "Predatory" use of natural resources and environmental pollution cause serious damage to ecosystems.

There is no ecosystem on the Earth that has not been affected by man and many of them, especially small ones, have been completely destroyed. Large ecosystems have been significantly affected too. Even entire biomes, such as the steppes, have almost disappeared from the face of the Earth, whereas forests, especially tropical ones, are rapidly approaching this point of no return. About 100 thousand sq. km of forests are destroyed every year.

We must not forget that the containment of natural limiting factors for the human ecosystem is a temporary phenomenon. In addition, even a single factor that does not correspond to the optimum zone leads to stress and threat to the body, and the change of any biotic or abiotic factor causes a chain reaction and leads to unpredictable consequences.

Despite the fact that the human ecosystem is currently in a stage of rapid growth, no one is able to change the law of limiting factors or avoid its action. Therefore, it is quite logical to ask the following: "What will happen when certain natural resources are depleted?"

Today, people have succeeded greatly in creating the conditions for their rapid reproduction and spread. But are the conditions for the long–term sustainability of ecosystems taken into account?

It is known that natural ecosystems, characterized by long–term sustainability, operate according to certain principles that determine their viability.

According to the first principle in natural ecosystems, the use of resources and waste disposal are carried out within the circulation of elements. The development of any species occurs in strict accordance with the nature of the circulation of certain elements under the influence of natural factors.

Human economic activity brazenly violates the laws of circulation of both biogenic substances and inorganic components of the biosphere. So, today the reserves of phosphorus compounds available on continents are used mercilessly. With the products of life and wastewater, these substances get into water bodies, disrupting their living conditions, destroying aquatic ecosystems, and eventually being discharged into the oceans. At the same time, the reverse migration of phosphorus due to natural processes is millions of times lower than the rate of depletion of its reserves on land. There are many such examples. Resources are depleted and waste poisons the environment. For most types of fossil organic and inorganic substances, the natural cycle is severely disrupted.

Regarding the second principle, natural ecological systems exist due to excess solar energy, which is inexhaustible, does not lead to environmental pollution, and is unlimited in terms of reserves and time of use.

Today, in a technocratic society the main sources of energy are fossil fuels and nuclear energy. But they are associated with air pollution, acid rain, the greenhouse effect, ozone anomalies, and radioactive pollution.

According to the third principle, there can be no significant biomass at the end of long food chains.

Over the last 100 years, the number of people has grown at a phenomenal rate – by more than 90 million people a year. All this was accompanied by high intensive growth in food production with the constant expansion of sown areas over natural ecosystems. How far is it to the maximum level of food production?

2.1.2. Anthropogenic impact on the balance of ecosystems. Sustainability of the human ecosystem

According to one of the ecological principles, the size of the population is the result of a dynamic balance between abiotic potential and environmental resistance.

At the beginning of the human era, the size of the human population, like many others, was determined by environmental resistance.

For humans, the main parameters of environmental resistance were food shortages, diseases, and epidemics. The development of production, improvement of sanitary living conditions, development of medicine, vaccination campaigns, and other achievements have led to a population explosion that continues today. The sharp increase in the number of people is a result not so much of the birth rate as the increase in the survival rate of children due to the development of medicine.

The human population depends on the same laws as any other. When there is no environmental resistance, the population explosively grows. But unlike other living beings, humans have reduced the environmental resistance themselves by violating all natural balances at the same time.

In natural ecosystems, population growth leads to an increase in environmental resistance, and its decrease is accompanied by a decrease in environmental resistance. In the case of humans, there is no such inverse relationship. Often the increase in the number of people leads to the destruction of other populations, regardless of their number, and the resistance of the natural environment is reduced, or at least does not increase.

Given that the period of development of the organic world (living matter) on the Earth is about 4 billion years, the period of human existence is negligible, compared to many other species. The main condition that determines the viability of a species is its ability to establish and maintain balance with other species within the ecosystem, which ensures an efficient cycle of substances, nutrients, and a stable flow of energy and, therefore, long–term existence.

Mankind has created a system based not on balance, but on the growing consumption of natural resources and reduction of the genetic diversity of the biosphere, which in general catastrophically quickly destroys the sustainability of the human ecosystem and significantly shortens the period of its existence.

Self–assessment questions to subsection 2.1.2.

1. What is a system?
2. What are ecosystem biomes?
3. What are the main components of ecosystems?
4. What is the law of the minimum?
5. What is a limiting factor?
6. What limiting factors exist for the human population?
7. How is it possible to reduce the effects of limiting factors on the human population?
8. What is the impact of man on the functioning of ecosystems according to the first principle?
9. How does man affect ecosystems according to the second and third principles?

10. What determines the existence of the human population?

11. What components can human anthropogenic impact on the balance of ecosystems be divided into?

2.1.3. Causes of global environmental problems in Ukraine and the world as a whole

During the development of technology and machinery, often people no longer understand the possible harmful effects of the introduction of new machines, substances, and processes. This happened with the invention of the well–known pesticide – DDT (dichlorodiphenyltrichloroethane) – and its use to control agricultural pests. Its creator received the Nobel Prize, however many years later it was discovered that this drug is toxic to all living things and dangerous to humans.

Large–scale human economic activity causes not only local but also planetary consequences. For example, the greenhouse effect, which is expressed in rising temperatures on the Earth as a result of emissions of huge masses of carbon dioxide (and about 10 other gases called greenhouse gases) into the atmosphere by plants, vehicles, and utility companies. This "excess" gas for the biosphere can not be absorbed by the flora of the Earth, especially since there is a constant reduction in forest areas. The phenomenon of the greenhouse effect is so serious that after many years of heated discussions, the vast majority of climatologists have come to the conclusion that global warming has a man–made nature (which is especially noticeable in the Northern Hemisphere).

Unfortunately, the problem of climate change on the Earth due to greenhouse gas emissions is just one of many related to the progression of the current resource and environmental crisis.

Man's awareness of the impending crisis has its own history. The catastrophic decline in the number of animal species and forest areas due to the industrial and technological revolution became apparent by the early twentieth century. This provoked a public movement for nature protection, led by scientists, educated people, statesmen, and public figures.

During this period, a system of national parks (the first of them was Yellowstone National Park, USA, 1872) and then reserves (Kronotsky Nature Reserve, Russia, 1882, Crimean Nature Reserve, Ukraine, 1913) was created in the world. The creation of reserves was supported by Pyotr Semyonov–Tyan–Shansky – a prominent Russian scientist. The mass movement for the protection of the environment in Ukraine began in 1905–1906 with the emergence of ideas in Ukrainian society related to the protection of natural monuments. At first, it consisted mainly of highly educated people – natural scientists and wealthy landowners. The main forms of organization were societies of natural researchers, which conducted an inventory of natural monuments and their protection, as well as spread environmental knowledge. In 1911, Professor of Botany Valery Taliev founded the Kharkiv Society of Nature Lovers and organized the publication of a gazette of this society. In 1913, he published a popular science book "Protect Nature". In the same year, the Kharkiv Society of Nature Lovers organized the first nature protection exhibition in the Russian Empire, which was later shown in Kyiv. At the same time, international conventions were concluded, for example, on plant protection (1881), control of vineyard pests – phylloxera (1889), protection of agricultural birds (1902), fishing in the waters of the Danube and Prut (1907), protection of seals in the North Pacific (1911), regulation of fishing for sea and river flounder in the Baltic Sea (1929); international treaties regulating salmon fishing in the Rhine basin (1886), sea turtle fishing (between Great Britain and Nicaragua, 1916), and so on.

Natural–engineering geosystem (NEGS) is a system that includes engineering structures (a set of engineering structures) with part of the environment in the area of their (its) influence, which has operationally fixed space and time boundaries.

The man–nature system is an open natural–engineering system.

The global man–nature system can be considered at the level of major global systems, primarily related to the reducing non–renewable and poorly renewable resources, acreage reduction, and increasing construction rate.

The national man–nature system considers the main features of the problems associated with the development and man–made changes in the state of the natural environment in the country.

Regional man–nature NEGSs are considered in terms of addressing strategies and tactics of environmental management within the region.

A detailed man–nature NEGS is a system within cities and urban agglomerations.

Local NEGSs are systems made to implement methods of environmental management in certain areas where hazardous man–made processes develop.

The analysis of the man–nature system within the given boundaries of geospace is to determine the evolution conditions of this system under the influence of production facilities. The system evolutionize due to the energy of the Sun, the internal heat of the Earth, and due to man–made factors. The dynamics of the system depend on two main components: aimed human activity and the existing natural environment.

The spatial framework of the NEGS allows to control the entire study area with the specified detail for management decisions.

Self–assessment questions to subsection 2.1.3.

1. What are the harmful effects of machinery and technology on the environment?

2. What is the history of human awareness of all the consequences of technological progress?

3. Analyze the man–nature system.

4. What are the characteristic reactions arising from the anthropogenic impact on nature?

2.2. THE INFLUENCE OF INDUSTRIAL SECTORS ON THE ENVIRONMENT

2.2.1. General characteristics of the industrial technogenesis structure

The problem of environmental protection is one of the most important tasks of our time. Today, emissions of industrial enterprises, energy sector, transport into the atmosphere, reservoirs, and subsoil have reached such proportions that in some areas, especially large industrial centers, pollution levels significantly exceed the permissible sanitary norms.

The main danger is air pollution. In addition to the intensity of emissions, concentrations of harmful impurities in the atmosphere are affected by meteorological conditions. As for the intensity of air pollution of the surface air layer, the inversion of temperature in the atmosphere is an undesirable phenomenon.

Anthropogenic emissions into the atmosphere not only have a negative impact on the environment and human health but also have a significant impact on the operating conditions of technical means.

When considering a range of issues related to environmental protection, issues related to the negative impact of noise, infrasound, and ultrasound on human health are often not duly reflected.

In some cases, there may be "pollution" of the environment by thermal emissions, electromagnetic fields, ultraviolet, infrared, light, and ionizing radiation.

Environmental research conducted in recent decades in many countries around the world has shown that the growing destructive impact of anthropogenic factors on the environment has brought it to a critical state. Among components of the environmental crisis, the issue of air, water, and soil pollution by industrial and transport waste has become the most threatening.

As a result, the role of industrial ecology, which should develop and improve engineering and technical means of environmental protection, approaches to create closed and low–waste technological cycles and industries by assessing the scale of industrial impacts on the environment, has increased dramatically in modern society.

The problem of environmental protection is global and must be addressed at both the national and international levels.

Today, the main air pollutants are metallurgy, energy sector, fuel and chemical industries.

Transport plays a significant role in air pollution in large cities, often reaching 50–70 % of total emissions.

In solving environmental problems, serious difficulties arise due to the specifics of many industries, which, as a rule, require an individual approach to organize effective environmental protection.

2.2.2. The impact of electricity on the environment

Today, most of the energy is produced by burning and processing natural organic raw materials – coal, oil, gas, oil shale, and peat. In Ukraine, a significant part of electricity is produced by nuclear power plants. Despite the Dnieper River System of Dams, hydroelectric power plants provide a relatively small part of electricity.

Depending on the properties of the primary resources used, power plants affect the environment in different ways with the waste of their production: pollute the air basin with combustion products, cause thermal pollution of the atmosphere, pollute water bodies with wastewater, determine the ecological status of hydroelectric power plants, cause electromagnetic radiation (high voltage lines) or radioactive contamination (nuclear energy), etc. At the same time, certain territories are often withdrawn from use.

The air basin and surface waters are most affected. The construction of hydroelectric power plants has a significant impact on the state of the environment due to the creation of reservoirs. The creation of reservoirs has its advantages but often leads to exacerbation of environmental issues: loss of runoff water due to water evaporation, flooding, loss of fertile soils, deterioration of water quality, etc.

In the energy sector, the main sources of pollution are thermal power plants, the operation of which is accompanied by significant emissions of toxic substances, aerosols, and greenhouse gas – CO_2.

Nuclear power plants have a special impact on the environment. The source of potential danger is the entire process of the nuclear fuel cycle – from the extraction of radioactive material to the disposal of irradiated fuel. Nuclear power plants are also characterized by significant thermal pollution of wastewater.

Typical emissions of the power plants are sulfur dioxide, carbon oxides, nitrogen oxides, soot, vanadium (V) oxide, and benzopyrene.

The energy sector is characterized by large volumes of water used. In terms of water consumption, it is among the leaders. The most of water is used in cooling systems.

Pollutants, including petroleum products, sludges, chlorides, sulfates, heavy metals, and specific substances, are discharged into water bodies through wastewater.

2.2.3. Ferrous and non–ferrous metallurgy

Ferrous metallurgy is one of the largest industries in Ukraine. However, most plants are obsolete, characterized by high levels of energy consumption and low levels of environmental safety.

Ferrous metallurgy has the greatest impact on atmospheric air and surface water, as well as on the level of pollution of ground and underground water, soil.

The main emissions into the atmosphere are carbon oxides, sulfur dioxide, nitrogen oxides, aerosols, and dust.

The main amount of water (≈ 75 %) is used to cool the structural elements of metallurgical furnaces and machines. In this case, the water is only heated and practically not polluted. Up to 20 % of water is used to cool equipment (e.g. rolling mills) by direct contact, to transport mechanical impurities (sludge, scale), etc. The water is not only heated but also contaminated with metal and other insoluble and soluble impurities.

Wastewater is mainly contaminated with sludge, sulfates, chlorides, iron and heavy metal compounds.

According to the aerospace survey of snow cover, the area affected by ferrous metallurgy plants can be 60 km.

The impact of non–ferrous metallurgy on the state of the environment is similar to the impact of ferrous metallurgy on the environment.

Atmospheric pollution by non–ferrous metallurgy enterprises is characterized mainly by emissions of sulfur dioxide, carbon oxides, and dust.

Sources of harmful emissions in the production of alumina, aluminum, lead, tin, zinc, copper, and nickel are various types of furnaces, crushing and grinding equipment, converters, drying units, material loading and unloading facilities, open warehouses.

Non–ferrous metallurgical wastewater is contaminated with minerals, flotation reagents, heavy metal salts, arsenic, fluorine, mercury, antimony, sulfates, and chlorides.

A big problem is huge volumes of metallurgical sludge and slag.

2.2.4. Oil, refining, chemical, and petrochemical industries

The production activity of the oil industry leads to the following environmental impacts:

- withdrawal of land resources for the construction of oil production facilities, soil disturbance and contamination;
- emission of pollutants into the atmosphere, wastewater discharges into surface and groundwater;
- extraction of highly mineralized waters with oil;
- drilling waste disposal;
- accidental oil spills.

The oil production facilities have the main negative effect on the air. The main part of emissions (98 %) is liquid emissions and gases. Among the pollutants, there are hydrocarbons (48 %), carbon oxides (33 %), and solids (19 %).

Accidents on drilling rigs and platforms, as well as on main gas and oil pipelines cause additional damage to the environment.

The volume of wastewater discharges from oil production facilities is insignificant.

Oil refineries are major sources of air and water pollution. The main sources of pollution are sulfur extraction process, fluidized–bed catalyst cracking regenerators, heaters and boilers. In addition, potential contaminants may be storage tanks for raw materials and products, water and oil separators.

Oil refineries pollute the atmosphere with emissions of hydrocarbons (73 %), sulfur dioxide (18 %), carbon oxides (7 %), and nitrogen oxides (2 %).

They use a large volume of water. With wastewater, a significant amount of petroleum products, sulfates, chlorides, nitrogen compounds, phenols, and salts of heavy metals are discharged into the water bodies.

Oil refineries are sources of soil contamination with petroleum products. The chemical and petrochemical industries are characterized by a large number of different pollutants.

The main sources of harmful emissions into the atmosphere are the industrial production of acids (sulfuric, hydrochloric, nitric, phosphoric acids), rubber products, phosphorus, plastics, dyes, artificial rubber, fertilizers, solvents, and cracked oil.

The structure of emissions is as follows:

- solids – 13,4 %;
- volatile substances – 86,6 %, including:
  - carbon dioxide – 32,6 %;
  - volatile organic compounds – 21,1 %;
  - sulfur dioxide – 19,3 %;
  - carbon monoxide – 8,8 %;

- hydrocarbons – 4,8 %.

In addition, these production facilities are sources of mercury, vanadium oxide (V), and hexavalent chromium emissions. Large volumes of water are used in the pulp and paper industry.

2.2.5. Coal industry

In terms of environmental impact, the coal industry is one of the most harmful industries.

The main coal consumers are power plants, industrial and utilities sector, coke plants, households, and agriculture.

The main types of negative impact are the following:

- land withdrawal and soil disturbance;
- depletion of water resources and violation of the hydrological regime of groundwater and surface water;
- pollution of groundwater and surface water bodies when discharging industrial and domestic wastewater of enterprises and municipalities;
- air pollution by solid and gaseous emissions during coal mining, processing, and combustion;
- earth's surface pollution the with waste due to coal mining, coal and shale gas enrichment.

The main problems of coal basins are purification of mineralized mine waters with high content of chlorides and sulfates. With the wastewater of the coal industry, a large amount of sludge, sulfates, chlorides, petroleum products, iron, copper, nickel, aluminum, magnesium, manganese, and formaldehyde is discharged into the water bodies.

2.2.6. Machinery

The machinery industry has the highest rates of development of new products compared to other industries. And this means the use of new technologies which are new sources of environmental pollution. In addition, machine manufacturing facilities are usually located in large cities and therefore are especially dangerous for the population.

The main sources of air pollution are foundry production, machining shops, welding shops, painting shops. Emissions typically include carbon oxides, sulfur dioxide, various types of dust and aerosols, nitrogen oxides, xylene, toluene, acetone, gasoline, butyl acetate, ammonia, ethyl acetate, sulfuric acid, manganese, chromium, and lead. Hexavalent chromium emissions are particularly dangerous.

The machinery industry pollutes the water basin with sewage from etching and galvanic shops. Such sewage releases a large amount of pollutants, primarily petroleum products, sulfates, chlorides, sludge, cyanides, ammonia, nitrates, salts of iron, copper, zinc, nickel, chromium, molybdenum, phosphorus, cadmium.

2.2.7. Utilities sector

The operation of housing and utility service companies has a negative impact on the environment due to the following reasons:

- they collect large volumes of natural water for drinking and industrial water supply;
- they discharge untreated or insufficiently treated domestic and industrial wastewater into water bodies, as well as there is surface runoff from urbanized areas;
- there are emissions into the atmosphere from boiler rooms, district heating systems;
- household and industrial waste is disposed of in organized and unorganized landfills;
- there is the urbanization of natural areas.

2.2.8. Agriculture

The main sources of agricultural negative impact on the environment are related to the use of chemicals – mineral and organic fertilizers, pesticides.

Significant damage is caused by erosion, reduction of humus content and basic elements for the mineral nutrition of plants.

Large livestock and poultry farms are the sources of danger to the environment.

Improper storage of fertilizers and pesticides causes pollution of the environment as well.

Self–assessment questions to subsection 2.2.

1. Which industrial facilities are the main polluters of the air basin today?
2. How can the environmental impact of nuclear power plants be assessed?
3. What is the impact of ferrous and nonferrous metallurgy on the environment?
4. What are the main sources of environmental pollution in the chemical industry?
5. What are the main directions of solving the problem of the negative impact of the coal industry?
6. What are the main sources of air pollution in the machinery industry?
7. What are the main examples of the negative impact of public utilities on the environment?
8. What is the negative impact of agricultural production on the environment?

2.3. SOURCES, CONSEQUENCES, AND SCALE OF ATMOSPHERIC POLLUTION

2.3.1. Functions of the Earth's atmosphere. The ozone layer in the Earth's atmosphere and its role in life on the planet

The atmosphere is the outer gas layer of the Earth. It is a part of the biosphere and consists of a mixture of gases. The total mass of the atmosphere reaches approximately $5{,}15 \cdot 10^{15}$ tons. About 50 % of the total mass of the atmosphere is concentrated in the layer up to a height of 5,5 km and 99 % is in the layer up to a height of 40 km.

Atmosphere functions:

- it regulates the Earth's climate and daily temperature fluctuations (if the atmosphere did not exist, the daily temperature fluctuations on Earth would reach ± 200 ^{0}C);
- it transmits thermal radiation of the Sun;
- it retains heat and acts as a moisture carrier;
- it is a medium for the propagation of light and sound (there would be total silence without air on the planet);
- it is a source of oxygen for living organisms;
- the main processes of the biosphere – photosynthesis and energy exchange – take place within the atmosphere.

Atmospheric air is one of the main sources of life on the Earth. A person cannot live without air for more than 5 minutes. The human need for air depends on his general condition, conditions of work and it is in the range of 15 to 150 thousand liters per day.

The history of the origin and development of the atmosphere is quite complex and long. The atmosphere is about 3 billion years old. During this period, the composition and properties of the atmosphere have changed many times, but scientists believe that they have stabilized over the past 50 million years.

With altitude, the density and pressure of the atmosphere decrease sharply and the temperature changes unevenly. In relation to these changes, in the vertical direction, the atmosphere is divided into:

- troposphere;
- stratosphere;
- mesosphere;
- thermosphere;
- exosphere;

- geocorona.

The ***troposphere*** is the near–surface layer of the atmosphere with an average thickness of 11 km (it is 8–10 km above the poles and 16–18 km above the equator). It accounts for ¾ masses of the entire atmosphere. Within it, the air is in the molecular state. The troposphere is heated by the Earth. With altitude, the temperature decreases by an average of 0,5 ^{0}C per every 100 m. The troposphere contains up to 80 % of all moisture, there is very intense vertical and horizontal air movement.

The ***stratosphere*** (up to a height of 40 km) is characterized by a constant temperature – 90… –70 ^{0}C, low moisture content, and low barometric air pressure. In the stratosphere, there is an increase in ozone content, and therefore it is also called the ozone sphere, which protects the biosphere from ultraviolet radiation. Maximum ozone is concentrated at an altitude of 20–25 km.

In the **mesosphere** (up to 80 km), the temperature first increases with altitude (up to 50–60 km) and then decreases to –100 ^{0}C.

The ***thermosphere*** (ionosphere) is at a height of 80 to 1000–1200 km. There is a high concentration of electrons and positive ions. The temperature varies in the range of 1000–1400 ^{0}C. The thermosphere protects the biosphere from ultraviolet and X–rays.

The ***exosphere*** (up to 20,000 km) consists of ionized hydrogen with minor impurities of helium. This is a shield that protects the biosphere from high energy electrons. The temperature reaches 1600 ^{0}C.

The ***magnetosphere*** is the space above the atmosphere in which the Earth's magnetic field is formed. The magnetosphere protects the biosphere from the direct influence of the flow of high–temperature solar plasma which consists of very high–energy particles and strong magnetic fields. The Moon and Mars are not protected by their magnetic field and are constantly exposed to solar plasma, which helps to sinter the surface layer of dust and turn it into a relatively strong spongy mass.

2.3.2. Gas composition of the atmospheric

The atmosphere that exists today on the Earth did not always have such a composition. According to geological data, the original atmosphere of the Earth differed from the current one. It was similar to the atmosphere of some other planets in the Solar System, such as Venus, and consisted almost entirely of carbon dioxide with impurities of methane, ammonia, etc. The current oxygen–nitrogen atmosphere of the Earth is a product of the biosphere. The life that exists on our planet has transformed the primary atmosphere over millions of years.

The modern atmosphere consists of the following main components:

Nitrogen – 78,084 %;

Oxygen – 20,946 %;

Argon – 0,934 %;

Carbon dioxide – 0,027 %;

Small impurities (hydrogen, neon, helium, methane, krypton, etc.) – 0,009 %.

In addition, the atmosphere contains water vapor, the content of which ranges from 0,2 % (in the polar latitudes) to 3 % (near the equator), as well as aerosols, i.e. suspended in the air extremely small solid and liquid particles of various substances, the content of which varies greatly.

The main components of the atmosphere – nitrogen, oxygen, and carbon dioxide – play a very important role in the biosphere. Over the millions of years of existence of the biosphere, certain cycles of these gases have formed.

Nitrogen is the main component of the atmosphere. Its weight is $3{,}7 \cdot 10^{15}$ tons. Nitrogen is a mandatory component of protein, where its content is 15–19 %. However, the bulk of atmospheric nitrogen is in molecular form. Some organisms have learned to bind molecular nitrogen to chemical compounds. These are nitrogen–fixing bacteria that live in special nodules on the roots of legumes. In general, plants consume nitrogen compounds, mainly nitrates. Some nitrogen compounds enter the atmosphere also as a part of volcanic gases. Large amounts of nitrogen oxides are released into the atmosphere due to the operation of automobile and aircraft engines. Many of these compounds are formed during nuclear explosions in the atmosphere. Nitrogen oxides are very harmful. Their presence in exhaust gases causes the formation of photochemical smog in cities, acid rains, ozone depletion.

Oxygen is an active oxidant involved in chemical reactions in the biosphere. Its mass in the atmosphere is $1{,}5 \cdot 10^{15}$ tons. The main source of oxygen we breathe is the photosynthesis of green plants. The cells of plants with such an active compound as chlorophyll produce organic matter from water and carbon dioxide with the help of solar energy. A by–product of this reaction is free oxygen released into the atmosphere. According to the estimations, about 80 % of all oxygen released into the atmosphere is produced by marine phytoplankton – microscopic algae that live in the upper layers of the ocean water – and 20 % of oxygen is produced by terrestrial vegetation, mostly tropical forests.

Carbon dioxide is an active component of the atmosphere and is an essential component of plant photosynthesis. This gas is formed during the combustion of organic matter and decay; it is also released with volcanic gases. Human activities (deforestation, urbanization, and mainly the burning of mineral fuels and ocean pollution) lead to an increase in the amount of CO_2 in the atmosphere. Over the last 120 years, the content of this gas in the air has increased by 17 % (on average by 0,14 % per year). Over the last decade, this growth has already amounted to 0,36 % per year. Most of the carbon dioxide, namely 70 %, is absorbed by the oceans and biosphere and only 30 % remains in the atmosphere. Some scientists predict a doubling of the carbon dioxide content in the atmosphere by the middle of the XXI century, which will cause an initial increase in average temperature due to the greenhouse effect.

Aerosols contained in the atmosphere are divided into 4 groups:

- sulphate aerosols of volcanic and industrial origin (NH_2SO_4, H_2SO_4);
- sea spray aerosols (particles of sea salts);
- mineral aerosols (dust from the earth's surface);
- hydrocarbon aerosols of industrial origin (soot).

In the troposphere, aerosol particles are retained for days and weeks, and in the stratosphere, where they enter with upward air currents, they are retained for years.

Self–assessment questions to subsection 2.3.2.

1. What is the atmosphere?
2. Describe the main functions of the atmosphere.
3. What is the troposphere?
4. Describe the stratosphere.
5. What is the mesosphere?
6. What is the main function of the thermosphere?
7. What does the exosphere protect from?
8. Where is the Earth's magnetic field formed?
9. What is the gas composition of the atmosphere?

2.3.3. Global problems of the atmosphere. Natural and anthropogenic sources and types of air pollution

The global environmental crisis is the current state of the persistent imbalance between mankind and nature which results in the degradation of the environment.

Currently, there are hundreds of arguments and facts that characterize the various features of the environmental crisis, and dozens that deny its existence. Therefore, it is advisable to analyze in detail the phenomena that give an idea of the state of the Earth's biosphere as a whole.

Today, no one has any doubts about the harmful effects of industrial and transport emissions on human health. This applies to emissions of CO, NO_x, SO_2, and other toxic substances. However, industrial emissions, transport emissions, and emissions from other sources not only directly affect human health, but also lead to global ecological changes in the biosphere. For example, there is global warming on the planet due to the accumulation of greenhouse gases in the atmosphere. These substances absorb scattered infrared rays. This results in an increase in temperature in the atmosphere and in the biosphere as a whole. Greenhouse gases CO_2, NO_x, methane and hydrocarbons, water vapor are transparent to sun rays but they absorb infrared rays. In general, they largely determine the heat balance on the Earth's surface. It should be noted that the greenhouse effect is most noticeable in the warm season when the flow of solar radiation is greatest.

Water vapor makes the main contribution to the heat balance. However, given the relatively stable area of water and land from which water vapor enters the atmosphere and relatively stable temperature, we can say that the average annual concentration of water vapor in the atmosphere is constant and its impact on the thermal regime of the planet is stable. Therefore, temperature fluctuations on the Earth's surface are associated with CO_2 fluctuations in the air.

It is believed that for the last 20 thousand years from the last maximum level of glaciation to 1765, the CO_2 content has been increasing naturally by 0,002 % per year, for the next 230 years – by 0,13 % per year, and in the period from 1960 to 1995 – by 0,36 % per year [8]. This is due to the fact that recently up to 27 billion tons of carbon dioxide have entered the atmosphere in a result of combustion. With such rates of CO_2 emissions, it is believed that by 2050 the CO_2 content in the atmosphere will increase from 0,03 % to 0,05 %, and by the end of the 21st century it will increase up to 0,09 % [3].

According to the World Meteorological Organization, with the current level of greenhouse gas emissions, the increase in average temperature will be 1 degree Celsius by 2040. Taking into account the growth of emissions, the increase in temperature will be 2–3,5 °C by 2050. As a result, it is expected that the level of the World Ocean will increase by 1–1,5 m [5].

According to observations, the following facts were revealed:

- after reaching the peak warming in 2016, when the average temperature on the planet was 1 °C higher than the average temperature in 1951–1980, this figure decreased slightly in 2017 to 0,91 °C, and in 2018 – to 0,83 °C [11];

- over the last 100 years, glaciers in the Alps and the Caucasus have halved, in Kilimanjaro they decreased by 73 % [10];
- 2018 was the fourth warmest year in history (the other three warmest years are 2015, 2016, and 2017), and 2016 was the warmest since the beginning of temperature recording in 1860 [11];
- since 1970, the number of natural disasters (droughts, floods, typhoons, earthquakes) has quadrupled in the world; only in 2016 there were 400 such phenomena [11];
- for the last 100 years of observations, the average annual temperature has increased by almost 0,5 °C on the territory of Ukraine [3];
- in general, during the 20th century, the ocean level rose by 0,17 m [6].

The situation is complicated by deforestation (reduced photosynthesis) and phytoplankton decline in the oceans.

Another consequence of global air pollution is the destruction of the Earth's ozone layer. The maximum ozone content is at an altitude of about 20–35 km. Ozone effectively absorbs radiation with a wavelength of 325–400 nm [25].

The main causes of ozone depletion are interactions with organohalogen substances, including CFCs. One chlorine atom decomposes 100,000 ozone atoms. Nitric oxide NO also decomposes ozone [8].

Studies of ozone content began in 1930. Studies carried out in the period from 1990 to 1991 showed that the rate of ozone depletion is 0,224 % per year [5].

Particularly dangerous are sulfur compounds and nitric oxide that enter the atmosphere due to the operation of thermal power plants and automobile engines and form acid rain by combining with atmospheric moisture.

According to the estimations, about 50 % of all sulfur dioxide emissions are converted into acid within 180 hours in the summer. For nitrogen dioxide, this period is significantly reduced and is only 12–14 hours [10].

When it falls to the ground, such rain has a very negative effect on the vital processes of organisms and human health. Over the past 180 years, the acidity of precipitation has increased 100 times [11].

These rains have a detrimental effect on environmental factors:

- the yield of many agricultural crops is reduced by 3–8 % due to damage to leaves caused by acids;
- acid rain causes the washing of calcium, potassium, and magnesium from the soil, which causes degradation of fauna and flora;
- forests degrade and die (cedar, yew, and beech are especially vulnerable to acid rain);
- acid rain poisons the water of lakes and ponds where fish and many insect species die (Acid rain has led to acidification of the environment in large areas of Europe and North America. In these regions, the acidity of precipitation is pH = 4,5, while its usual value is 5,6–5,7. Half of the lakes in Norway became dead, fish died there (pH = 5)) [12];
- the disappearance of insects in water bodies leads to the disappearance of birds and animals that feed on them;
- acid rain also increases the corrosion of various materials and structures, especially those decorated with marble, limestone;
- man's inhalation of air contaminated with acid fog causes respiratory diseases, eye irritation, etc.

In Ukraine, the area of acid soils has increased by 33 % over the last 35 years [8].

Self–assessment questions to subsection 2.3.3.

1. What is the global environmental crisis?
2. What are the features of the environmental crisis?
3. What are the consequences of the environmental crisis?
4. What are the causes of global warming on the Earth?
5. What are the main causes of ozone depletion on the Earth?
6. What are the main causes of acid rain?

2.4. THE INFLUENCE OF HUMAN ACTIVITY ON THE ECOLOGICAL CONDITION OF THE HYDROSPHERE

2.4.1. Water resources. The main sources of water supply

Among natural resources, water holds a special place. During its long geological history, it has created a favorable environment on our planet for the emergence of all living things, including human beings.

Freshwater reserves are small – taking into account part of the groundwater, they are about 35 million km^3. At the same time, 70 % of freshwater is concentrated in the glaciers of Antarctica, Greenland, and mountain peaks [10]. About 30 % of the world's freshwater reserves are groundwater, only a small part of which is available [12]. The waters of rivers and lakes make up a small part of the hydrosphere – about 200 thousand km^3 (about 1 %) [11].

Water is also divided by origin and purpose. According to the origin, the waters are atmospheric water, surface water, and groundwater.

Atmospheric waters fall to the Earth's surface in the form of rain, snow, hail, dew, and frost. These waters are saturated with hydrogen sulfide, nitric oxide, and other gases that pollute the atmosphere, especially in industrial areas. Atmospheric water does not contain salts, calcium, and magnesium.

Surface waters include waters of rivers, lakes, seas, oceans, and reservoirs. In addition to impurities that are common to atmospheric water, these waters also contain salts and other substances that are in the soil solution. The waters of rivers and lakes are self–purified under the influence of solar energy and beneficial microorganisms, plants and algae, and other underwater inhabitants. Harmful microbes present in the water often die.

Groundwater is the water of springs, artesian wells, geysers, and mines. Its composition depends on the soil through which it leaks. In most cases, this water is transparent and free of microorganisms. Mine water often contains salts of non–ferrous and rare metals, bromine, hydrogen sulfide, etc. Groundwater is a unique raw material for the chemical industry. Thus, water with sodium chloride dissolved in it is used to produce chlorine, caustic soda, hydrogen. Some of these waters have medicinal properties – the waters of Truskavets, Myrhorod, Satanov.

According to the purpose of use, water is divided into drinking water and industrial water. The content of impurities in such waters is regulated by relevant standards.

According to sanitary standards, **drinking water** must be safe to drink, odorless, tasteless, and discolored. Water suitable for drinking should not contain impurities above the established rate as their excess is harmful to the life of organisms.

Groundwater may be:

- Chemically bound (crystallized) water in the soil. It is a part of minerals. It takes the first place in their crystal structure but does not participate directly in the processes of soil formation.
- Vapor–like water. It is formed due to evaporation of surface and soil moisture in the presence of free liquid water in the soil. The ground air contains the maximum possible (at a given temperature) number of vapor molecules. At night, due to the condensation of steam in the surface horizons of the soil and the corresponding decrease of power in these places, steam moves up. During the day, it moves in the opposite direction.
- Bound (residual) water. It is formed as a result of the action of surface forces of the solid phase of the soil on water molecules (vapor or liquid). Molecules are bound due to their dipole nature. Hygroscopic water is sorbed molecules of water vapor. The more dispersed the soil is, the more such particles it contains, the larger their total surface area, and, accordingly, the more sorbed water there will be. Depending on the concentration of water vapor molecules in the air, several layers of dipole water vapor molecules can be formed around the solid particle.

Soil can sorb the largest amount of hygroscopic water from air with a relative humidity of about 100 %, i.e. saturated water vapor.

Free soil water available to plants is divided into capillary and gravitational.

Capillary water moves in thin holes under the action of capillary forces. In some types of soils, such forces are so strong that they are stronger than water weight force. The height of the water rise depends on the structural features of the soil, its particle size, and particle mineral composition.

Capillary water is divided into suspended, supported, and pendular water. The suspended water is kept in the soil by meniscus forces that exceed the action of gravity. If it exceeds the action of gravity. If capillary water is supported by free groundwater or underground water it is called capillary–supported moisture. Pendular water remains in the soil after draining free water from sandy medium fine gravel. It is kept at the joints between soil particles.

Capillary water is the most accessible to plants. It plays an important role in the process of redistribution of easily soluble compounds in the soil.

Gravitational water mixes in the soil under the action of gravity. This water flows freely from the upper horizons into the deeper ones, accumulating in the earth material or replenishing the groundwater reserves.

Gravitational water is available to plants, but it is quite mobile, which makes it somewhat difficult to access.

The waters of the World Ocean make up 96,4 % of all hydrosphere water. The World Ocean is a complex structural and functional system with a specific geological and geomorphological structure, geochemical, physicochemical, and biological processes that take place in the water column and bottom sediments. It differs from continental reservoirs by the special nature of substance exchange and energy flow. This applies to both the oceanosphere (ocean water masses) and its interaction with the atmosphere and the ocean floor. From an ecological point of view, the World Ocean is an extremely complex ecosystem determined by the close interaction of physical, chemical, and biological processes. The constant movement of water masses, which causes their mixing, and the system of currents are determining factors in the functioning of the ocean as a single ecosystem. Large–scale circulating processes in the ocean ecosystem form a kind of chemical, hydrological, and hydrobiological water regimes and determine the distribution of suspended and dissolved substances of abiotic and biotic origin.

The water of rivers, lakes, and other continental reservoirs is only 0,015 % of all water, and water in the form of continental ice, snow cover, and permafrost zones makes up almost 1,88 % [12].

Lakes are formed by filling the land depressions (basins) with water. The shape of a basin depends on the terrain and the nature of its formation.

A ***river*** is a relatively large watercourse, usually constant, which may dry up sometimes in some areas (in arid areas). The river is fed by runoff from the water intake area, as well as by groundwater.

The ***main stem (or parent) rivers*** are rivers that flow into the oceans, seas, or lakes. The rivers that flow into such main stem rivers are the *first–order tributaries*. The tributaries of the first–order tributaries are second–order tributaries, and so on. The main stem river and its tributaries of all orders form the ***river system*** and the land area from which such river collects water is called the ***water catchment area***. The catchment area, separated by a watershed from similar areas of other rivers, forms the ***river basin*** of the main river. The amount of water carried by a river over a certain period of time characterizes the *water content* of the river, and the volume of water that the river carries per unit of time (m^3/sec, dm^3/sec) is its *discharge.* The water flow in rivers is turbulent due to the presence of various bottom irregularities. As a result, whirlpools are formed. They help to mix water and saturate it with oxygen. Among the abiotic factors of river systems that significantly affect aquatic organisms, the flood regime plays an important role. It is determined by the level of rainfall and snowmelt. During floods, the water level in rivers can rise by 10–15 m. At the same time, this causes an intensive river bank erosion and a significant amount of suspended solids entering the water.

The origin of the hydrosphere is closely linked to the evolution of the planet. The age of the modern hydrosphere is about 2,5–3,0 billion years. Most researchers believe that the hydrosphere was formed as a result of degassing of the Earth's oceanic mantle and volcanic activity.

Water is the most common substance both in space and on the Earth.

Thus, there are ice caps at the poles of Mars, ice–covered satellites of Jupiter, Saturn, and other planets, water vapor in the atmosphere of Venus, ice nuclei of comets and comet–like bodies. All this is indisputable evidence that the primary matter of our planet must have included water molecules and possibly quite large ice objects and water–forming components – hydrogen and oxygen.

By appearance, the Earth is a planet of water, not land, because its surface is mostly covered with water.

Self–assessment questions to subsection 2.4.1.

1. What types of water are known by the origin and the purpose of use?
2. What types of water belong to surface waters?
3. What types of water belong to groundwater?
4. What are the types of groundwater?
5. Classify capillary water.

2.4.2. Water use in industry, utilities, and agriculture. Water supply systems. Rational water use

All sectors of the economy are divided into 2 groups in relation to water resources, namely ***consumers*** and ***users***.

Consumers take water from the source, use it to produce industrial and agricultural products, and then return it, but in a different place, in smaller quantities, and with a different quality.

Users do not take water from the source. They use it as an environment (water transport, fishing, hydropower plants). However, they can also change water quality (e.g. water transport pollutes water).

Water can be used for various purposes: for the needs of industry, agriculture, and utilities.

The **industry** uses about 20 % of the total amount of fresh water and its consumption. The amount of water consumed by an industrial facility depends on the type of product, production technology, water supply system (direct or recirculated water supply), climatic conditions (usually, the same industrial facilities located in the northern regions use much less water than facilities located in the southern regions with high temperatures).

In the industrial sector, 65–80 % of water consumption is used for cooling.

Process water is divided into water that forms an environment, cleaning water, and reaction water. The water that forms the environment is used for dissolving and forming pulps, in the enrichment and processing of ores, hydrotransportation of products and production wastes; cleaning water is used for washing gaseous (absorption), liquid (extraction), and solid products; reaction water is used as part of the reagents. Process water is in direct contact with products.

Heating water is used to heat equipment, premises, and products.

The term ***water intensity*** of production is used to estimate the volume of industrial water consumption. It means the amount of water (m^3) required to produce 1 ton of finished product. The water intensity of different types of economic activities is very different [21]:

- Ore mining and beneficiation 2–4
- Production of rolled products 10–15
- Cast iron production 40–50
- Cellulose production 400–500
- Viscose silk production 1000–1100
- Chemical fibers production 2000–5000.

The largest industrial consumer of water is the nuclear energy sector – nuclear power plants use on average twice as much water per 1 kW of electricity generated than thermal power plants.

To quantify the use of water resources, it is necessary to know not only the total volume of withdrawn water but also the amount of consumptive water use. The ***consumptive water use*** is calculated as a % of the volume of water taken and depends on the type of water use, the volume of water supply, and local physical and geographical conditions. The consumptive water use in industry is small and is 5–10 % of the total volume of water intake. In the heating industry, it is even lower – 0,5–2 %.

Agriculture is the main consumer of fresh water (70 % of all its use). This is primarily due to the increase in the area of irrigated land. Irrigated land yields much more crops than non–irrigated land. Thus, today about 15 % of all agricultural land is irrigated in the world. However, such land produces more than 50 % of all products (by value).

The area of irrigated land is growing rapidly in the world: at the beginning of the twentieth century, it was 40 million hectares, in 1970 – 235 million hectares, and today – 420 million hectares.

Specific water consumption during irrigation depends on the following:

- type of crops;
- physical and geographical conditions of the area;
- technical condition of irrigation systems;
- methods of irrigation.

Here are the rates of irrigation of different crops, m^3/ha:

• Cereals	1500–3500
• Sugar beet	2500–6000
• Perennial grasses	2000–8000
• Rice	8000–15000

Irreversible losses of water during irrigation (due to evaporation) reach large values (from 20 % to 60 % of water intake).

The **water supply** satisfies the population's needs for drinking water as well as municipal and household needs (the work of utility service companies, watering of streets and green areas, fire–fighting measures, etc.). There is a concept of ***specific water consumption***, i.e. the daily volume of water in liters, which is necessary to meet all the needs of one inhabitant of a town or village. The values of specific water consumption vary widely: from 200–600 L/day per person in cities, up to 100–200 L/day per person in rural areas, and in the absence of a water supply network it is 30–50 L/day per person. Specific water consumption largely depends on the quality of public services and amenities (availability of water supply network, sewerage, district heating, etc.).

In the big cities of the world, the specific water consumption is as follows: New York and Moscow – 600 L/day per person, Kyiv – 515 L/day per person, Paris and Luhansk – 500 L/day per person, Vinnytsia and Uzhgorod – 305 L/day per person, London – 263 L/day per person, Ivano–Frankivsk – 230 L/day per person [9].

According to the nature of water use, water supply systems are divided into direct, repeated, circulating, and closed ones.

The simplest system is a ***direct*** water supply system. After passing through the technological cycle, water enters the sewage treatment facilities. Sewage water treated to the required degree is discharged into the watercourse. These systems are used when there is a sufficient amount of water resources, in industries with low water use and low pollution of industrial effluents.

Water recycling or repeated use of water is the collection of return water (without additional purification or treatment) for processing needs, irrigation, etc. After passing through the shop or production cycle, the water enters the next shop or is used again in production. Repeated use of water in various technological operations pollutes the water so much that its further use becomes impossible without local treatment. In this case, water may be used 10–14 times (hot waste water is used for heating plant premises, residential areas, greenhouses, and warm water is used for irrigation).

Circulating water is used in production repeatedly, with periodic or continuous treatment. In the case of circulating water supply, it is important to provide the necessary wastewater treatment, cooling of circulating water, purification, and reuse of wastewater.

The use of a circulating water supply allows to reduce the consumption of natural water by 10–50 times (in case of direct water supply 2100 m^3 of fresh water is needed to obtain 1 ton of rubber and in case of circulating water supply this figure is only 165 m^3) [10]. With the circulating water supply, capital and operating costs are significantly reduced. Circulating water must meet certain values: T, pH, content of suspended solids and biogenic substances, COD.

Circulating water is mainly used in heat exchange equipment to remove excess heat. It is repeatedly heated to 40–45 ^{0}C and cooled in ventilated cooling towers or spray water ponds. Much of it is lost as a result of splashing and evaporation. In addition, due to the malfunction and leakage of heat exchange equipment, it is contaminated to a certain extent.

To prevent encrustation, corrosion, and biological fouling, part of the circulating water is removed from the system (purge water). At the same time, fresh water or treated wastewater is added into the system.

In some cases, rationalization of the use of natural waters in the industry can ensure the formation of completely closed water management systems.

A ***closed*** system of industrial water management means a system in which water is used repeatedly without treatment or after appropriate treatment, which eliminates the formation of any waste and wastewater discharge into reservoirs.

Fresh water is supplied to closed systems if there is not enough treated wastewater to eliminate water losses in these systems. Water losses are also allowed in technological operations in which treated wastewater can not be used under technology or due to hygienic reasons. Fresh water is used only for drinking and household purposes.

To create closed water consumption systems, industrial wastewater must be treated by mechanical, chemical, physicochemical, biological, and thermal methods to the required quality, which depends on the type of production. Treated water must meet the quality of process water.

Rational use of water resources in industrial production involves:

- wide introduction of low–water and waterless approaches;

- development of closed water supply systems;
- optimization of water supply and water treatment processes (supply and distribution for technological production operations, regeneration of waste solutions, extraction of valuable waste from wastewater and their disposal, treatment of circulating water, sludge disposal, etc.);
- full use of water resources of the industrial unit, which includes the use of urban and industrial wastewater for irrigating fields and at other facilities.

Self–assessment questions to subsection 2.4.2.

1. Who is a consumer of water?
2. How do water consumers affect the aquatic environment?
3. What percentage of water is used by industrial facilities and what does it depend on?
4. What is the water intensity of production?
5. What is the consumptive water use?
6. Why is agriculture the main consumer of fresh water?
7. What determines the specific water consumption during irrigation?
8. What is the specific water consumption of the population?
9. What determines the specific water consumption of the population of different cities and countries?
10. Describe the operation of a direct water supply system.
11. Describe the operation of a water supply system with repeated water use.
12. Describe the operation of a circulating water supply system.
13. Describe the operation of a closed water supply system.
14. What is the essence of rational water use?

2.4.3. Sources and types of pollution of surface water and groundwater of the continents and the oceans. Classification of hydrosphere pollution. Influence of hydrosphere pollution on water degradation and human health

The hydrosphere is a dynamic system in which physical, chemical, and biological processes are taking place constantly. All the natural waters of the planet are in a continuous cycle. The physical basis of this cycle is solar radiation, which heats water and land, evaporation, horizontal gradients of atmospheric pressure, transfer of air masses in the atmosphere and water masses in the oceans, concentration of moisture in the atmosphere and its precipitation in the form of rain and snow, water flow in rivers and oceans. Thus, the ***water cycle*** is a continuous process of movement and exchange of water on Earth. The water cycle is one of the main properties of the hydrosphere and it represents the unity of the planet's natural waters.

The rate of use of water resources in the world is growing much faster than the construction of treatment facilities. Therefore, at the present stage, the problem of pollution of natural reservoirs is very acute.

Pollution of natural waters means the change of their physical, chemical, and biological parameters, which is the cause of harmful effects on humans or the natural environment, as well as limited possibility of using these waters. The causes of pollution of natural water bodies are a number of factors, both natural and anthropogenic ones.

According to the National Standard of Ukraine DSTU 3041–95, ***water pollution is the entry of physical, chemical, or biological substances or energy into a water body that causes deterioration of water quality.***

Types of pollution of natural water bodies.

Pollution of water resources is changing their physical, chemical, and biological properties due to the ingress of harmful liquid, solid and gaseous substances that make water unsafe for use and cause damage to the economy and human health.

There are physical (mechanical), chemical, biological (bacterial), radioactive, and thermal pollution (Table 2.1).

Table 2.1

Types of surface water and groundwater pollution

Type of pollution	Pollutants
Physical	Insoluble impurities: clay, sand, sludge, dust, etc.
Chemical	Heavy metals, acids, alkalis, mineral salts, petroleum and petroleum products, synthetic surfactants, synthetic detergents, mineral fertilizers, pesticides
Biological	Various microorganisms (bacteria, viruses), helminth eggs, fungal spores
Radioactive	Radionuclides (cesium–137, strontium–90, potassium–40, etc.)
Thermal	Heated waters of thermal power plants and nuclear power plants

Physical pollution is a change in the physical properties of water (transparency, content of suspensions and other impurities). Suspensions (sand, sludge, clay) enter water bodies as a result of surface runoff by rainwater from agricultural lands, industrial plants, and existing mining facilities, with emissions of nuclear power plants that contain radioactive impurities and emissions of thermal power plants that contain ash particles, etc. Dust enters the water bodies as a result of strong winds, especially in dry weather. Solid particles reduce the transparency of water inhibiting photosynthesis of aquatic plants, block the gills of fish, impair the taste of water.

Chemical pollution of water is pollution due to the inflow of various harmful impurities of inorganic (acid, alkali, salt) and organic (oil and petroleum products, synthetic surfactants, synthetic detergents, etc.) nature into water bodies with wastewater. Most of the pollutants, namely arsenic, lead, mercury, cadmium, chromium, fluorine, etc., are toxic to aquatic flora and fauna, as well as humans. For example, the consumption of fish and crabs caught in pesticide and mercury–

contaminated waters of Minamata Bay in Japan has caused chronic central nervous system disease (Minamata disease). Patients have impaired speech, impaired vision, and paralysis of the muscles of the arms and legs. Another disease – itai–itai – was caused by chronic cadmium poisoning due to contamination of rice plantations and is associated with damage to the human skeletal system. Organic substances have a very negative effect on the condition of water bodies, as they reduce the oxygen content in the water. Pulp and paper mills, oil refineries, livestock complexes, and chemical plants discharge significant amounts of organic pollutants into the water.

Biological pollution of water is when the components of wildlife pollute the water bodies. There are bacteriological pollution of water bodies and purely biological one. Bacteriological pollution is understood as the entry of bacteria and viruses into water bodies, which can be the causative agents of various diseases. Biological pollution is caused by the entry of invertebrates, crustaceans, and higher animals into water bodies that may cause biological imbalance due to the displacement of relics from water bodies. Migrants tend to be more adapted to environmental factors than relics. Sources of bacteriological pollution are municipal wastewater and industrial wastewater from the food industry, biosynthesis, wood industry, etc. Even in the presence of treatment facilities some viruses and bacteria are not retained by filters and enter water bodies. Biological pollution occurs in water bodies during floods because different water bodies are connected with each other, etc.

Radioactive pollution of water is the entry of radionuclides into natural reservoirs, which can have a negative impact on living organisms, causing somatic and mutagenic effects. Sources of radioactive pollution of water bodies are nuclear power plants, military–industrial complex, and industrial facilities that use sources of ionizing radiation in the production run.

Thermal pollution of water is the ingress of heated water into natural reservoirs. An increase in water temperature in reservoirs is a double danger. First, with increasing water temperature, the solubility of oxygen in water decreases which can cause the death of water inhabitants. Secondly, the increase in water temperature contributes to the rapid development of unicellular green algae and eutrophication. Higher water temperature contributes to the rotting processes and the swamp formation. Sources of thermal pollution of natural reservoirs are heated water discharged by thermal power plants, nuclear power plants and hot water discharged by cooling units. A nuclear power plant produces 60 % more excess heat than a thermal power plant of the same capacity. Water from its cooling systems is discharged into nearby rivers and lakes, which raises the water temperature by 5–6 °C [11]. The most efficient cooling systems at NPPs are cooling towers and artificial reservoirs which somewhat reduce thermal pollution.

Sources of pollution are sources that bring pollutants, microorganisms, or heat into surface or groundwater.

All sources of pollution are divided into six types:

– industrial wastewater;

– municipal wastewater;

– agricultural wastewater;

– surface wastewater;

– precipitation;

– oil and petroleum products.

Wastewater is water that is discharged after use in domestic and industrial activities. It is calculated that each cubic meter of wastewater pollutes 40–60 m^3 of clean water. *Industrial wastewater* is water that is used in various technological processes. Characteristics of industrial and domestic wastewater are given in Table 2.2.

Table 2.2

Characteristics of industrial and domestic wastewater

Indicator	**Industrial wastewater**	**Domestic wastewater**
How it is generated	As a result of technological processes	Due to economic and domestic activities
Quantity	Determined by the needs of technological processes	Limited by the limits of water consumption
Appearance	Significantly different	Monotonous
Mulled substances	Very diverse in quantity	Are constantly determined by quantity and quality
Reaction	From highly alkaline to highly acidic	Neutral or slightly alkaline
Chemical composition	Different: organic, synthetic, mineral compounds	Homogeneous, mostly organic compounds
Toxicity and bactericidal properties	Can be determined with a varying degree	Not applicable
Hygienic significance	General sanitary	Mainly epidemiological
Methods of disinfection	Chemical and mechanical	Biological with disinfection

Pollutants are substances that lead to impaired water quality (legally established water quality indicators by type of water use).

All pollutants entering wastewater are conventionally divided into several groups:

– by physical state: insoluble, colloidal, soluble;

– by origin: mineral, organic, bacterial.

The most powerful source of pollution in natural waters is *industrial wastewater* which is characterized by large volumes and a variety of chemical compositions. Usually, the temperature of wastewater is very high. Wastewater is the large–tonnage industrial waste that is generated by various industries (see Table 2.3)

Table 2.3

The main pollutants by industry

Industry	**Pollutants**
Pulp and paper industry, wood industry	Organic substances (lignins, resinous and fatty substances, phenol, etc.), ammonium nitrogen, sulfates, suspended solids
Oil and gas	Petroleum products, phenols, ammonium nitrogen, sulfides
Machinery, metalworking, metallurgy	Heavy metals, suspended solids, ammonium nitrogen, petroleum products, resins, phenols, etc.
Chemical and petrochemical industries	Phenols, petroleum products, polycyclic aromatic hydrocarbons, mineral fertilizers, pesticides, suspended solids
Light, textile, and food industries	Petroleum products, organic dyes, organic substances

Municipal wastewater. Municipal wastewater is characterized by the presence of detergents, organic substances, and biogenic components. When such effluents enter natural reservoirs this causes their eutrophication due to the presence of significant amounts of organic matter and compounds of phosphorus and nitrogen, and the presence of various pathogens makes them dangerous to humans and animals.

Agricultural wastewater. Such waters enter natural reservoirs from arable lands and pose a double danger. *First*, along with wastewater, a significant amount of mineral fertilizers enters the reservoirs. In the case of nitrogen or phosphorus fertilizers, eutrophication of reservoirs is observed. Due to the creation of anaerobic conditions, a stable and irreversible hydrogen sulfide zone is formed in the natural layers. The formation of such a zone leads to the loss of water. This happens due to biochemical reactions under anaerobic conditions when sulfate ions, which are found in significant quantities in natural waters, are reduced to hydrogen sulfide under the influence of bacteria:

$$SO_4^{2-} + 5AH_2 + Bacter \rightarrow H_2S + 4H_2O + 5A,$$

where AH_2 is an organic compound, hydrogen carrier.

Natural water bodies may contain up to 500 mg/dm^3 of sulfates, and the presence of hydrogen sulfide is not allowed.

If potassium fertilizers get into natural reservoirs it changes the mineral composition of the water and gives it a bitter taste, which can lead to the death of aquatic organisms.

Secondly, agricultural wastewater may contain pesticides of different classes: herbicides, bactericides, insecticides, zoocides, etc. Due to the high biological activity of pesticides, the balance in water bodies may be disturbed. The reasons for this may be the death of flora (herbicides), bacteria (bactericides), fauna (zoocides), etc.

Surface wastewater. Such waters are a source of physical pollution of natural reservoirs, which leads to their shallowing and siltation. Surface wastewater together with precipitation can wash away local and industrial dirt.

Precipitation. As a source of pollution, precipitation plays a special role in industrial areas and coastal areas. Such precipitation may contain acidic components, dust, soot, toxic chemicals, industrial effluents with solid particles, radioactive substances, etc. Atmospheric precipitation of coastal marine areas may contain impurities of salts, which is the cause of changes in the salt composition of freshwater.

Oil and petroleum products. Oil and petroleum products belong to a separate group of sources of pollution of natural water bodies, although their pollutive components can be attributed to the chemical type of pollution. Oil and petroleum products are very persistent water pollutants. They spread over a distance of 300 km or more from the source of pollution. Petroleum products are toxic to a number of aquatic organisms. With a high concentration of petroleum products in water ≥0,5 mg/dm^3, the taste of fish changes. It gets a taste of oil from which it is impossible to get rid. With a high concentration of petroleum products in water ≥1,2 mg/dm^3, plankton dies. When oil enters water bodies, a molecular film is formed that is resistant to oxidation. This film prevents gas and moisture exchange between the atmosphere and the water body and disrupts the biochemical regime of water bodies, reduces the amount of soluble oxygen in the water. When 1 ton of oil enters a water body, a molecular film with an area of up to 12 km^2 is formed. According to scientists, currently, 20 % of the surface of the World Ocean is covered with a film of oil or petroleum products. The oil film is found even in Antarctic waters, where it kills seals and penguins. In the case of oil pollution, unicellular golden algae multiply en masse, forming a belt up to 10 km wide and 35 m thick that moves at a speed of 25 km per day, destroying everything in its path.

Oil slicks are detected from ships, aircraft, and artificial satellites of the Earth. All remote detecting methods are based on differences in physical and chemical properties of water and oil and petroleum products (oil contains more than 1000 chemical compounds, the chemical composition of oil in each oil field is unique, which allows not only to detect slicks, determine its size, area, main components but also to identify the culprit tanker).

Heavy fractions of oil settle to the bottom, causing toxic damage to natural flora and fauna.

Sources of pollution of natural reservoirs with oil and petroleum products are oil production companies and oil refineries, petroleum storage depots and fleets. A special problem of oil production is the extraction of oil–field water together with oil. This water is characterized by high mineralization and high content of petroleum products. Approximately 12 million tons of oil and petroleum products enter the seas and oceans each year, excluding emissions from oil fields and tanker accidents.

Therefore, any pollution of natural water bodies poses a certain danger. However, nature has mechanisms that provide the self–cleaning of water bodies from pollutants. Thus, human economic activity should be aimed at supporting and preserving such processes.

Self–assessment questions to subsection 2.4.3.

1. What is a hydrosphere?
2. What is the pollution of natural water bodies?
3. What are the types of pollution of natural water bodies?
4. Describe the physical pollution of water.
5. What is the chemical pollution of water?
6. What is the source of biological water pollution?
7. Facilities of what industry do contribute to the ingress of radioactive pollutants into water bodies?
8. What is wastewater?
9. What are the consequences of oil and petroleum products entering the aquatic environment?

2.5. WASTE DISPOSAL AND TREATMENT

2.5.1. Waste generation in the industrial, municipal, and agricultural sectors. Waste classification, methods of waste utilization and disposal

The problem of environmental protection is global and must be addressed at both the national and international levels.

Today, the main air pollutants are metallurgy, energy sector, fuel and chemical industries.

Transport plays a significant role in air pollution in large cities, often reaching 50–70 % of total emissions.

In solving environmental problems, serious difficulties arise due to the specifics of many industries, which, as a rule, require an individual approach to organize effective environmental protection.

Due to the imperfection of modern production processes, as well as the specifics of consumption and use of natural resources, the major part of such resources is disposed of as waste – solid, liquid, and gaseous one. Liquid and gaseous wastes are sources of pollution of the hydrosphere and atmosphere. In addition to industrial waste, municipal solid waste is a significant problem, often growing faster than the population. Thus, in 1970 in the United States, the amount of waste per capita was 0,63 tons a year and in 1990 it was 0,91 tons a year.

Landfills occupy large areas and are a source of pollution of groundwater and air. Waste incineration causes air pollution and generates highly toxic sludge.

One way to solve the problem is to sort waste and use it in secondary production.

In addition to industrial production, the main sources of water pollution are municipal sewage and wastewater from agricultural lands. In addition to highly toxic substances such as radionuclides, heavy metals, and non–ferrous metals, wastewater contains biogenic substances (nitrogen and phosphorus compounds, humus–rich organic matter), minerals, and many other pollutants. Industrial effluents are often toxic and hazardous to biota, other effluents pose a threat of infectious diseases, deterioration of natural water quality (increase in biochemical oxygen demand and decrease in soluble oxygen content), eutrophication of water bodies. In addition, wastewater poses many other threats.

The main sources of air pollution are industrial production, thermal power plants, boiler houses, individual activities, and all modes of transport.

The level of air pollution is determined by three factors:

- release of pollutants into the air;
- the volume of space where they are dispersed;
- mechanisms for removing pollutants from the air.

As a rule, the concentration of natural air pollutants is maintained well below the threshold level. The only exception is areas close to natural sources of emission, such as active volcanoes.

Anthropogenic emissions and impacts are much larger, such as acid rain, ozone anomalies, and the greenhouse effect.

The most common toxic emissions are aerosols, including aerosols of heavy and non–ferrous metals, carbon soot, carcinogenic polycyclic hydrocarbons, hydrocarbons (methane, gasoline, organic solvents, etc.), carbon monoxide (CO), sulfur dioxide (SO_2), oxides (NO_x), ozone and other photochemical oxidants, heavy metals.

Today, there is no general scientific classification of industrial solid waste which covers all their diversity according to certain principles, due to the wide range, even within one industrial facility. Existing classifications of solid waste are quite diverse and mostly one–sided. Thus, solid waste is classified by:

- industries (wastes of chemical, metallurgical, fuel and other industries);
- specific production facilities (waste of sulfuric acid, soda, phosphoric acid production, etc.);
- tonnage;
- degree of use;
- value indicators;
- impact on the environment;
- ability to ignite;
- corrosion effects on equipment, etc.

Self–assessment questions to subsection 2.5.1.

1. Name the main industries that are the most intense polluters of the Earth's biosphere.
2. Give the characteristics of landfills.
3. Name the types of waste generated by man–made activities.

4. Name the main sources of water pollution.
5. Name the main sources of air pollution.
6. Name factors that characterize the level of air pollution.
7. Give the classification of solid waste.

2.5.2. Conditions for waste accumulation and disposal. Principles of creating low–waste technologies

The term **"industrial waste"** means residues of various compositions and physicochemical properties which are characterized by potential consumer value (suitability for useful use) and which are secondary raw materials (SRMs) by their nature. The use of SRM in material production, as a rule, requires certain additional operations in order to provide them with the necessary properties.

In many industries, a significant amount of solid waste is accumulated due to the existing level of processing technology of the respective raw materials and the lack of their integrated use. Removal and disposal are expensive measures. At metallurgical plants and thermal power plants, the cost of such measures is about 8–30 % of the cost of basic products. Meanwhile, large masses of rocks and wastes from mineral processing and treatment enter the dumps every year. At the same time, the level of operational waste disposal is very low: only 1/5 of non–ferrous metallurgical slag, 10–12 % of ash and slag waste, 4 % of coal beneficiation waste are involved in economic circulation that results into the waste accumulation [3].

At the same time, a significant part of solid waste from industrial facilities can be used efficiently in the national economy. Thus, the construction industry and the building materials industry annually extract and use large volumes of non–metallic raw materials, most of which can be replaced by industrial waste. The utilization of the latter is an urgent issue because one needs 2–3 times fewer costs to organize the production of goods on their basis than to organize such production on the basis of specially extracted raw materials.

The creation of low–waste technologies involves measures to ensure the removal of pollution through the effective conversion of raw materials into useful products and prevents the generation of waste. That is, the method is implemented until the moment when waste is generated.

When waste is generated and cannot be used directly in this production, it is possible to apply measures to control waste, processing it into other products, and their disposal. These are useful and necessary measures, but they cannot be called low–waste technologies.

Recycling is a method in which generated waste or by–products are used in another production process. This method has a clear advantage over other waste management approaches, as it saves primary raw materials and reduces waste, but it is less important than reuse. When reused, waste and by–products are returned to the process in which they were produced. Barriers to the use of the recycling method are the following:

- It is necessary to find an industrial facility that is able to use waste as raw material. This system provides a fairly high level of information exchange between companies about their existing waste, which is quite problematic in the current competition and the relationship between companies and environmental authorities. In this system, the best approach is to create databases on the availability of different types of waste in different companies;
- Another problem is the quality standard and certain features that raw materials (waste) must meet. Often the waste that one company has does not meet the parameters of raw materials needed by another company;
- After finding a company that is ready to use waste as raw materials, such waste must be transported there, which leads to increased production costs and is accompanied by additional environmental pollution;
- There is another problem common to both internal and external recycling, namely – spent energy, financial, and human resources, which are invested in waste and cannot be returned. New costs are needed to convert waste into a new product.

Waste treatment involves processes that change the composition, concentration and/or amount of waste. This applies to gas emissions treatment, wastewater treatment, and treatment of other types of waste (solids, suspensions, emulsions, wet sludge, etc.). Examples are settling, filtration, compaction, evaporation, absorption, adsorption, destruction, combustion. Waste treatment reduces waste toxicity and amount and/or converts it into a form suitable for reuse in other processes or for disposal. Two opposite methods can be attributed to treatment: concentration and destruction.

The main issue of waste treatment is that waste does not disappear, but only moves from one environment to another, and in the case of destruction, new pollutants are formed.

Self–assessment questions to subsection 2.5.2.

1. What is meant by the term "industrial waste"?
2. What is low–waste technology?
3. What is the recycling method?
4. What are the barriers to recycling?
5. What are the problems with waste treatment?
6. What are the methods of waste treatment?

SECTION 3. ENVIRONMENTAL PROTECTION MANAGEMENT

3.1. ENVIRONMENTAL DECISION–MAKING METHODS

3.1.1 Sustainable nature management. The concept and principles of environmental protection management

The industrial activity of humankind is currently a very important environmental factor, which significantly affects the state of ecological systems and the state of the Earth's biosphere. Humanity itself is responsible for the transformation of the environment under the influence of its economic activities. Any kind of living creature affects the environment to some extent. There are known examples when the excessive growth of the elephant population led to the destruction of vegetation in the territory of reserves where they lived, which threatened the existence of the entire ecological system. Only artificial reduction of these populations allowed normalizing the situation.

Significantly more complex problems result from human activity. First of all, by creating artificial conditions of existence, the number of humans on Earth has grown to unusual proportions. No large animal or bird can compare with humans in terms of the headcount. There is virtually no territory on the planet where humans are not present to some extent. Now people use mechanisms, devices, materials, and means that have never existed before in the wild. Thus, the human population has grown to unimaginable proportions and is still growing, and its impact on the environment is constantly increasing due to powerful mechanisms and ever–improving machines. All this has led to the fact that the anthropogenic influence on the biosphere has equaled to and in some cases exceeded the influence of natural factors. Anthropogenic influence has now become a real threat to the stability of the biosphere. Today the planet is a source of natural resources for people and, at the same time, a place of waste accumulation. All attempts by philosophers, ecologists, and biologists to reduce the role of man to the role of an ordinary animal species, to consider all kinds of living organisms as equal in nature look quite unconvincing. Humankind will never conserve nature for the sake of all existing species at the cost of its vital interests. This is an axiom. It is the essence of human nature. Only one argument can make people respect nature – it is their own safety, the awareness that humanity is destroying its own environment by destroying nature. It is what can make people not waste huge sums of money on mindless actions destroying the natural resources like military re–equipment and unjustifiably luxurious existence. However, not all powerful actors perceive this persuasive argument, and if they do, they do not always realize its seriousness.

Anthropogenic effects on the environment can be subdivided into two components:

- the depletion of natural resources in the course of turning them into various objects and products required for human life and meeting human needs, which are often unjustifiably exaggerated;
- pollution of the environment by industrial and other wastes.

By **natural resources**, people mean everything they can take from the natural environment to meet their needs. Some resources are used directly, while others require some processing. All resources are subdivided into exhaustible and inexhaustible, renewable, non–renewable, and conditionally renewable.

Exhaustible resources are resources that are found in the earth's crust in limited quantities and, in principle, can be fully utilized (metals, metal ores, oil, gas, coal, phosphates, sulfur, etc.). They can be classified as **conditionally renewable resources**. Because of geological processes, they can be regenerated over millions or billions of years.

Scientists predict that if current trends in resource use and development continue, by the middle of the 21st century, there will be an increase in production volumes and living standards, followed by a sharp decline.

In practice, it is impossible to use exhaustible resources to the end. However, if they are used intensively, they switch into the category of **depleted resources**, the development of which is unfeasible (the cost of their development exceeds the profit from their use).

Inexhaustible resources include those that exist in unlimited quantities and are available on Earth. First and foremost, these are the energy of the sun and its derivatives, such as wind power and hydropower. Inexhaustible resources can include **renewable resources** – plants, animals, bioresources, biodiversity, air oxygen, and fertile soils. However, under certain conditions of environmental impact, it is quite possible to transfer renewable resources into the category of exhaustible resources. This is shown by the pollution of the aquatic environment, the atmosphere, the reduction of soil fertility, as well as the destruction of many biological species known and unknown to humankind. Another example is fishing in the ocean and other water bodies. Many valuable species of fish have virtually disappeared, such as species suitable for commercial catching and harvesting. Whales are rare animals today.

As we know, all species of living things are collectively referred to as the biota. To date, approximately 1,5 million plant and animal species have been studied, named, and systematized. Scientists believe there are at least 5–10 million more unstudied species. At the same time, ecosystems are being destroyed across the globe. Under such circumstances, millions of species are condemned to extinction over the lifetime of the current generation of humans.

The increasing rate of biota and biodiversity destruction weakens the sustainability not only of ecosystems but also of modern civilization. The factor of biota and biodiversity conservation is a kind of barometer of the state of the biosphere.

The value of natural biota to humans can be assessed in five aspects:

- the base of agriculture and forestry;
- resources for medicine;
- direct benefit and utility;
- opportunities for recreation, meeting the aesthetic needs and research interests;

- commercial capabilities.

As for energy resources, a significant amount of them is used in agriculture, industry, transportation, and utilities. Energy consumption is increasing every day. For example, today in the USA, it takes ~8 calories of energy when using agricultural equipment and auxiliary materials, i.e. fertilizers, pesticides, as well as for melioration and irrigation to produce 1 calorie of energy from food.

The current production volumes require large quantities of energy. Sustainable development requires sustainable energy resources. Therefore, in addition to the conventional use of fossil fuels and nuclear energy, the issue of use of energy from the sun and its derivatives, i.e. the movement of air (winds), water, and geothermal energy, is a relevant one.

In addition to the direct use of solar energy, a promising direction is the production of energy carriers based on biomass created by photosynthesis. For example, the production of alcohol by fermentation of starches and other derivatives of carbohydrates or the production of diesel fuel by transesterification of vegetable fats.

Self–assessment questions to subsection 3.1.1.

1. Which natural resources are called inexhaustible?
2. Is it possible to restore exhaustive resources?
3. Are all renewable resources considered inexhaustible?
4. How can we assess the value of natural biota for humans?
5. How does humanity use the planet's biological resources?
6. Which energy resources are considered sustainable?

3.1.2 Decision–making system in the field of environmental protection. Regulatory and legal framework of Ukraine on environmental policy. Key provisions for environmental risk reduction

The sources of environmental law are legal acts containing the environmental legal standards intended for regulation of environmental legal relations. In Ukraine, the main sources are legislative and subordinate regulatory acts.

The Constitution of Ukraine is the Main Law and acts as the beginning of any rule–making process, including the environmental law. It is the Constitution that contains generally recognized principles, on which environmental legislation is based and developed. Specifically, Article 13 of the Constitution of Ukraine proclaims that land, its subsoil, atmospheric air, water, and other natural resources, which are located within the territory of Ukraine, natural resources of its continental shelf of the exclusive (maritime) economic zone are the objects of ownership of Ukrainian people. Every citizen has the right to utilize the natural objects of the people's property rights in accordance with the law. At the same time, everyone is obliged not to cause harm to nature and to compensate for damage (Article 66 of the Constitution of Ukraine).

Due to the numerous legislative acts governing the environmental relations, as well as depending on the types of relations governed by the standards of environmental law, legislative acts can be subdivided into several groups:

1. Legislative acts mainly governing the natural resource use, i.e. the Land Code of Ukraine dated October 25, 2001; Code of Ukraine on Subsoil dated July 27, 1994; Forest Code of Ukraine dated January 21, 1994; Water Code of Ukraine dated June 06, 1995; Law of Ukraine on Fauna dated December 13, 2001; Law of Ukraine on Natural Reserve Fund dated June 16, 1992; Mining Law of Ukraine dated October 06, 1999; Law of Ukraine on the Exclusive (Maritime) Economic Zone dated May 16, 1995; Law of Ukraine on Flora dated April 09, 1999; Law of Ukraine on Beekeeping dated February 22, 2000; Law of Ukraine on Extraction and Processing

of Uranium Ores dated November 19, 1997; Law of Ukraine on Melioration dated January 14, 2000; Law of Ukraine on Hunting Farming and Hunting dated February 22, 2000; Law of Ukraine on Concessions dated July 16, 1999, etc [20].

2. Legislative acts, which mainly regulate environmental protection: the Law of Ukraine on Atmospheric Air Protection dated June 21, 2001; the Law of Ukraine on Environmental Protection dated June 25, 1991; the Law of Ukraine on Nuclear Energy Use and Radiation Safety dated February 08, 1995; the Law of Ukraine on Radioactive Waste Management dated June 30, 1995; the Law of Ukraine on Waste dated March 05, 1998; the Law of Ukraine on Transportation of Dangerous Cargoes dated April 06, 2000, etc. [20].

3. Legislative acts which mainly govern the environmental relations associated with the implementation of environmental protection functions by the authorized state bodies: the Law of Ukraine on the Zone of Environmental Emergency dated July 13, 2000; the Law of Ukraine on the Legal Regime of Emergency dated March 16, 2000; the Law of Ukraine on Environmental Impact Assessment dated February 09, 1995; the Law of Ukraine on Protection of the Population and Territories against Anthropogenic and Natural Emergencies dated June 08, 2000; the Law of Ukraine on Emergency Rescue Services dated December 14, 1999; the Law of Ukraine on Protection of People Against Ionizing Radiation dated January 14, 1998, etc.[20].

The framework documents, developed and approved by the authorized state bodies, which represent the conceptual basis of the state environmental policy, are of particular importance. In particular, the Law of Ukraine "On Fundamental Principles (Strategy) of Ukraine’s State Environmental Policy for the period until 2030" dated February 28, 2019, should be mentioned in this regard. The law defines the root causes of Ukraine's environmental problems, as well as how to introduce the ecosystem approach into industry policy and improve the integrated environmental management system. Another important law that defines the principles of strategic planning in the field of rational nature management is the Law of Ukraine "On the Approval of the National Program for the Development of

Mineral Resources Base of Ukraine for the Period until 2030" (as amended on June 10, 2012).

The subordinate regulatory acts include the Decrees and Orders of the President of Ukraine. In particular, these are Decree of the President of Ukraine No. 111/2021 "On the Decision of the National Security and Defense Council of Ukraine "On Challenges and Threats to National Security of Ukraine in the Environmental Sphere and Priority Measures to Neutralize Them" dated March 23, 2021"; Decree of the President of Ukraine No. 104/2021 "On the Decision of the National Security and Defense Council of Ukraine "On Measures to Increase the Level of Chemical Safety on the Territory of Ukraine" dated March 19, 2021"; Decree of the President of Ukraine No. 511/2019 "On Some Measures to Preserve Forests and Rational Use of Forest Resources"; Decree of the President of Ukraine No. 722/2019 "On the Sustainable Development Goals of Ukraine for the Period up to 2030"; Decree of the President of Ukraine No. 512/2019 "On Some Issues of the Development of Territories Exposed to Radioactive Contamination as a Result of the Chernobyl Disaster"; Decree of the President of Ukraine No. 381/2017 "On Additional Measures for the Development of Forestry, Rational Nature Management and Preservation of the Objects of the Nature Reserve Fund".

Also, this category includes government resolutions, departmental regulations of the ministries and departments, as well as acts of local authorities.

The Orders of the Cabinet of Ministers of Ukraine approve and implement the subordinate regulatory acts of the executive authorities. For example, the Regulation on State Environmental Monitoring was approved by the Cabinet of Ministers of Ukraine on September 23, 1993, which determines the procedure for establishment and operation of the system for monitoring, collection, processing, transmission, storage, and analysis of information on environmental conditions; the Order of the Cabinet of Ministers of Ukraine on Approval of the Regulation on Control of Transboundary Movements of Hazardous Waste and Their Recycling/Disposal and the Yellow and Green Waste List dated July 13, 2000; the Order of the Cabinet of Ministers of Ukraine on the State Technological Center for Soil Fertility Protection dated August 04, 2000; the Order of the Cabinet of Ministers of Ukraine dated August 04, 2000, which approved the Procedure for Monitoring of the National and International Projects in the Field of Nuclear and Radiation Safety and Radioecology; the Concept of Public Policy in Climate Change for the Period up to 2030 approved by Order No. 932-r of the Cabinet of Ministers of Ukraine dated November 7, 2016; the Strategy for the Radioactive Waste Management in Ukraine approved by Order No. 990 of the Cabinet of Ministers of Ukraine dated August 19, 2009; the National Strategy for Waste Management in Ukraine until 2030 approved by Order No. 820 of the Cabinet of Ministers of Ukraine dated November 8, 2017; the Concept of Implementation of Public Policy in Industrial Pollution approved by Order No. 402 of the Cabinet of Ministers of Ukraine dated May 22, 2019; the Plan of Measures for Implementing the Concept of Implementation of Public Policy in Industrial Pollution approved by Order No. 1422 of the Cabinet of Ministers of Ukraine dated December 27, 2019; the Concept of Combating Land Degradation and Desertification approved by Order No. 1024 of the Cabinet of Ministers of Ukraine dated October 22, 2014; the National Action Plan for Combating Land Degradation and Desertification approved by Order No. 271 of the Cabinet of Ministers of Ukraine dated March 30, 2016; the Irrigation and Drainage Strategy in Ukraine until 2030 approved by Order No. 688-r of the Cabinet of Ministers of Ukraine dated August 14, 2019; the Action Plan for Implementing of the Irrigation and Drainage Strategy in Ukraine until 2030 approved by Order No. 1567 of the Cabinet of Ministers of Ukraine dated October 21, 2020; the Concept of Reforming the System of State Supervision (Control) in the Field of Environmental Protection approved by Order No. 616-r of the Cabinet of Ministers of Ukraine dated May 31, 2017; the Action Plan for Implementing the Concept of Reforming the System of State Supervision (Control) in the Field of Environmental Protection approved by Order No. 353-r of the Cabinet of Ministers of Ukraine dated May 23, 2018; the Strategy for Ensuring Biological Safety and Biological Protection approved by Order No. 1416-r of the Cabinet of Ministers of Ukraine dated November 27, 2019.

The framework environmental regulations are supplemented by orders, instructions, regulations, rules, and methods issued at the departmental level by sectoral ministries and departments and approved by respective orders. Thus, the order of the Ministry of Environmental Protection of Ukraine (*as of the beginning of 2023 — the Ministry of Environmental Protection and Natural Resources of Ukraine*) dated February 27, 1996, approved the Regulation of the Ministry of Environmental Protection and Nuclear Safety on the State Management of Environmental Safety in the Regions and Cities of Kyiv and Sevastopol. According to the said Regulation, the task of the specified state authority is to implement management functions in the field of environmental protection, and ensure environmental and radiation safety in the territory of regions and cities of Kyiv and Sevastopol. the Order of the Ministry of Environmental Protection and Nuclear Safety of Ukraine dated September 08, 1999, which approved the Regulation on Environmental Control at the Checkpoints on the State Border and in the Zone of Regional and Other Customs; the Order of the Ministry of Ecology and Natural Resources of Ukraine dated December 14, 2000, which approved the Rules for Storage of Nuclear Materials, Radioactive Wastes and Other Sources of Ionizing Radiation; the Order of the Ministry of Environmental Protection and Natural Resources of Ukraine "On Approval of the Action Plan for the Preservation and Reproduction of Bison (Bison bonasus L.) in Ukraine" dated 12.28.22; the Order of the Ministry of Environmental Protection and Natural Resources of Ukraine "On Approval of the Methodology for Determining Damage and Losses Caused to the Territories and Objects of the Nature Reserve as a result of the Armed Aggression of the Russian Federation" dated October 13, 2022, etc.

It should be noted that a special place among the regulations on ecology is held by the local acts, i.e. the decision of local referendums, acts of local governments, and local management authorities in the field of ecology on relevant issues of local importance. For example, the Order "On the Strategic Action Plan of the Department of Ecology and Natural Resources of the Executive Body of the Kyiv City Council (Kyiv City State Administration)" dated August 23, 2019.

In addition to regulations of the national legislation of Ukraine, the sources of environmental law are international treaties with the participation of Ukraine. They include: UNECE Convention on Access to Information, Public Participation in Decision-making and Access to Justice in Environmental Matters dated June 25, 1998 (Aarhus Convention); Stockholm Declaration (Declaration of the United Nations Conference on the Environment) dated June 16, 1972; Rio Declaration on Environment and Development dated June 14, 1992; European Agreement Concerning the International Carriage of Dangerous Goods by Road joined by Ukraine in 2000; Convention on the Conservation of Migratory Species of Wild Animals joined by Ukraine pursuant to the Law of Ukraine dated March 19, 1999; Berne Convention on the Conservation of European Wildlife and Natural Habitats dated September 19, 1979, joined by Ukraine pursuant to the Law of Ukraine dated October 29, 1996; Ramsar Convention on Wetlands of International Importance Especially as Waterfowl Habitat dated February 02, 1971 (with amendments pursuant to the Paris Protocol dated December 03, 1982, and Regina Protocol dated May 28, 1987) joined by Ukraine pursuant to the Law of Ukraine dated October 29, 1996.

Ukraine has signed about 50 bilateral international agreements and treaties with countries near and far abroad, in particular, Georgia, Moldova, Slovakia, Poland, Austria, Finland, and Israel. For example, the Agreement between the Government of Ukraine and the Government of the Republic of Poland on Early Notification of Nuclear Accidents, Exchange of Information and Cooperation in the Field of Nuclear Safety and Radiation Protection, signed in Kyiv on May 24, 1993 in view of the Convention on Early Notification of a Nuclear Accident dated September 26, 1986 (the IAEA Convention); the Agreement between the Ministry of Environmental Protection of Ukraine and the Ministry of Environmental Protection, Natural Resources and Forestry of the Republic of Poland on Cooperation in the Field of Environmental Protection signed in Warsaw on May 18, 1992; the Memorandum of Understanding between the Government of Ukraine and the Government of the United States in the field of prevention and liquidation of natural and anthropogenic emergencies dated June 05, 2000, etc.

In 2014, Ukraine concluded the Association Agreement between Ukraine, on the one hand, and the European Union, the European Atomic Energy Community and their member states, on the other hand. The basis of the environmental component of the Association Agreement is Chapter 6 "Environment" of Chapter V "Economic and Industry Cooperation". The document pays attention to the following main directions in the field of environmental protection and rational use of natural resources: cooperation in the field of the environment; cooperation in the field of civil protection; cooperation for the development of a comprehensive strategy in the field of environment. The parties also undertake to pay attention to the development of industry strategies for improving the quality of air, water and management of relevant resources; management of waste and resources aimed at protecting nature, preventing industrial pollution, including due to industrial accidents.

The mechanism of ensuring environmental security means a set of interrelated government and legal means aimed at achieving environmental security by regulating and controlling the activities of subjects of environmental legal relations with the help of environmental legal regulations.

Environmental safety of the population is the most humane, noble, and responsible task of environmental legislation, which, firstly, enshrines the environmental rights of the citizens of Ukraine, secondly, guarantees their implementation, and thirdly, defines the legal, economic, and social basis for environmental protection. Thus, under Article 9 of the Law on Environmental Protection dated June 25, 1991, all citizens of Ukraine have the right to an environment that is safe for their health and life; participation in the discussion of draft regulations, materials on placement, construction and reconstruction of facilities that may have a negative impact on the state of the natural environment, and making proposals to state and economic bodies, institutions and organizations on these issues; participation in the development and implementation of measures to protect the natural environment, reasonable and integrated use of natural resources; implementation of general and special use of natural resources; association in public environmental groups; obtaining of full and reliable information about the state of the natural environment and its impact on public health in the prescribed manner; participation in public environmental assessments; environmental education; filing of claims against government agencies, enterprises, institutions, organizations and citizens for compensation for damage to their health and property as a result of the negative impact on the natural environment to the court.

At the same time, it should be noted that the citizens of Ukraine also have the corresponding duties, namely to preserve nature, protect and use its wealth reasonable in compliance with laws on environmental protection; to carry out activities to comply with environmental safety, other environmental standards and limits of natural resources; not violate environmental rights and legitimate interests of the other subjects; pay for special use of natural resources and fines for environmental offenses; compensate the damage caused by pollution and other negative impacts on the environment (Article 12 of the Law of Ukraine on Environmental Protection).

At the same time, the environmental rights of people are ensured by the system of guarantees. Specifically, according to Article 10 of the Law of Ukraine on Environmental Protection, these are implementation of large–scale state measures to maintain, restore and improve the state of the natural environment; obligations of ministries, departments, enterprises, institutions, and organizations to implement technical and other measures to prevent harmful effects of economic and other activities on the environment, to meet environmental requirements during the planning and placement of productive forces, construction and operation of national economic facilities; participation of public associations and citizens in environmental protection activities; implementation of state and public control over compliance with environmental legislation; compensation for damage caused to health and property of citizens as a result of the violation of environmental legislation in a prescribed manner; the inevitability of responsibility for violation of environmental legislation.

In the system of legal measures aimed at protecting the environmental rights of citizens, an important place is occupied by environmental programs, environmental expertise, control and supervision in the field of environmental protection; education and training in this area.

Environmental programs are developed in order to carry out an effective and purposeful activity for the arrangement and coordination of activities on environmental protection, environmental safety, reasonable use and reproduction of natural resources. For example, they include such national programs as the State Target Ecological Program for Environmental Monitoring of Natural Environment, approved by the Resolution of the Cabinet of Ministers of Ukraine dated December 05, 2007; the National Program for Establishing a National Environmental Network for 2000–2015 approved by the Law of Ukraine dated September 21, 2000; the Program for Prevention and Response to Emergency Situations of Anthropogenic and Natural Origin for 2000–2005 approved by Order of the Cabinet of Ministers dated August 22, 2000; the National Program for Toxic Waste Management approved by the Law of Ukraine dated September 14, 2000; the Program for Search and Neutralization of Chemical Agents Submerged in the Exclusive (Maritime) Economic Zone of Ukraine for 1997–2002 approved by Order of the Cabinet of Ministers of Ukraine dated November 25, 1996; the National Program of Protection and Reproduction of the Environment of the Azov and Black Seas approved by Law of Ukraine dated March 22, 2001, etc.

Self–assessment questions to subsection 3.1.2.

1. What groups are legal acts subdivided into?
2. What means subordinate legal acts?
3. What documents can be referred to as regulations?
4. What is a mechanism of ensuring environmental security?

3.2. MANAGEMENT IN THE FIELD OF ENVIRONMENTAL PROTECTION

3.2.1. Environmental monitoring. The purpose, objective, concept, and principles of organization. Types of monitoring

The need for an international environmental monitoring system was justified first in 1971 by the Scientific Committee on Problems of the Environment (SCOPE) of the International Council of Scientific Unions (ICSU) [27].

Initial monitoring was defined as a system for monitoring of one or more elements of the environment in space and time for a certain purpose in accordance with a predetermined program. In a broader sense, monitoring was understood as a system of monitoring, control and management of the state of the environment, which is carried out at different scales, including globally.

Subsequently, the definition given by Y. A. Izrael (1984) became generally accepted:

Monitoring means a system of surveillance, assessment, and forecasting of the state of the environment, which allows highlighting changes in the state of the biosphere under the influence of human activity.

The monitoring system is information–based and does not include management elements. It is part of the environmental management and its quality regulation system.

General monitoring consists of the following components:

Sanitary and hygienic monitoring is the monitoring of the environment in terms of its impact on the health of an individual and the population in general. Monitoring detects anthropogenic pollutants (solid, liquid, gaseous, noise, and electromagnetic fields).

Geo–environmental monitoring. The subject of monitoring is geosystems, the transformation of natural systems into natural–technical ones: agro–, industrial, and urban environments.

Geophysical monitoring studies the abiotic component of the biosphere. Determination of reactions to pollution in different layers of the atmosphere, changes in the hydrosphere and lithosphere.

Biological monitoring determines the state of the biological component of the biosphere. It studies the reaction of biota to anthropogenic actions and deviations from normal values caused by anthropogenic actions.

Biosphere monitoring ensures surveillance and control on a global scale. It provides the definition of changes in the biosphere as a whole and includes studies of geophysical characteristics – solar radiation, ozone layer condition, and changes in the gas composition of the atmosphere. It collects data on the state of natural waters and soil productivity, i.e. provides an assessment of the overall biosphere performance.

Monitoring is subdivided into:

- local, conducted in certain areas;
- national, conducted in each country;
- global, conducted on a worldwide scale.

The Global Environment Monitoring System (GEMS) program provides for work in a variety of areas, but its most important task is to monitor the large–scale carryover and deposition of pollutants (pollution monitoring) [29].

In turn, the ultimate goal of global pollution monitoring within GEMS is:

- to determine the concentration of priority pollutants in the environment, their distribution in space and change over time;
- to assess the magnitude and velocity of the fluxes of pollutants and harmful products of their transformations;
- to ensure the unified sampling and analytical methods to obtain comparable results between countries, as well as the to exchange experience in organizing the monitoring systems;
- to ensure the global provision of information relevant for decision–making on pollution control management.

Self–assessment questions to subsection 3.2.1.

1. What is monitoring?
2. Define sanitary and hygienic monitoring.
3. Characterize geo–environmental monitoring.
4. What is geophysical monitoring?
5. What is biological monitoring?
6. Describe biosphere monitoring.
7. What are the monitoring components?
8. What is the purpose of global monitoring?

3.2.2 Key tasks and organization of air basin and ozone layer monitoring

The augmentation of anthropogenic impact on the environment requires the availability of diverse and detailed information about it, allowing not only to assess the real situation but also to predict the state of the environment in the future, to establish a reasonable system of environmental protection activities and control the state of ecosystems.

Global international and regional systems of observation and control of atmospheric air pollution in developed countries are organized in line with recommendations of the UN, developed during the creation of monitoring programs. The atmospheric air has been monitored since the 1970s. Atmospheric air monitoring systems of different countries usually track air quality and its changes in critical emergencies. The list of pollutants to be monitored is determined by each country at its sole discretion. A similar approach to the organization of the atmospheric air monitoring system is used in the CIS countries and Ukraine.

The Law of Ukraine on Atmospheric Air Protection (1992) significantly expanded the functions of atmospheric pollution monitoring and control services which apply the calculation and experimental methods in their practice. Based on theoretical and experimental studies of the impurities distribution in the atmosphere, the basic principles were developed with regard to monitoring organization, laboratory (chemical) analysis of air samples, collection, processing, and generalization of information on pollution.

Information about the content of pollutants in the air is provided by the monitoring service network. The State Committee of Hydrometeorology of Ukraine is responsible for its operation.

Monitoring organization implies control over the distribution of harmful impurities both in the atmosphere itself and between the elements of the "atmosphere – hydrosphere – lithosphere – biosphere" system. This activity requires:

- information on the existing and prospective sources of atmospheric pollution (taking into account the development of economic areas);
- characteristics of pollutants (toxicity, chemical reactivity, self–purification ability);
- hydrometeorological data;
- results of preliminary monitoring of atmospheric pollution (expeditionary research);
- information about pollution levels in neighboring countries;
- information about transboundary carryover of harmful admixtures.

The set of tasks associated with the collection of this information is performed by a special monitoring service composed of the monitoring system and the control system.

The ***monitoring system*** ensures monitoring of the quality of atmospheric air in cities, settlements and territories located outside the impact zone of specific pollution sources. The monitoring is carried out by the services of the State Committee for Hydrometeorology, which provide the data on meteorological conditions and concentrations of harmful substances. The Ministry of Health conducts random monitoring of pollution levels in places where people live. The Research Committee of the National Academy of Sciences of Ukraine organizes aerospace monitoring of the ozone layer condition and global pollution of the atmosphere. There is environmental monitoring of certain industrial facilities.

The ***control system*** monitors and controls pollution sources and emissions of harmful substances into the atmosphere. For this purpose, the Ministry of Ecology and Natural Resources organizes monitoring of sources of industrial emissions into the atmosphere and compliance with standards of maximum permissible emissions, controls the implementation of measures to protect the atmospheric air, compliance with relevant requirements during the placement, design, construction, and commissioning of new industrial facilities. During the organization of monitoring of the state of the air, preliminary studies are used, which involve surveying the territory (weather conditions, content of pollutants) using mobile laboratories to conduct the sampling and analysis in order to study the location of current sources of pollution and industrial development.

After determining the existing and prospective level of atmospheric air pollution, one should assess changes in the concentration of impurities in space and time, develop a scheme of placement of permanent (stationary) monitoring stations in the city and their work programs. The monitoring stations may provide information on the general condition of the air basin (if they are located outside the influence zone of individual emission sources) and monitor emission sources (if they are located within the influence zone of emission sources). When making a decision on their location, priority is given to residential areas with the highest population density, where the established thresholds of hygienic indicators (MAC) may be exceeded. The operation of monitoring stations should meet the following conditions:

- mandatory display of general condition of the air basin and control of emission sources;
- mandatory monitoring of all impurities, the concentrations of which exceed the MAC;
- mandatory determination of dust, sulfur dioxide, carbon monoxide, and nitrogen oxides.

The radioactive pollution of atmospheric air is controlled with regard to background radiation, as well as in the areas of impact of nuclear power plants and other sources of possible releases of radioactive substances. When controlling background radiation of radioactive pollution, background radiation stations or special stations installed 50–100 km away from the possible source of radioactive pollution are used. For monitoring within a radius of up to 25 km, the control network and special monitoring stations are used, where gamma–radiation sensors, as well as air sampling and analysis devices are installed. The stations for remote control of radioactive pollution of atmospheric air are arranged within the sanitary protection zones (SPZ).

Monitoring of territory pollution on the basis of snow gauging (monitoring of snow cover pollution) ensures control of the level of atmospheric air pollution in clean (background) areas, cities and other settlements. Important methods of controlling the transboundary transport of global fluxes of impurities over long distances from the point of emission is a system of ground and airborne stations, as well as mathematical models of pollutant distribution in the air. The network of transboundary carryover stations is equipped with systems for sampling gas and aerosols, collecting dry and wet precipitation, and analyzing the content of impurities in the collected samples.

Information is received by Western and Eastern European meteorological synthesizing centers. According to the degree of promptness, it is subdivided into the following types:

– *emergency information* which contains data on sudden changes in levels of atmospheric air pollution immediately transmitted to controlling and economic organizations;

– *operational information* which contains generalized monthly results of monitoring;

– *regime information* which contains data on the average and the highest level of air pollution over a long time (usually a year); is used when planning the activities, assessing the damage caused to the national economy as a result of atmospheric air pollution.

To ensure the effectiveness of air protection measures, the information must be complete and reliable. The completeness of the information is ensured by a sufficient number of monitored components, a long monitoring period, and strategic placement of the network. Reliability of information is achieved by strict compliance with regulatory requirements. Reliability significantly depends on the homogeneity of information.

Atmospheric air pollution in Ukrainian cities is assessed on the basis of data of the monitoring carried out in 54 cities at 166 stationary stations and 2 transboundary carryover stations. A reasonably organized system of monitoring and control over the state of atmospheric air allows obtaining the required information about the quality composition of air in the settlements and areas of impact of emission sources, about transboundary transport of pollutants, to identify the areas characterized by exceedances of MACs of pollutants. The availability of reliable and comprehensive monitoring data is a prerequisite for the development of recommendations to improve the atmosphere condition.

Self–assessment questions to subsection 3.2.2

1. What is environmental monitoring? What is its purpose?
2. Characterize the environmental monitoring subsystems.
3. Provide a classification of the principles of the state environmental monitoring in Ukraine.
4. Describe the structure and levels of the state environmental monitoring in Ukraine.
5. Describe the organization of the state environmental monitoring in Ukraine.
6. Analyze the key requirements for the organization of monitoring of atmospheric air pollution.

3.2.3 Surface water quality monitoring

Surface waters are land waters that are permanently or temporarily located on the earth's surface in the form of various water bodies in liquid (streams, reservoirs) and solid (glaciers, snow cover) states.

Household, industrial and agricultural discharges lead to chemical, physical, biological, and thermal pollution of the hydrosphere.

Chemical pollution of water occurs as a result of the introduction of harmful impurities of inorganic and organic origin: arsenic, lead, mercury, copper, cadmium, chromium, fluorine compounds, as well as oil and petroleum products into water bodies with wastewater. They are absorbed by phytoplankton and further carried over by the trophic chain to the other organisms with a cumulative effect. Most of these impurities are toxic for the inhabitants of water bodies.

The condition of water bodies is adversely affected by sewage and discharge waters containing the dissolved organic substances or suspensions of organic origin, because they lead to a decrease in the water oxygen content.

Discharge water is water diverted from irrigated farmland, homestead lands, as well as from areas where hydromechanization is applied.

Wastewater is water generated in the course of domestic and industrial activities (except for sewage and discharge waters), as well as by diverting atmospheric precipitation from the polluted area.

The amount of chemical pollutants is increasing constantly. We still known little about the harmful effects of some of them because they have a prolonged effect, i.e. harmful mutations, genetic disorders, etc. that manifest themselves in subsequent generations of living beings.

Physical pollution of water causes changes in physical properties, i.e. its transparency, the content of suspended and other insoluble impurities, radioactivity and temperature.

Biological pollution of the aquatic environment involves the introduction of various types of microorganisms, plants and animals (viruses, bacteria, fungi, worms) that are not typical of the aquatic ecosystem into water bodies with wastewater. Most of them are pathogenic. The most harmful are municipal and domestic wastewaters. Industrial biological pollutants are tanneries, meat processing plants, and sugar refineries.

Surface water monitoring means a system of consecutive sessions of monitoring, collection, and processing of data on the state of water bodies, forecasting of changes and development of evidence–based recommendations to make management decisions that may affect the state of water.

The **main purpose** of arranging the system of monitoring and control of water body pollution is to obtain information about the natural quality of water and assess changes in water quality due to anthropogenic factors.

The Monitoring and Control Service performs the following **tasks**:

- monitoring and control of the level of the aquatic environment pollution by chemical, physical and hydrobiological indicators;
- study of the dynamics of pollutant content and identification of conditions under which the pollution level is fluctuating;
- study of patterns of self–purification processes and accumulation of pollutants in bottom sediments.

In Ukraine today, according to the Procedure of State Water Monitoring and the Regulation on the State System of Environmental Monitoring, state water monitoring is an integral part of the state environmental monitoring system. On the basis of these two governmental documents, Unified Interagency Instruction on Organization and Implementation of State Water Monitoring (UII) was developed. This document establishes uniform requirements for the organization and implementation of monitoring of surface waters, coastal zones of reservoirs, groundwater, sources of water pollution, hydrological, physico–chemical, biological, and radiological indicators of water quality. Compliance with the UII requirements is mandatory for all units of state water monitoring, as well as responsible water users who monitor the quantitative and qualitative condition of waters.

The main units of state monitoring include the Ministry of Ecology and Natural Resources, including the Chief State Environmental Inspectorate and State Department of Environmental Protection in the regions, organizations of the Hydrometeorological Service; geological territorial organizations; the Ministry of Emergency Situations; the Ministry of Health; the Ministry of Agrarian Policy; the State Committee of Ukraine on Water Management; the State Committee on Construction, Architecture and Housing Policy of Ukraine.

The most of work on river monitoring is performed by monitoring stations of the Hydrometeorological Service. These stations are distributed between 10 river basins of Ukraine. Most of the monitoring stations are located in the Dnieper basin, the monitoring network is developed in the basins of the Danube and Dniester. The current hydrological network of Ukraine includes 374 monitoring stations.

Water pollution is monitored at permanent and temporary monitoring stations, which are arranged in places where the influence of economic activity is present or absent.

A surface water quality monitoring station means a place on a water body or watercourse, where a set of works is carried out to obtain the data on water quality and quantity characteristics.

The key objects requiring the monitoring are places of discharge of sewage and rainwater of cities, villages, agricultural complexes, wastewater of industrial facilities, TPP, NPP; places of discharge of collector and drainage water diverted from irrigated or drained lands; final sections of large and medium rivers flowing into the sea and internal water bodies; borders of economic regions, republics, and countries crossing the transit rivers.

3.2.4. Water quality indicators

Since there is no single indicator defining the entire set of water characteristics, the assessment of water quality is based on a system of indicators. These indicators are subdivided into physical, bacteriological, hydrobiological, and chemical ones. Another form of classification of water quality indicators is their distribution into general and specific. The *general* ones are characteristics typical of all water bodies. The presence of *specific indicators* in water is conditioned by local natural conditions, as well as the peculiarities of anthropogenic impact on a water body.

The main *physical indicators* of water quality include temperature, odor, transparency, color, and content of suspended solids.

Bacteriological indicators characterize the water contamination with pathogenic microorganisms. The most important bacteriological indicators include the coli–index, i.e. the number of E. coli per liter of water, and the coli–titer, i.e. the amount of water in milliliters in which one E. coli can be found.

Hydrobiological indicators allow assessing water quality by the animal population and vegetation of water bodies. Changes in the species composition of aquatic ecosystems can occur under such weak pollution of water bodies, which is not revealed by any other methods. Therefore, hydrobiological indicators are the most sensitive.

Physical, bacteriological, and hydrobiological indicators refer to general indicators of water quality.

Chemical characteristics can be general and specific. General chemical indicators of water quality include dissolved oxygen content, chemical and biochemical oxygen demand; hydrogen index; nitrogen and phosphorus content and mineral composition.

The most common specific water quality indicators include phenols, petroleum products, surfactants, synthetic surfactants, pesticides, and heavy metals.

3.2.5. Specifics of sampling for surface water monitoring

The monitoring regime of hydrological and hydrochemical indicators is determined by the water regime of the river. In most watercourses, sampling is carried out 7 times a year: during floods – at the rise, maximum, decline; during the summer low water season – at the slightest water discharge and after the rain flood; in autumn before the freeze–up; during the winter low water season.

Flood is a phase of the water regime of rivers characterized by the highest water content, a significant relatively long–term increase in water level, and observed annually in the same season.

Low water season is a phase of the water regime of the rivers characterized by low water content, prolonged maintenance of low water levels, and observed as a result of decreased supply of the watercourse.

Hydrochemical information about lakes and reservoirs is collected seasonally, i.e. four times a year.

Proper assessment of water quality ensures that the following conditions are met:

- proper water sampling in the proper amount;
- representativeness of samples (compliance with the set task both in terms of quality and volume, as well as in terms of selected points and time of sampling, as well as sampling technique, pretreatment, storage and transportation conditions).

Samples are subdivided into simple and mixed ones.

Simple samples characterize the water quality at a certain point of sampling and are taken at a certain time in the required volume.

Mixed samples combine several simple samples to assess water quality over a certain period or a certain area of the object under study.

Depending on the purpose of the study, one–time or regular sampling is chosen.

One–time sampling is used if the measured parameters do not fluctuate significantly in terms of space (depth, water surface of the reservoir) and time; the patterns of fluctuations of the determined parameters are known in advance; only the general ideas about the quality of water in the water body are needed.

Regular sampling means that each sample is taken in spatial and temporal interdependence with the others.

3.2.6 Water quality assessment and forecasting

Water quality assessment is based on a system of reference characteristics against which the quality of the water under study is compared. Single, indirect, and comprehensive assessments of surface water pollution by hydrochemical indicators are used. It is comprehensive assessments that provide the most accurate and objective information on the quality of surface waters.

Comprehensive assessment of surface water pollution means information about the water pollution or quality, expressed through certain systems of indicators or a limited set of characteristics of its composition and properties, compared with water quality criteria or standards for a particular type of water use or water consumption.

According to the **Water Code of Ukraine**, the water quality assessment is based on the standards of ecological safety of water use and ecological standards of water quality in water bodies.

Water quality assessment based on standards of ecological safety of water use. The current standards allow assessing the quality of water used for municipal, domestic, drinking, and fishery needs.

The regulatory framework for assessing the water quality is formed on the basis of general requirements for the composition and properties of water, as well as the values of maximum allowable concentrations of substances in the water of water bodies. The general requirements define the permissible composition and properties of water, which are evaluated by the most important physical, bacteriological, and generalized chemical indicators.

Maximum allowable concentration (MAC) is the level of substance concentration in water. If it is exceeded water is considered unsuitable for a particular type of water use.

All substances are subdivided into five groups by the nature of their adverse influence. Each group combines substances of the same level of influence, called a harmful index. The same substance in different concentrations can lead to different levels of harm.

Limiting harmful index (LHI) is a level of harm that appears at the smallest concentration of a substance.

Group I includes substances subject to general requirements for the amount of dissolved oxygen, biological oxygen demand (BOD_5), suspended solids, hydrogen index (pH), mineralization; the level of harm is general sanitary one. Group II includes substances with sanitary and toxicological limiting harmful indices: SO_4, Cl, Ca, Mg, Na, K, NO_3, Cr. Group III includes substances with toxicological LHIs ($N - NH_4$, $N - NO_2$, synthetic surfactants, Cu, Zn, Ni). Group IV includes substances of LHIs for fishing, i.e. phenols and petroleum products. Group V includes substances with organoleptic LHIs [9].

While evaluating the quality of water in water bodies for municipal, household and drinking water use, the *toxicity class* is determined. It is determined depending on the toxicity, cumulativeness, mutagenicity and LHI of the substance. There are four hazard classes: class I – extremely hazardous; class II – highly hazardous; class III – hazardous; class IV – moderately hazardous [9].

When assessing the water quality, the **principle of additivity** is applied, i.e. a unidirectional action, according to which when several substances have the same LHI their negative impact is summed up.

Water bodies are considered suitable for municipal, household, and drinking water use if the following conditions are met simultaneously [9]:

- the general requirements for the composition and properties of water for the relevant category of water use are not violated;
- for substances of the toxicity classes III and IV, the following condition is met:

$$C \leq MAC,$$

- where C is the concentration of the substance in the water body, g/m^3;
- for substances of the toxicity classes I and II, the following condition is met:

$$\sum_{i=1}^{n} \frac{C_i}{MAC_i} \le 1$$

n – кількість аналізів за місяць

where Ci and MACi are, respectively, the concentration and MAC of the *i*–th substance of class I and class II.

Water bodies are considered suitable for fishery use if the following conditions are met simultaneously:

- the general requirements for the composition and properties of water for the relevant fishery category are not violated;
- for substances having the same LHIs, the following condition is met:

$$\sum_{i=1}^{n} \frac{C_{iMAD}}{MAC_i} \le 1$$

C_{iMAD} -концентрація нормованої речовини при ГДС

where Ci and MACi are, respectively, the concentration and MAC of the *i*–th substance with a particular LHI.

Physico–chemical and other processes take place in polluted water bodies in order to restore the natural state of waters, i.e. their self–purification. The main ones are the processes of dilution and transformation.

Water quality at a particular station is evaluated by comparing the maximum concentration of a pollutant with its maximum permissible value.

The maximum concentration of the limiting substance in the river below the effluent flow varies within the range of $C_n < C_{\text{max}} < C_{\text{ww}}$, where C_n is the average concentration of the substance (in milligrams per liter), determined as follows:

$$C_n = Q_r C_r + Q_{\text{ww}} C_{\text{ww}} / (Q_r + Q_{\text{ww}}),$$

where Q_r, Q_{ww} are the flow of water in the river and the flow of wastewater, m^3/s, respectively; C_r, C_{ww} are the concentration of the substance in the river water and wastewater, mg/l, respectively.

When calculating the dilution, summary values of pollutant concentrations, C_{sum}, are used. This value is defined as the excess over the natural background. If C is the actual concentration of the pollutant in the pollution area, then

$$C_{sum} = C - C_r.$$

The summary concentration of pollutants in wastewater will be as follows:

$$C_{ww \cdot sum} = C_{ww} - C_r.$$

When evaluating the water dilution, the dilution index n and the mixing ratio γ are used. The dilution index n is a universal characteristic that shows by how many times the concentration of a pollutant is reduced in the wastewater within a certain section of the river. The dilution index is determined as follows:

$$n = (C_{ww} - C_r) / (C_{max} - C_r).$$

The mixing ratio γ indicates how much of the water flow is mixed with the wastewater. The dilution index and the mixing ratio have the following interdependences:

$$n = (Q_{ww} + \gamma Q_r) / Q_{ww};$$
$$\gamma = (n - 1)Q_{ww} / Q_r.$$

The mixing ratio is calculated only when the wastewater is not spread across the entire width of the stream in the control section.

The reduced concentration of pollutants in wastewater simultaneously with dilution is predetermined by biochemical and physical–chemical processes occurring in water bodies. One of the ways to quantify the decrease in concentration due to these processes is the coefficient of non–conservativity k_n which takes into account the substance transformation rate cumulatively. Its value is established on the basis of laboratory studies. The value of this coefficient is negative, and its dimension is day^{-1} (1/day), s^{-1} (1/s).

In general terms, the process of biochemical transformation can be described by a first–order equation:

$$C_t = C_0 \, exp\,(-(k_1 + k_2 + \ldots + k_n)\, t),$$

where C_0, C_t are concentrations of a substance at the initial moment and at time t, respectively; k_n are the ratios related to a particular process that take into account the transformation of substances in a water body.

The discharge of wastewater into water bodies refers to one of the types of special water use and is carried out on the basis of a permit issued by the local environmental safety authorities. The discharge of wastewater into water bodies is regulated by maximum permissible discharges (MPD) of substances. **MPD** is the maximum permissible mass of a substance discharged with wastewater per unit of time, which allows ensuring compliance with water quality standards in the control section of the water body for the worst conditions of water use. MPD is established for each discharge of the wastewater into the water body. For each indicator of water quality, MPD is determined as the product of the maximum wastewater flow rate per hour and its maximum allowable value:

$$\text{MPD} = Q_\text{ww}\, C_\text{MPD},$$

where C_MPD is the maximum allowable value of the indicator, g/m^3; Q_ww is the maximum wastewater flow rate per hour, m^3/hour.

The value of C_{MPD} should not exceed the actually achieved (design) concentration C_{ww} of the substance to be controlled in the wastewater.

For substances of the hazard classes I and II, the quality standards will be met in the wastewater if the following condition is met:

$$\sum_i \frac{C_{MPDi}}{MACi} = 1.$$

For each substance, C_{MPD} is part of its MAC, i.e.

$$C_{MPD} = K_i\, MAC_i, \text{ where } K_i<1$$

Self–assessment questions to subsection 3.2.6.

1. What is surface water?
2. What causes chemical pollution of water?
3. What is the difference between discharge water and wastewater?
4. Characterize the physical pollution of water.
5. Describe the biological pollution of water.
6. What is the main purpose of surface water monitoring?
7. What is the purpose of a surface water quality monitoring station?
8. What are the physical indicators of water?
9. What are the biological indicators of water pollution?
10. What are the types of chemical indicators?
11. What is a flood?
12. What is a low water season?
13. What is the basis for the water quality assessment?
14. What is MAC?
15. What is LHI?
16. How is MPD determined?

3.2.7. Land resources monitoring

Land monitoring is an integral part of the monitoring of the state of the ecological network, which is a system that monitors changes in environmental components within the ecological network in order to detect negative trends in a timely manner, to assess the possible consequences of such changes, to predict, prevent negative processes, and eliminate their consequences. Land monitoring includes:

- collection of information on the structure of land use and land tenure, land transformation, condition and quality of soils and compliance with the regime of land use of water protection zones, etc.;
- changes in the state of land on specific territories – identification of land degradation processes and diagnostics of their condition;
- detection of pollutants, their characteristics, and harmful effects;
- identification of the direction and size of negative processes;
- forecasting social and economic consequences;
- taking adequate actions (antidegradation, agrochemical ones, etc.);
- recommendations for land use;
- management decisions to improve the state of land, protect the same, prevent and eliminate the consequences of negative processes.

The tasks of land monitoring include:

- long–term systematic monitoring of the state of land;
- analysis of the land ecological state; timely detection of changes in the state of land;
- assessment of these changes, forecasting, and development of recommendations to prevent negative processes and eliminate their consequences;
- information support for maintaining the state land cadaster, land management, state control over the use and protection of land, etc.

Information on the condition of land resources and their use obtained in the course of monitoring shall be accumulated in archives and databanks of the automated information system. Operational summaries, research forecasts, and recommendations shall be prepared on the basis of the information collected and the results of the land condition assessment and shall be forwarded to the local bodies of state executive authority, local self–government bodies, and other state bodies for taking actions to prevent negative processes and to eliminate their consequences.

The materials obtained objectively characterize the physical, chemical, and biological processes in the environment, the level of soil contamination, which allows public authorities to impose requirements on land users to eliminate offenses in the use and protection of land.

The State Committee for Land Resources of Ukraine is monitoring:

- the structure of land use and land tenure;
- the land transformation depending on its intended purpose;
- the condition and quality of soils and pollution in landscapes;
- the condition of irrigated and drained lands, as well as lands with signs of secondary waterlogging and salting;
- the condition of the shorelines of rivers, seas, lakes, reservoirs, estuaries, and bays.

The bodies of the State Committee for Land Resources provide all stakeholders of the monitoring system with information on the state of the land fund, the structure of land use, land transformation, and actions to prevent negative processes and eliminate their consequences.

Self–assessment questions to subsection 3.2.7.

1. Identify the key land monitoring components.
2. What is the task of land monitoring?
3. List the key parameters of soil condition control.
4. What does the "land contamination" mean?
5. Characterize the land state monitoring conducted by the State Committee for Land Resources of Ukraine.

3.3.THE CONCEPT OF ENVIRONMENTAL LAW

Environmental law as a branch in the legal system of Ukraine emerged relatively recently. **Environmental law** is a system of legal regulations governing the relations of ownership, use, and restoration of natural resources in their inseparable connection with the environment in order to implement environmental interests and ensure the environmental security of the state.

Environmental law establishes the regulations, rules, and standards that must be observed to preserve the environment as a necessary condition for the existence of people, protect the environmental rights of citizens, and establish an optimal balance between the environmental and economic interests of the public.

The objective of environmental law is to regulate the protection, use, and reproduction of natural resources, ensure environmental safety, establish the legal arrangements to minimize the negative impact of economic and other activities on the environment, conservation of natural resources, genetic fund of wildlife, landscapes, other natural complexes, naturally protected areas and objects.

Environmental rights of citizens determine the aggregate measure of the possible permitted human behavior in terms of attribution of natural objects, their use, restoration, and protection of the environment. Environmental rights of citizens are enshrined by the Constitution of Ukraine, environmental codes, and laws. According to Article 9 of the Law of Ukraine on Environment, a citizen of Ukraine has the right:

- for the environment which is safe for his/her life and health;
- to participate in the discussion of draft legislation on the placement, construction, and reconstruction of facilities that may adversely affect the state of the environment;
- to participate in the development of measures to protect the environment and sustainable nature management;
- to carry out both general and special environmental use;

- to obtain reliable information about the state of the environment and its impact on public health;
- to participate in public environmental expertise;
- to obtain environmental education;
- to submit claims to the court, government agencies, business entities, organizations, institutions, and citizens for compensation of damage caused to their health and property as a result of the negative impact on the environment.

Environmental safety is the state of the environment, which ensures the prevention of environmental degradation and the emergence of health hazards.

Along with environmental rights, citizens also have duties stipulated by applicable laws. A citizen must first fulfill environmental duties in order to exercise his or her environmental rights.

The Citizens of Ukraine shall:

- protect nature, safeguard and use its riches reasonably in compliance with laws on the environmental protection;
- operate in compliance with environmental safety, limits, and standards for the use of natural resources;
- not violate the environmental rights and legitimate interests of the other entities;
- pay fees for special use of natural resources and fines for environmental offenses;
- compensate for damage caused by pollution and other negative impacts on the environment, as well as perform the other duties in the field of environment protection.

3.3.1 System of environmental law

The system of environmental law as a branch of law is the internal structure of environmental law, the key components of which are sub–branches, legal institutions, and legal norms. They must be coordinated with each other. The primary element of the environmental law system is a legal norm. It contains specific environmental legal prescriptions.

By the nature of effect, the environmental standards are subdivided into substantive and procedural. The latter is the means of practical implementation of material environmental standards. Both material and procedural environmental standards can be contained in both purely environmental and other regulations. It is associated with their "floating" nature in the complex system of environmental law.

The institutes of environmental law include the institutes of nature management, ensuring the environmental safety and protection of natural territories and objects of environmental network. There are also the institutes of ownership of natural resources; environmental rights of citizens; management and control; standardization, licensing, auditing and expert examination; legal liability for environmental offenses, etc.

A characteristic feature of the environmental law as a complex branch is the inclusion of the other branches of law which are recognized today, i.e. land, mining, water, forest, fauna, and atmosphere protection law. These branches have their own internal structure, their own subject and method of legal regulation. In the system of environmental law, they are sub–branches of environmental law.

3.3.2 Subject and methods of environmental law

The subject of environmental law is public relations in the field of interaction between the public and the environment. The object of environmental law is natural and natural–anthropogenic values subject to public relations as an interaction between the public and the environment.

The **object** of environmental law is heterogeneous. According to the Law of Ukraine on Environmental Protection, it is possible to distinguish between the environment as a whole and its three main components: 1) natural resources; 2) natural areas and objects subject to special protection; 3) human health and life.

The environment is a set of natural and natural–social conditions and processes, natural resources both involved in economic circulation and not used in the economy in a given period (land, subsoil, water, air, forest and other vegetation, wildlife), landscapes and other natural complexes (i.e. a complex ecosystem, consisting not only of purely natural but also of natural and anthropogenic factors and patterns).

In a broad sense, natural resources include all natural resources that serve human needs. In a narrow sense, they include natural sources to meet the needs of material production.

In accordance with the Law of Ukraine on Environmental Protection, the natural territories and objects subject to special protection are territories and objects of the natural reserve fund, spa and therapeutic facilities, recreational facilities, water protection facilities, field protection facilities, and other types of territories and objects determined by the laws of Ukraine.

All the diversity of the relevant territories and objects is covered by the concept of "environmental network", which is regulated by the Law of Ukraine on Environmental Network of Ukraine. This network, which is a unified territorial system, is formed in order to improve the conditions for the formation and restoration of the environment, increase the natural resource potential of the territory of Ukraine, conservation of landscape and biodiversity, habitats and growth of valuable species of fauna and flora, the genetic fund, animal migration routes through the combination of areas and objects of the natural reserve fund, as well as the other areas of special value for environmental protection and in accordance with the laws and international commitments of Ukraine are subject to special protection [19].

According to the Law of Ukraine on Environmental Protection, human health and life are subject to state protection from the negative impact of adverse environmental conditions. The subject of environmental law is complex and includes four groups of social relations: 1) relations on the environmental protection; 2) relations on the use of natural resources; 3) relations on ensuring the environmental safety; 4) relations on the formation of conservation and reasonable use of the environmental network [20].

These relations are closely related to each other and can be detailed (i.e. subdivided into smaller groups of social relations on a subject basis, which is reflected in Article 1 of the Law of Ukraine on Environmental Protection).

According to this provision, the task of legislation on environmental protection is to govern the relations in the field of protection, use and reproduction of natural resources, ensure the environmental safety, prevent and eliminate the negative impact of economic and other activities on the environment, conserve the natural resources, genetic fund of wildlife, landscapes and other natural complexes, unique areas and natural objects related to the historical and cultural heritage.

The environmental law method is a set of means and methods of influence on the parties to social relations in order to ensure the legal requirements for the protection of the natural environment and environmental network, sustainable nature management, and environmental safety.

Environmental law borrows the methods of legal regulation from classical homogeneous branches of law – administrative, criminal, and civil ones. An imperative method is the most common in the sphere of environmental legal regulation; it is manifested in the permits and prohibitions, standardization, certification, licensing and environmental expert examination, application of the measures of administrative responsibility for environmental offences, etc.

The criminal law method is used to combat environmental crime, and the civil law method is used to address disputes regarding the recovery of environmental damage.

These methods "link up" in environmental law on the basis of their environmental modulation. A characteristic manifestation of this is the standards of environmental law, allocated in a special chapter in the Code of Ukraine on Administrative Offences (Administrative Offences in the Field of Nature Protection, Use of Natural Resources, Protection of Historical and Cultural Monuments) and a section in the Criminal Code of Ukraine (Crimes against the Environment).

As for civil (material) liability, here the tax method of calculating the damage caused by the corresponding offenses, which is inherent only in the environmental sphere, comes into play. The application of such a civil–law method as restoration of natural objects violated by unlawful actions has certain peculiarities.

Self–assessment questions to subsection 3.3.

1. What is environmental law?
2. What are the objectives of environmental law?
3. Who is the person at law of environmental law?
4. What is the object of environmental law?
5. What obligations do Ukrainian citizens have under environmental law?
6. Describe the system of environmental law.
7. What is the subject of environmental law?
8. What is the essence of the environmental law method?

3.4. ENVIRONMENTAL IMPACT ASSESSMENT AND ENVIRONMENTAL EXPERT EXAMINATION

The process of taking into account and assessing compliance with environmental requirements in the planned economic activities at the conceptual and design stages is called the **environmental impact assessment (EIA)**. The purpose of the EIA is to determine the possible violation of the components of the natural system in the planned activities, to identify ways to reduce it, to compare the proposed project with the impact of alternative projects, including "zero", that is, the existing situation. EIA is carried out during the development of a proposal to implement any project or program, regardless of their cost and affiliation, as well as the environmental justification for obtaining a license and a certificate. The permit to implement a project or program in accordance with environmental requirements is given by the environmental expert examination board to monitor the compliance with the EIA rules. Principles of expert examination: mandatory approach, evidence–based support, objectivity and legality, independence in carrying out its activities, extensive publicity and public involvement, presumption of potential environmental hazard and priority of environmental safety, complexity of assessment, probability and completeness of information, as well as responsibility for conclusions. The environmental expert examination may be mandatory (state) and voluntary (public).

Self–assessment questions to subsection 3.4.

1. What is the EIA? List its purposes.
2. What is the environmental expert examination? List its principles.

3.5. ENVIRONMENTAL MANAGEMENT AND AUDIT

Environmental management is both a system of relations and a set of methods to manage and solve a variety of natural resource and environmental issues arising at different levels of economic activity (depending on the object of management) by justifying the improvement of the environmental safety of production and consumption processes, resource conservation and minimization of environmental risks.

Environmental management, depending on its objects: 1) allows nature to support biodiversity and abundance of natural resources itself; 2) helps companies to reveal opportunities to economize raw materials, develop new environmental markets, and increase their competitiveness on this basis; 3) helps countries and regions to improve quality of the environment for the present and future generations.

Environmental management may be also applied to the objects requiring a special approach:

1. Landscapes. The purpose of regulating landscapes is determined not only by their natural and aesthetic properties but also by socio–economic and technological methods of operation. When managing landscapes in a natural condition or in a condition close to it, as well as with unique natural properties, one

cannot change their natural environment. They should be used as nature reserves, national nature parks, green areas of cities, and resorts. Landscapes with minerals in their subsoil can be changed (by extraction of these minerals). The management of landscapes, which are used in agriculture and forestry, should provide for the preservation and restoration of their natural potential and bioproductivity through wildlife sanctuaries. Management of landscapes for civil and industrial construction may involve their radical restructuring and new properties.

2. Environmental system, biogenesis. The main thing in the environmental management of these systems is to control and take into account their hierarchy and to observe natural laws (those that we know).

Not only natural but also human–modified natural–anthropogenic complexes (NAC) are subject to regulation. Industrial enterprises, as well as large industrial and economic complexes, can be considered local representatives of these systems, and they are associated with pressing environmental issues. These objects are studied by corporate environmental management, which is a system of company business management in those forms and directions, which are directly or indirectly related to the interaction of a particular company with the natural environment.

Environmental management at enterprises and companies is regulated by the family of international standards ISO series 14000, which appeared in 1996. The decision to develop ISO 14000 is the result of the long-term work of experts from many countries and is the result of the Uruguay Round of Multilateral Trade Negotiations (1986–1994) and high-level meetings on environment and development held in Rio de Janeiro in 1992.

Given that Ukraine became an associate member of the European Union in 2014, and received the status of a candidate for EU membership in 2022, our country is actively studying the European experience in the field of environmental management, in particular the Eco-Management and Audit Scheme (EMAS), which was developed by the European Commission in 1993 and is a voluntary environmental management tool. EMAS approaches enable organizations to assess, manage and continuously improve their environmental performance. The scheme is applicable worldwide and is open to all private and public organizations. To register with EMAS, organizations must meet the requirements of the EU EMAS Regulation. At the moment, more than 4,600 organizations and more than 7,900 specialized web resources are registered in the system.

Nature-based Solutions (NbS) is a concept that was proposed in the late 2000s (in particular, by the International Union for Conservation of Nature (IUCN) and the World Bank), and then developed by European institutions, primarily the European Commission. NbS are "actions to protect, sustainably manage, and restore natural and modified ecosystems that address societal challenges effectively and adaptively, simultaneously benefiting people and nature" (as defined by the International Union for Conservation of Nature (IUCN). IUCN mentions NbS in the position paper of the UN Framework Convention on Climate Change. The European Commission report emphasizes that NbS can offer innovative measures to create jobs and ensure growth in the context of a green economy. The term began to be used in the mainstream media before the Global Climate Action Summit in California in September 2018. *[Science for Environment Policy (2021) The solution is in nature. Future Brief 24. Brief produced for the European Commission DG Environment. Bristol: Science Communication Unit, UWE Bristol]*.

An **environmental audit** is an analysis of the current environmental condition of all environment components (lithosphere and mineral resources; geophysical fields of the Earth and Space) and their impact on the environment and human health; geomorphosphere (relief) and dangerous endo– and exogeodynamic processes, destroying the lithosphere and transforming the relief; surface and underground hydrosphere and water resources; atmosphere and climatic resources; phyto– and zoosphere and biological resources; demosphere and state of the public health in connection with environmental factors; technosphere and its influence on all previous components of natural ecosystems). The persons at law of environmental audit can be customers, individuals and legal entities, and audited entities can be companies, constituent organizations, branches, etc. [9].

The purpose of an environmental audit is to verify compliance with environmental protection laws.

The objectives of the environmental audit are as follows:

1. To collect reliable information about the environmental aspects, production activities of the audited entity and to make conclusions based on it.

2. To determine whether the audited entity complies with the legal requirements on environmental protection.

3. To assess the impact of the audited entity's operations on the state of the environment.

The core principles of the environmental audit include:

1. Objectivity and independence of auditors from business entities subject to the environmental audit, as well as owners and managers of environmental organizations and third parties when conducting the environmental audit.

2. Professionalism and competence of auditors on environmental protection, environmental management, as well as the peculiarities of business entities.

3. Sufficiency and completeness of the information provided by business entities.

4. Planning of works for the environmental audit.

5. Integrity of environmental audit (coverage of all aspects of environmental impact).

6. Confidentiality of information obtained as a result of the environmental audit.

7. Responsibility of auditors for the results of their research.

The environmental audit in Ukraine is carried out in accordance with the Law of Ukraine on Environmental Audit dated 2004 in order to ensure compliance with environmental legislation in the course of economic and other activities. The regulator gives the following definition:

The environmental audit is a documented systemic independent process of assessing the entity subject to the environmental audit, which includes the collection and objective assessment of evidence to establish compliance of certain activities,

activities, conditions, environmental management system and information on these issues with the laws of Ukraine on environmental protection of the natural environment and other criteria of environmental audit.

The ultimate goal of the environmental audit is to determine the compliance of the current environmental situation with environmental standards ensuring the optimal state of the environment and safety of human life.

For example, for an oil and gas industrial area, the result of environmental monitoring is the establishment of a correlation between the morbidity of the population in the studied areas and environmental factors, including:

- databases of different levels of morbidity in different areas by disease according to the current International Classification of Diseases (ICD);
- database on chemical pollution of soils, surface water and groundwater, atmospheric air, and vegetation with heavy metals, radionuclides, and oil products;
- computer maps of the environmental state of the geological environment, geophysical fields, geomorphosphere, and landscapes;
- electronic maps of chemical pollution of soils, hydrosphere, atmosphere, and phytosphere;
- maps of the environmental state of the local technosphere.

Computer correlation analysis of the morbidity databases of each group of ICD diseases together with computer (electronic) maps of the environmental state of each of the environmental components of the study area allows determining a direct correlation between various diseases and the degree of environmental transformation.

Based on the environmental audit and management, a forecast of the environmental situation is developed, depending on a specific scenario of the oil and gas production prospects in a particular area.

Types of the environmental audit: mandatory and voluntary. A mandatory environmental audit is carried out when implementing international obligations in the field of environmental protection, by order of the state bodies, to take into account the environmental factor in the privatization of state and municipal companies, during the implementation of bankruptcy procedures, as well as during the compulsory environmental insurance. A voluntary environmental audit is performed by the decision of the management of companies or organizations. There is an internal (voluntary, held at the initiative of the enterprise) and external (mandatory) environmental audit. Based on the decision of the company's management to conduct an external audit, a contract is signed between the audited company and the relevant audit firm. The audit contract shall specify the general environmental protection issues, the assessment of the potential client's reputation with regard to environmental issues, the significance of the environmental protection activity of the client within the scale of its entire activity, and the assessment of the possible influence on the financial condition of the client, as well as identification and assessment of risks associated with taking or failure to take the improvement actions with regard to the environment. General environmental audit procedures include the analysis of compliance with laws and regulations, interviews with company staff, testing, review of documentation, logs and other materials, as well as sampling and analysis. Sources of funds for conducting an environmental audit can be both ecology funds and entities themselves. The primary result of an environmental audit is financial savings through more reasonable management of natural resources and compliance with environmental regulations.

ISO 14000 standards set general requirements for the construction of an environmental management system (ISO 14001, ISO 14004) and for the audit of these systems, including an environmental audit. Ukraine continues active work to implement international environmental audit regulations and standards into its national legislation.

Self–assessment questions to subsection 3.5.

1. Explain the concept of environmental management.
2. What actions does environmental management permit?
3. List the environmental management objects.
4. What is the environmental audit?

5. What are the main tasks and objects of the environmental audit?
6. What are the types of the environmental audit?
7. What are the sources of funds for conducting an environmental audit?

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