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ENVIRONMENTAL SUSTAINABILITY AND LIFE SAFETY

Tutorial

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B38

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The tutorial presents a lot of material revealing the concept and international experience of the formation of "Sustainable Development". The characteristics of global and environmental problems of mankind are given. The generalized characteristics of devices for purification of emissions into the atmosphere and into the hydrosphere, as well as issues of organizing life safety are given. The sections and topics outlined in the manual will help to form students' ecological consciousness, the ability to adequately assess the state of the environment and the degree of influence of harmful and dangerous factors on humans. The manual is recommended for students of higher educational institutions of all specialties in the discipline "Environmental sustainability and life safety."

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Content

Introduction

The growing global threats associated with climate change, energy, water and food security issues, as well as regional conflicts require new solutions and the integration of efforts of the entire world community [1]. The problems on Earth are diverse: poverty, drought, famine, environmental pollution, demographic problems, the threat of nuclear war, global warming, etc. The goal of sustainable development of mankind is to solve these problems and to meet the needs of present and future generations. The concept of sustainable development has three main aspects: social, economic and environmental, in this regard, it is based on the concepts of “environmental sustainability” and “environmental development”.

Environmental sustainability is “the ability of an ecological system to maintain its structure and functions in the process of exposure to internal and external factors” [1]. A synonym for this concept is environmental stability. Environmental sustainability is expected to be achieved in the following ways:

- increasing the efficiency of resource use through the introduction of environmentally friendly and advanced technologies, restructuring in the structure of the economy, nature management, rational scientific, secondary use and consumption of industrial waste;
- increase in average life expectancy by improving its quality, environmental and social safety, improving people's health and introducing the “idea of a healthy society” with a healthy lifestyle;
- reduction of anthropogenic pressure on nature by reducing emissions, cleaning territories from “historical pollution”, waste management, preventing environmental emergencies and improving environmental protection through the introduction of an effective economic mechanism (including “green investments”) and cross-border transformations based on ecosystems [2].

Negative environmental phenomena constantly have an adverse effect on people.

Negative influences of the surrounding world have had and are having a negative effect on man from the day he appeared on Earth to the present day. In modern ecology, great importance "is paid to the problems of human interaction with the natural environment, this is due to a sharp increase in the mutual negative influence of man and the environment, the increased role of economic, social and moral aspects, in connection with the sharply negative consequences of scientific and technological progress" [2] . The modern scale of production activity, the volume of which doubles every 15 years, is causing a change in the quality of the natural environment and its resources. At the end of the twentieth century. teachings appeared on human life safety (BZD) and environmental protection (AIA), the development of techniques and means of protecting people [3]. In the light of the events of the beginning of 2020 related to the beginning of the coronavirus pandemic, while working on the manual, it was decided to supplement the section "Life Safety" with a description of emergency situations associated with infectious diseases, which will help students to respond correctly and to know the basic safety measures.

The discipline "Ecological sustainability and life safety" is a compulsory general professional discipline for all areas of educational programs in higher education. The aim of the course is to form a holistic understanding among students of the basic laws of nature; concepts of sustainable development of society; safe human interaction with the environment and protection from the negative factors of emergency situations. Studying the discipline will allow future specialists:

- analyze and evaluate their production activities in terms of environmental impact;
- make environmentally sound decisions and thereby contribute to the sustainable development of the biosphere and society;
- acquire skills in hazard detection and the timely use of protective equipment to ensure personal and collective security, protection of economic facilities.

The objectives of the discipline "Environmental sustainability and life safety" are the formation of students a comprehensive, objective and engineering approach to discussing the most relevant and complex problems of ecology, environment, sustainable development, ensuring life safety, as well as mastering and knowledge:

• basic principles of the functioning of living organisms, ecosystems at different levels of organization, the biosphere as a whole and their sustainability;

• the basic laws of interaction of the components of the biosphere, environmental consequences resulting from human activities, especially in the context of intensification of natural resources;

• modern presentation of concepts, strategies and goals of sustainable development in various countries and the Republic of Kazakhstan;

• safe human interaction with the environment, methods and means of protection from the negative factors of emergency situations.

1 Sustainable Development Concept

1.1 The idea of sustainable development

The term “Sustainable Development” became popular after the United Nations Conference on Environment and Development, held in Rio de Janeiro in 1992. The report of the Brundtland Commission (World Commission on Environment and Development, 1987) made a great contribution, emphasizing the importance of sustainable development.

The starting point for the formation of the theory of "Sustainable Development" is the ethical idea of sustainability. It is based on obligations to future generations and assumes the equality of generations. With regard to specific resources and services (for example, fresh water, the atmosphere as a carbon sink, a wide variety of ecosystems), it is obvious that the continued growth in their use according to current consumption rates is unsustainable.

The problems on earth are diverse: underdevelopment, poverty, drought and hunger, depletion of the environment, waste of resources, etc. The goal of sustainable development is to solve these problems and create such conditions of existence that will be long-term for present and future generations .

Sustainable development excites everyone and affects the interests of all countries of the world, all regions, cities, enterprises and households. Sustainable development is an anthropocentric concept because people are at the center of interest. It is also a normative concept.

The concept has three main pillars that embody social, economic and environmental aspects.

A simple model of the world is the basis for developing strategies for implementing sustainability on Earth. The main limitations are the limited ability of the land to restore and the inability of a person at this stage of development to utilize the waste of their activities. Both limits are influenced by population growth and meeting people's needs. The development of natural resources and their existence depends on the bearing capacity of the earth. Our planet, or rather all the spheres of the Earth, can recover if the restrictions on the negative impact are met. Restrictions on ecosystems are affecting our economic system.

On the agenda is the solution of urgent questions: how should humanity handle natural resources, especially non-renewable ones, how should humanity solve such problems as poverty, poverty, hunger?

The concept of “Sustainable Development” has many ways of self-determination, but the most frequently quoted definition is borrowed from the Brundtland Report “Our Common Future” (1987): “Sustainable development is a development that meets the needs of the present generation without compromising the ability of future generations to meet their own needs. ”

Sustainable development contains two key concepts:

• a concept of needs, in particular the basic needs of the poor in the world, which should be given high priority;

• the idea of limiting the negative impact on the environment caused by modern technologies to maintain the ability of the Earth to meet the present and future needs of mankind [4].

The concept of sustainable long-term development is considered in several aspects:

I. Political and legal aspect:

- developed modern democracy (constitutional power, rule of law:

- “a system of reasonable legislation and taxation;
- decent wages, respect for human rights;
- freedom and equality of all people before the law;
- friendship of the peoples of the world, civil liability;
- the orientation of the actions of the state and society on the development of the noosphere [5].

II. Economic aspect:

- a reasonable ratio of private and state property, a civilized market economy;
- sufficient production of agricultural and industrial products, cultural property to meet the needs of mankind;
- the promotion of active humane and useful work of people.

III. Environmental aspect:

- the harmonious coexistence of people and the natural environment, the direction of all transformations and activities towards the creation of the noosphere;
- providing actual opportunities for present and future generations to meet the necessary needs;
- theoretical development and practical application of methods for the efficient use of natural resources;
- environmentally sustainable transition to the noosphere;
- transition to low-waste production, development and implementation of a closed production cycle that excludes waste generation, innovations in the use of biotechnology.
- the transition from traditional sources of fuel for energy generation to renewable and environmentally friendly sources of energy (wind, solar, hydropower, hydrothermal energy, biomass energy).
- conservation of biodiversity on Earth;
- Improving the environmental culture of the population, conducting environmental disciplines, circles and sections in schools and higher educational institutions, with a view to respecting the natural environment.
- compliance by citizens of the country with the norms, laws and rules prescribed in the environmental code and other environmental regulatory documents.

IV. Social aspect :

- the fight against poverty and hunger on the planet;
- the manifestation of participation and caring for socially vulnerable segments of the population: the elderly, children, people with disabilities, single parents, etc .;

- provide children with the opportunity to attend preschool and school educational institutions;
- expanding opportunities for affordable quality education;
- advanced training of the population to improve labor resources;
- the cultural evolution of mankind through the development of directions and the growth in the number of organizations of culture and art [5].

1.2 The history of the formation of "Sustainable Development" in the world community

The United Nations Conference on the Human Environment was held in Stockholm (Sweden) from June 5 to 16, 1972 and was the first conference devoted to international environmental problems. The reason for the Stockholm conference was the proposal of Sweden (1968) that the UN should hold an international conference to study environmental problems and identify those that require international cooperation. The conference was attended by delegations from 114 countries. The conference reflected a growing interest in environmental conservation around the world and laid the foundations for environmental regulation.

The final declaration of the Stockholm Conference was an environmental manifesto, which is a convincing statement about the endless nature of Earth's resources and the urgent need for a careful attitude to the environment. The Conference also adopted the United Nations Environment Program (UNEP) in December 1972 to coordinate global efforts to promote sustainability and environmental protection. The documents created during the conference influenced the further development of international environmental law. One vivid example was the final declaration, which clarified 26 principles relating to the environment. An “Environmental Action Plan” was also prepared at the conference, containing 109 specific recommendations regarding settlements, international organizations, the rational use of natural resources, environmental pollution, and educational and social aspects [6].

The term "Green Marketing" became known in the late 1980s and early 1990s. The American Marketing Association held the first seminar on Environmental Marketing in 1975, the implementation of which was to become a means of solving environmental problems. Green marketing is the marketing of products that are considered environmentally friendly. Thus, green marketing includes a wide range of activities, including product modification, changes in the production process, packaging changes, as well as advertising changes. Green marketing refers to the process of selling products or services based on environmental benefits. Such products or services can be environmentally friendly, as well as be produced or packaged in an environmentally friendly way [6].

In December 1983, under the leadership of former Norwegian Prime Minister Gro Harlem Brundtland, the UN created the World Commission on Environment and Development. As a result, a political concept was developed for the sustainable development of mankind, which included three main aspects: environmental, social and economic (Figure 1.1) [6]. The Commission's recommendations became the prerequisites for the Earth Summit - the United Nations Conference on Environment and Development (UNCED) in Rio de Janeiro in 1992.

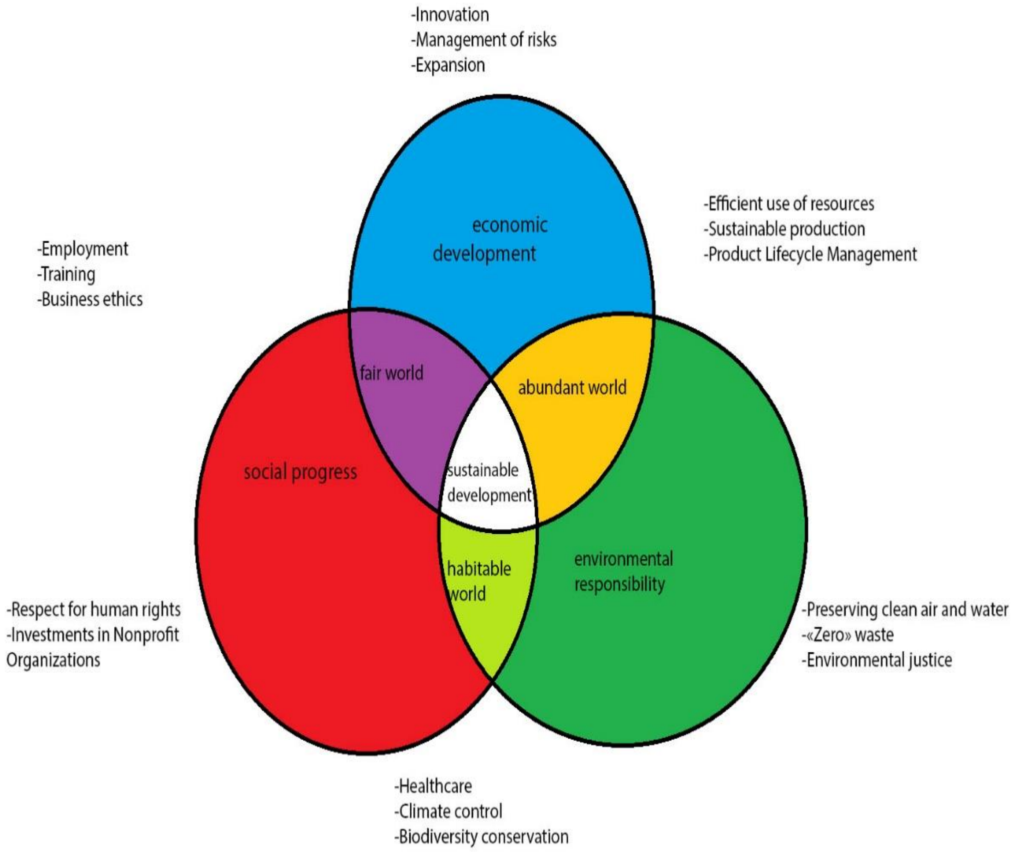


Figure 1.1 - a triune concept of sustainable development

On October 28, 1982, Member States of the United Nations adopted the World Charter for Nature. It proclaimed five basic principles of environmental conservation, which should be taken as a basis for the harmonious existence of man and nature:

- you need to be careful about nature and not violate its basic processes;
- The genetic fund on earth should not be at risk; all life forms of flora and fauna should be provided with habitats;
- all land and water resources must be conserved; special protection needs unique places of nature, rare or endangered species of animals and plants;
- living organisms, ecosystems, natural resources should be used by man, without violating their sustainable productivity.
- Avoid wars and armed conflicts, as they can harm the environment.

In 1988, the World Meteorological Organization (WMO) and the United Nations Environment (UNEP) established the Intergovernmental Panel on Climate

Change (IPCC) to assess climate change based on the latest scientific research. As part of the IPCC, thousands of experts from around the world synthesize the latest advances in climate science, adaptation, vulnerability and mitigation, and publish assessment reports every five to seven years. Government officials are working with experts to prepare a “Resume for Politicians”, which highlights the most important changes in the Earth’s climate system for strategic plans. Scientists, experts, teachers and students can find information on climate change and the consequences for humanity in the submitted reports, which are available on the IPCC website [6].

The United Nations Conference on Environment and Development, entitled “Earth Summit,” was held in Rio de Janeiro, Brazil (June 3–14, 1992) to harmonize economic development around the world with environmental protection. The Earth Summit, which was attended by 117 heads of state and representatives from 178 countries, became a platform for international cooperation on sustainable development. Through treaties and other documents signed at the conference, most countries of the world nominally pledged to strive for economic development in such a way as not to harm the environment and rationally use non-renewable resources.

Agenda 21 is an action plan developed by the United Nations for the sustainable development of the world community following the Earth Summit (UN Conference on Environment and Development), held in Rio de Janeiro. The document is an action program for the United Nations and other multilateral organizations around the world that can be implemented locally, nationally and globally. The number “XXI” means that the development goals must be achieved by 2021. However, later at other conferences, the governments of the countries agreed that the year 2021 is overly optimistic for achieving the set objectives and the new agenda schedule is aimed at the year 2030. The goal remains the same - achieving global sustainable development.

Agenda 21 is a document divided into 40 chapters, grouped into 4 sections:

- Section I. Socio-economic aspects aimed at combating poverty, especially in developing countries, changing consumption patterns, health promotion, sustainable decision-making.
- Section II. Conservation and sustainable management of resources, which includes the protection of the atmosphere, the fight against deforestation, the protection and control of environmental pollution, the conservation of biological diversity, the sustainable management of biotechnologies, as well as radioactive waste.
- Section III. Strengthening the role of key populations, including the role of children, youth, women, local authorities, trade unions, workers, and strengthening the role of indigenous peoples and their communities.
- Section IV. Achieving sustainable development through scientific development, technology transfer, education and financial mechanisms.

In September 2000, the United Nations Millennium Declaration was adopted. The adopted declaration obliged countries to work together to reduce extreme poverty and established a series of eight time-limited goals - with a deadline of 2015 - which became known as the Millennium Development Goals (MDGs).

The final report on the development of mankind showed that thanks to

- in the fight against poverty: since 1990, the number of people living in extreme poverty has more than halved; the proportion of undernourished people in the region decreased by two [4-6];
- primary school enrollment in developing regions has reached 91 percent, and there are now more girls enrolled in schools than 15 years ago;
- Significant successes have been achieved in the fight against HIV/AIDS, malaria and tuberculosis;
- in the world, the mortality rate of children under the age of five has halved, and maternal mortality has decreased by 45 percent;
- halved the indicator of access to clean drinking water.

The concerted efforts of governments, the international community, civil society and the private sector have helped overcome and solve many of the problems of humanity and embark on the path of sustainable development.

The global sustainable development goals continue to channel policies and funding, starting with the historic commitment of September 25, 2015, to poverty alleviation.

In 2002, from August 26 to September 4, the Rio + 10 World Summit on Sustainable Development was held in South Africa. It was convened 10 years after the first Earth Summit (Rio de Janeiro) to discuss the results and next steps for the sustainable development of mankind. The main outcome of the Summit was the Johannesburg Declaration, which includes a developed action plan to solve global problems:

«1. We, representatives of the nations of the world, gathered at the World Summit on Sustainable Development in Johannesburg (South Africa, September 2–4, 2002), reaffirm our commitment to sustainable development.

2. We commit ourselves to building a humane, fair and caring global society, recognizing the need for human dignity of all people.

3. The children of the world say that the future belongs to them, and they must inherit a world free from the humiliation and obscenity caused by poverty, environmental degradation and unsustainable development.

4. In response to the statement of our children, who represent our collective future, all of us, who have come from all over the world, having life experience, are united by one impulse to create a new world of hope.

5. Accordingly, we take collective responsibility for promoting and strengthening the interdependent and mutually reinforcing foundations of sustainable development - economic development, social development and environmental protection - at the local, national, regional and global levels.

6. On this continent, which is the cradle of humanity, we declare in the submitted Plan of Implementation of the decisions of the World Summit on Sustainable Development and in this Declaration that we are responsible to each other, to the world community and to our children».

The Johannesburg Plan of Implementation, agreed by governments, sets out in more detail the actions that need to be taken in specific areas, including gaps in the implementation of Agenda 21, and introduces new themes for action, such as globalization and corporate accountability. Key commitments agreed upon in the World Summit Implementation Plan:

- halving the number of people without access to basic sanitation by 2015;
- minimizing the harmful effects on health and the environment from the production and use of chemicals by 2020;- остановить сокращение рыбных запасов и восстановить их до устойчивого уровня к 2015 году;
- stop the loss of biodiversity by 2010;
- significantly increase the use of renewable energy in global energy consumption;
- creation of programs for sustainable consumption and production of resources.

In accordance with the decisions adopted at the World Summit on Sustainable Development, the UN Commission on Sustainable Development (CSD) has a major role in reviewing and monitoring the implementation of Agenda 21 [6].

In September 2009, the United Nations Environment Program (UNEP), in response to the financial and economic crisis, called for a "Global Green New Deal" to revive the world economy and increase employment, while also combating climate change, environmental degradation and poverty. On the basis of the prepared report "Rethinking Economic Recovery: A Global Green New Deal", UNEP recommended investing a significant portion of material resources (of approximately $ 3.1 trillion) to stimulate the following areas:

- Improving energy efficiency in old and new buildings;
- development of technologies for the use of renewable energy (wind, solar, biomass, geothermal energy, etc.);
- creation and transition to environmentally sustainable transport technologies, such as hybrid and electric vehicles, high-speed rail;
- improving the ecological infrastructure of the planet, including fresh waters, forests, soils and coral reefs;
- sustainable agriculture, including organic production.

The G-20 countries (the countries with the most developed and developing economies) have 66 percent of the world's population and 80 percent of global greenhouse gas emissions. In this regard, the G-20 countries should invest in financing climate change mitigation and adaptation measures, addressing the lack of natural resources and creating decent jobs.

UNEP called on the 20 most developed countries to participate in the Global New Environmental Agreement, investing only 1 percent of their total GDP in the development of green economy sectors [4-6].

From 20 to 22 June 2012, the United Nations Sustainable Development Conference "Rio 20" was held in Rio de Janeiro (Brazil). The conference was held 20 years after the Conference on Environment and Development in Rio de Janeiro in 1992 and 10 years after the World Summit on Sustainable Development in Johannesburg. The organizers of Rio 20 set three goals:

- ensuring a new political commitment to sustainable development;
- assessment of progress and gaps in the implementation of already fulfilled obligations;
- solving new problems.

The conference organizers also identified seven priority areas: jobs, energy, cities, food security, water and disaster preparedness (Figure 1.2) [6]:

- creation of decent jobs, ensuring decent working and living conditions for all workers and respect for the rights of workers;
- an increase in the share of investments in natural capital (natural resources), a low-carbon economy and sustainable resource management;
- improving energy efficiency and the share of renewable energy sources;
- urbanization growth is considered a constant trend, and the shape of cities, especially megacities, is seen as an essential element of sustainable development;
- food security, proper nutrition;
- ensuring universal access to clean water and sanitary conditions;
- increased attention to the blue economy includes calls for an agreement on the conservation and sustainable use of marine biological diversity and the management of marine areas;
- preparedness for natural disasters: proposals require action to implement the Hyogo Framework for Action 2005–2015 [6-9].

More than 150 world leaders attended the UN Summit on Sustainable Development September 25-27, 2015 in New York to formally adopt the new sustainable development agenda. This agenda was the launching pad for the actions of the international community and national governments aimed at prosperity and welfare for all people over the next 15 years.

The agenda, entitled “Transforming our world: the 2030 Agenda for Sustainable Development”, includes a Declaration on Sustainable Development. The agenda is unique in that it calls for action by all countries: poor, rich and middle-income. The agenda says that poverty can only be eradicated according to the proposed action plan, which includes the economic dimension and takes into account a number of social needs: education, health, social protection, employment opportunities, as well as addressing climate change and protecting the environment.

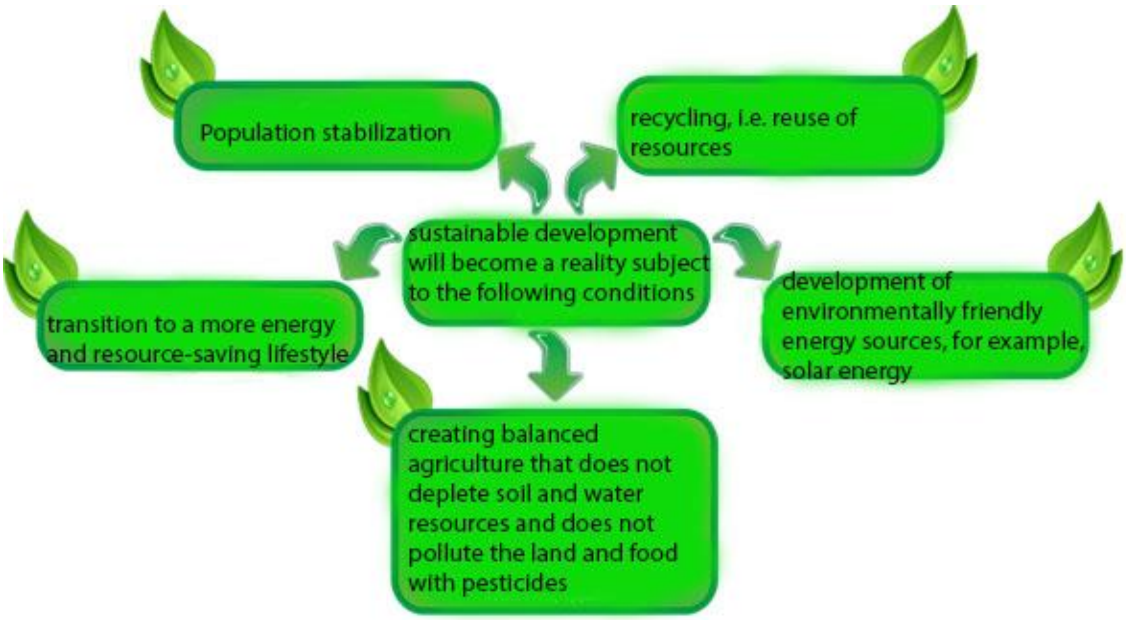


Figure 1.2 - Priority directions for sustainable development “Rio + 20”

The Sustainable Development Goals (SDGs) cover almost all aspects of society and their achievement will save humanity from poverty and hunger, protect it from the worst effects of climate change. United Nations Development Program (UNDP) is one of the leading programs where the SDGs are scheduled for 2030 [18].

Goal 1 is the eradication of poverty. In 2000, the world community set the goal of halving the number of people living in extreme poverty by 2015. However, more than 800 million people around the world still live on less than $ 1.25 a day.

Goal 2 is to eradicate hunger, achieve a food-security situation, improve food quality, and promote sustainable agriculture. According to the UN, over the past 20 years, the number of starving people has almost halved. Many countries where people used to suffer from hunger can now meet the nutritional needs of their most vulnerable populations. Achieving sustainable development implies that everyone has access to adequate and nutritious food all year round.

Goal 3 is to improve the health and well-being of people of all ages. We all know how important it is to be healthy. Our health depends on many factors, even such as how much we enjoy life, to what work we do.

Therefore, this goal poses the challenge for us - providing people with health insurance, access to safe and effective medicines and vaccines.

Goal 4 - improving the quality of education. This goal implies the availability of quality education for all people on the planet. Unfortunately, today we cannot say that in the field of education in many countries there are no problems. Poverty, armed conflicts, terrorist attacks, and emergency situations prevent many children from all over the world from going to school. By 2000, tremendous progress was made towards the goal of ensuring access to primary education for all children (overall coverage in developing regions reached 91%). Now we need to achieve universal access to primary, secondary, higher education, vocational training, etc.

Goal 5 - Gender Equality. Unfortunately, in some countries women's rights are discriminated against. This is manifested in the privileged choice of men for certain posts, discrimination in government decisions, wage inequality, and there are also many unpaid “women’s jobs” such as childcare and housework. But at the same time, there has been an improvement in gender policy: more and more girls are starting to attend school compared to 2000. In most regions, gender parity has been achieved in primary education, and the percentage of women whose work remuneration is equal to that paid by men is also increasing. The Sustainable Development Goals are aimed at ending discrimination against women and girls throughout the world.

Goal 6 - Everyone on earth should have access to safe and affordable water resources.

Goal 7 is to provide people with clean water.

Goal 8 is to promote sustainable economic growth and full employment.

Goal 9 is to create sustainable cities.

Goal 10 is to ensure sustainable production and consumption.

Goal 11 is to adopt and implement urgent action to combat climate change and its consequences.

Goal 12 is the conservation and sustainable use of oceans for sustainable development.

Goal 13 is to reduce the inequality between rich and poor in the country.

Goal 14 is to promote sustainable industrialization and innovation.

1.3 Sustainability Indicators and Indices

Agenda 21, adopted at the 1992 UN Conference on Environment and Development in Rio de Janeiro, emphasized the need to create and prepare indicators for sustainable development. This document was created with the aim of directing the world community to solving global problems that we faced most closely at the beginning of the 21st century. The program consists of four main sections and includes:

- “social and economic aspects;
- conservation and rational use of resources for development;
- strengthening the role of major population groups;
- means of implementation" [19].

In order to monitor the achievement of the listed goals of sustainable development, manage and monitor the progress of development, evaluate the productivity of the resources used, it is necessary to develop certain criteria and indicators of sustainable development.

The world community is actively developing sustainable development indicators. In this direction, major international organizations are conducting work, such as: the Scientific Committee on the Problems of the Environment around the

Environment (SCOPE), the Organization of Financial Cooperation and Development States, the UN, the World Bank, the European Commission, etc.

The results of these works, as well as their discussions, are held at various international conferences, seminars, etc. It is still too early to talk about the developed persistent indicators of sustainable development, but at the same time, many projects have just arrived that justify the feasibility of indicators for systems of various scales: at the global regional, national levels, as well as for a specific locality, farms, and industrial enterprises.

Indicators can serve as important guidance for decision making, translate physical and social knowledge into manageable information units, which can also facilitate decision making. Indicators can help measure and calibrate progress towards sustainable development goals, provide early warning, and help prevent economic, social, and environmental damage in time. Indicators are also important tools for conveying ideas, thoughts, and values, because “we measure what we value and value what we measure” [23].

An indicator is an indicator (derived from the initial data, which as a rule cannot be applied to explain the changes), with the help of which one can assess the state or change in the social, environmental and economic aspects. Simultaneously with indicators, development indices are developed and used in practice. According to [17.19], “Sustainable development indicators are relevant indicators and criteria that perform a kind of control over the achievement of sustainable development goals, manage this process, evaluate the effectiveness of the tools used and the level of achievement of the goals. An index is an aggregated or weighted indicator based on several other indicators or data. ” The use of indices is best applicable in situations where the causes and consequences of certain events can be traced. In contrast to them, with the help of indicators one can explain the phenomena, the state of the world around.

The newly revised indicators of the UN Commission on Sustainable Development [20,23] contain 50 indicators. These core indicators are part of a broader set of 96 sustainable development indicators. The introduction of a basic set helps to establish the basic criteria, while a larger set allows the inclusion of additional indicators that allow countries to conduct a more comprehensive and differentiated assessment of sustainable development. Key indicators meet three criteria:

- Firstly, they cover issues that are relevant to sustainable development in most countries:

- secondly, they provide important information;

- thirdly, they can be calculated in most countries with data that is either readily available or can be provided within a reasonable period of time.

Test results showed that indicators of sustainable development can undoubtedly help in decision-making at the national level. Many countries said they used or planned to use indicators to:

- introducing important issues into the political agenda;

- assistance in identifying key development trends in priority sectors;

- assistance in reporting on the status of sustainable development;
- assistance in conducting a national dialogue on sustainable development;
- assistance in the preparation and monitoring of development plans;
- assistance in assessing the effectiveness of policies and actions in implementing plans;
- wording of the concept of sustainable development in practical terms;
- drafting national and sectoral programs, state budgets aimed at sustainable development.

The following is a brief description of the individual indicators of sustainable development.

1. Poverty (percentage of population living below the national poverty line).

Indicator: basic indicator of income poverty.

Brief definition: the proportion of the population with a standard of living below the poverty line defined by the government. National Assessment).

Description: The indicator (also known as the national poverty level) is a standard indicator of poverty, especially income poverty. It provides information on progress in the fight against poverty, the main goal and demand for sustainable development. The national poverty level is one of the main measures of living standards and draws attention exclusively to the poor.

2. Percentage of population with income below $ 1 per day.

Indicator: poverty, measured by income.

Brief Definition: Percentage of population having per capita consumption of less than $ 1 per day.

Description: A population with an income below $ 1 per day determines a single measure of absolute poverty for developing countries using data from nationally representative surveys. Progress in the fight against absolute poverty is currently a universally accepted criterion for assessing overall effectiveness in developing countries.

3. The ratio of the share in the national income from the highest to the smallest.

Indicator: income inequality.

Brief definition: the ratio of the share in national income (consumption) attributable to the highest incomes of the population, to the share attributable to the lowest incomes of the population.

Description: the indicator shows the degree of inequality in the distribution of income within the country. Inequalities in outcomes such as income or consumption impede human development and are unfavorable for long-term economic growth. Poor people usually have less income, less access to services, less rights than more affluent people. When income is distributed equally and equitably in a society, this opens up wide opportunities for everyone.

4. The proportion of the population with access to good sanitation.

Indicator: The main indicator of sanitation.

Brief definition: Percentage of population with access to clean sanitation. Improved sanitary conditions range from simple but protected cesspools to toilets with sewers.

Description: Adequate sanitation is necessary to combat poverty, to protect human health and the environment. The indicator monitors progress in ensuring the accessibility of the population to sanitary facilities, basic and necessary social services.

5. The proportion of the population with access to clean drinking water.

Indicator: access to clean drinking water.

Brief definition: Percentage of population with access to clean drinking water at or near their place of residence. Improved drinking water sources include bottled water; clean rainwater; protected borehole sources and wells; public risers and piping connections to houses.

Description: Providing the population with clean water is necessary to combat poverty, to protect human health and the environment. The indicator tracks the progress of population access to improved water sources.

6. Number of reported intentional killings per 100,000.

Crime indicator.

Brief definition: The number of intentional homicides recorded in criminal statistics. In some countries, this indicator can be expanded, including violent crimes such as assault, rape, robbery.

Description: The indicator measures the number of intentional killings over time. Intentional killings as well as violent crimes have a very significant negative impact on sustainable development. The phenomenon of crime undermines human dignity, creates an atmosphere of fear and reduces the quality of life.

7. Percentage of population with access to basic health services.

Indicator: medical care.

Brief definition: Percentage of population with access to primary health care facilities. Primary health care is essential health care and should be affordable for all segments of the population.

Description: The indicator tracks progress in population access to primary health care. Accessibility of health services beyond physical access, including economic, social, cultural accessibility and acceptability, is fundamental to reflecting health system progress, equity and sustainable development.

8. Percentage of school-age children with access to primary education.

Indicator: level of education.

Brief definition: The total number of new students in the last grade of primary education, regardless of age, expressed as a percentage of the population. The indicator is also called the primary completion rate.

Description. The indicator shows whether the entire school-age population has access to school education and whether it is able to complete the full initial cycle. Universal primary education is an important goal of the international sustainable development agenda. Education is the process by which people and societies reach their full potential. This is critical to promoting sustainable development and enhancing people's ability to tackle environmental and development issues.

9. Demography. Population growth statistics.

Indicator: population change.

Brief definition: The average annual rate of change in population over a specified period.

Description. The population growth rate shows how quickly the population is changing. According to data separately for urban and rural areas, you can get an indicator of urbanization. High urban growth caused by the rate of natural growth (excess of fertility over mortality) in urban areas, migration from rural areas and their transformation into cities is a concern in many countries.

10. Natural disasters. The proportion of the population living in areas prone to natural disasters.

Indicator: Disaster Vulnerability.

Brief definition: the percentage of the country's population living in areas at significant risk of significant dangers: cyclones, drought, floods, earthquakes, volcanoes and landslides. The indicator can be calculated separately for each type of hazard. The risk of death due to natural disaster is a function of the physical impact of a hazardous event and its vulnerability to danger. The indicator measures risk at the subnational level.

Description: This indicator contributes to a better understanding of the level of vulnerability to natural disasters in a given country, thereby contributing to long-term, sustainable risk reduction programs to prevent natural disasters. Disasters caused by natural disasters have a strong negative impact on the development process in both industrialized and developing countries.

Human Development Index. The Human Development Index (HDI) is a composite index that measures the average achievement of a country in three main aspects of human development: health, knowledge and income. It was first developed by Pakistani economist Mahbub ul Haq in collaboration with Nobel laureate Amartia Sen and other leading development thinkers for the first Human Development Report in 1990. It was introduced as an alternative to traditional measures of national development, such as income and economic growth.

In 1990, the United Nations Development Program (UNDP) presented its first Human Development Report, including the first version of the Human Development Index (HDI). One of the paramount importance of economic growth and as the main criterion for development, it was decided to use the value of per capita income. In a World Bank report on world development, countries were sorted by per capita income using market exchange rates.

Following the publication of the first Human Development Report in 1990, UNDP introduced several key innovations:

1. Firstly, a new approach to development was proposed, based on the paradigm of human development, thereby challenging economic efficiency and per capita income. With this approach, economic resources are just a means to an end.

This gave the human development paradigm a more solid and convincing foundation;

2. secondly, the new HDI has provided indicators to track progress in human development. Although indicators such as the Physical Quality of Life Index (Morris 1979) or the Economic Commission for Latin America and the Caribbean to measure unmet basic needs (ECLAC 2009) were introduced earlier in the development of the HDI, the new HDI has proven to be more successful in applying and sustainable;

3. the third innovation was that the Human Development Report was a new series of flagship reports that continued the development of a human development paradigm linking it with issues of gender inequality, climate change, human security and human mobility. Alternative reports on these topics, based on the human development paradigm, were developed and included in the debate on international development.

Until 2010, the HDI was the arithmetic average of the three components shown in Figure 1.3 [19,20].

The HDI was created in order to emphasize that people and their capabilities should be the ultimate criteria for assessing a country's development, and not just economic growth. The HDI also indicates the right choice of national policy. How do two countries with the same level of GNI (gross national income) per capita have different results in the field of human development.

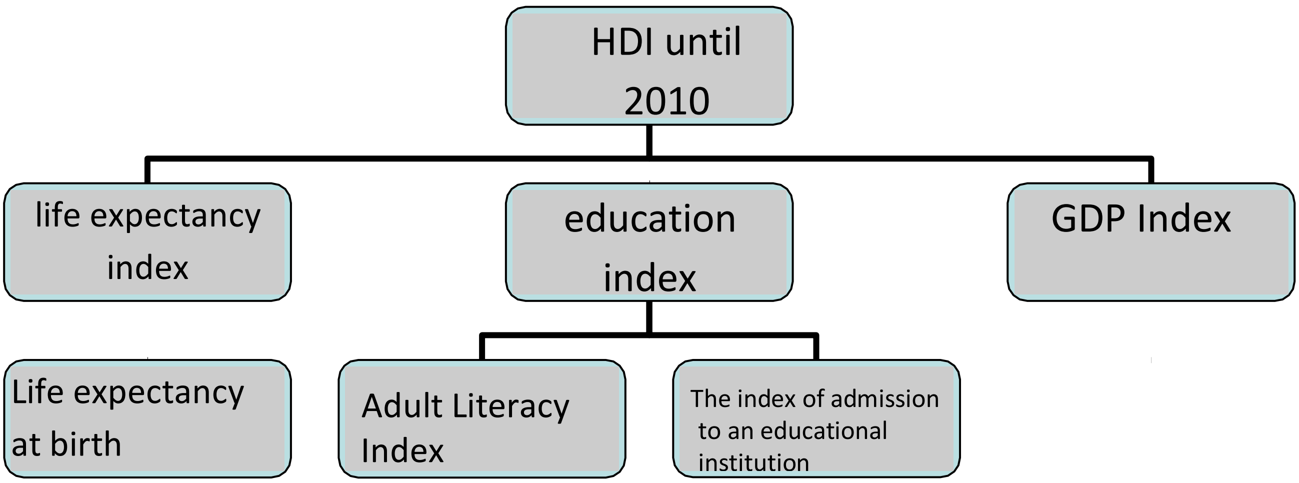


Figure 1.3 - the components of the calculation of the human development index until 2010

For example, in the Bahamas and New Zealand, per capita income levels are the same, but life expectancy and expected years of study in these countries vary widely, with the result that in New Zealand the HDI is much higher than in the Bahamas. These striking contrasts suggest discussions about public policy priorities.

Data for calculating the HDI comes from the following sources:

- Life expectancy at birth is provided by the UN Department of Economic and Social Affairs;

- the average number of years of study according to Barro and Lee (2010);
- expected years of study according to the UNESCO Institute for Statistics;
- GNI per capita according to the World Bank and the International Monetary Fund.

By actively promoting human development data, the Human Development Report Office does not collect data directly from countries.

GNI per capita is usually expressed in US dollars at purchasing power parity. The HDI measures the standard of living in 187 countries with very different price levels. To compare economic statistics by country, you must first convert the data into a single currency. Unlike market exchange rates, purchasing power parity (PPP) exchange rates allow this conversion to take into account price differences between countries. Thus, GNI per capita (PPP in US dollars) better reflects people's living standards. Theoretically, 1 PPP dollar (or international dollar) has the same purchasing power in the domestic economy as 1 US dollar in the US economy.

The report “Updated statistics 2018” presents the HDI values for 189 countries and territories; the most recent statistics are dated 2017 [21]. Of these countries, 59 are in the group with a very high level of human development, 53 countries are in the group with a high, 39 are in the middle and only 38 countries are in the group with a low level of human development. In 2010, the group with a low level of human development included 49 countries. The top five countries according to the global HDI ranking include Norway (0.953), Switzerland (0.944), Australia (0.939), Ireland (0.938) and Germany (0.936) (see table 1). The bottom five are Burundi (0.417), Chad (0.404), South Sudan (0.388), Central African Republic (0.367) and Niger (0.354). The highest rating increase for the HDI for the period 2012–2017. happened at Ireland, which rose 13 positions, as well as Botswana, the Dominican Republic and Turkey - each at eight positions. The largest decrease was observed in the Syrian Arab Republic (down 27 positions), Libya (26) and Yemen (20) [21]. Looking back at almost three past decades, it can be noted that all regions and groups of countries have made significant progress in terms of human development. The value of the global HDI in 2017 reached 0.728 - 21.7 percent higher than in 1990, when it was 0.598. All over the world people live longer, are better trained and have wider life opportunities. Life expectancy has increased by seven years since 1990, and universal primary school enrollment exists in more than 130 countries [21].

According to the ranking of countries by the Human Development Index (HDI) presented in the report, in 2018 Kazakhstan took the 50th place out of 189 and entered the group of countries with a very high level of human development. In the period from 1990 to 2018, the HDI in Kazakhstan increased by 18.5%, and gross national income per capita by 61.8%. Over 28 years, life expectancy at birth in Kazakhstan has increased by 6.5 years, average life expectancy has increased by 3.7 years, and life expectancy has increased by 2.9 years. Kazakhstan has achieved good results in several aspects of human development, but has some environmental problems [21].

The gap in levels of human development is a reflection of the inequality of access to education, health care, employment, credit and natural resources, due to gender and group affiliation, disparities in income and place of residence. Inequality is not only a deviation from social and legal norms, it is also dangerous. It can fuel extremism and undermine efforts to ensure inclusive and sustainable development. A high level of inequality can lead to negative consequences for social cohesion and the quality of institutions and political events, which, in turn, can slow down progress in the field of human development [19-21].

The key principles of the sustainable development strategy do not constitute a checklist of criteria to be met, but encompass a set of desirable processes and outcomes [22]:

1Anthropocentrism - an effective strategy requires a person-centered approach that provides long-term beneficial effects on disadvantaged and marginalized groups, such as the poor. This is the first principle of the declaration (Rio de Janeiro): people are the focus of sustainable development. They have the right to a healthy and productive life in harmony with nature. The principles of sustainable development are focused on the interests of people who depend on natural resources and the state of the ecological system.

2. Nature conservation. Preservation of the environment, biodiversity is the main reason why people should care about nature. But a person will be “perfect” if he cares and protects the environment. Therefore, it is necessary that the environmental component play an important role in the search for sustainability principles.

3. Justice and Equality. Justice can only exist when people are equal. This approach can be implemented in different ways and implies an equal distribution of goods between people, families, nations. The essence of sustainable development is to meet the needs of present and future generations. F.D. Demidov writes about equality and justice in the concept of SD as follows: “we are talking about extending the principle of justice to all people without exception, bearing in mind not only present but also future generations. Current generations, continuing to translate into the future the principles of management and especially nature management, leading to the destruction of the natural environment and the depletion of natural resources, find future generations at first to significantly reduce the quality of life, and then to death ... from the temporal aspect, current generations significantly violate the principle of justice, they basically live off future generations.” [22].

4. Complexity. Sustainability affects all countries and all of humanity. In most cases, environmental problems (for example, an increase in the greenhouse effect, depletion of the ozone layer) are global problems. An interdisciplinary approach should be taken, since economic theory alone cannot solve existing problems. Sustainable development includes integration, as well as an understanding of the complex relationships that exist between the environment, the economy and society. This is not the balancing or price of one question against another, but a recognition of the interdependent nature of the three pillars [22].

Questions for self-control:

1. What is the purpose and concept of sustainable development?
2. Describe the main aspects of sustainable development.
3. What is the significance of the Stockholm Conference on the Human Environment (1972) for the world community?
4. How does the introduction of "green marketing" help solve environmental problems?
5. What are the basic principles of the World Charter for Nature?
6. Describe the activities of the Intergovernmental Panel on Climate Change.
7. Expand the structure and content of Agenda XXI.
8. List the main goals of the development of the millennium.
9. What are the goals of sustainable development?
10. What does the concept of "indicator of sustainable development" mean?
11. What country's achievements can be measured using the human development index?
12. From what sources do the data for calculating the human development index come from?
13. List the key principles of a sustainable development strategy.

2 Environmental aspects of sustainable development

2.1 Basic concepts in ecology and stages of its development

The term "ecology" (from the Greek oikos - home, homeland and logos - teaching - the science of habitat) was first introduced in 1866 by the German biologist, professor at the University of Jena, Ernest Haeckel (1834-1919). To paraphrase Haeckel, we can describe ecology as a study of the interaction of organisms with their environment. The word comes from the Greek "oikos", which means "house". Therefore, ecology can be considered as a study of the "family life" of living organisms. *Ecology* is a science that studies the relationship of organisms between themselves and with the environment. Organisms form interacting systems or communities, these communities are connected with the environment through the transfer of matter and energy, therefore communities and the environment are interconnected.

The main object of traditional environmental research are the ecosystems of our planet and their elements. The main subject of research in ecology is the relationship (characteristics and development) of living organisms, ecosystem components, as well as the nature of the influence of natural and anthropogenic factors on the functioning of ecosystems and the biosphere as a whole [23].

A functional system formed by communities and their environment is called an ecosystem. Thus, ecology is the science of ecosystems or the totality of mutual interactions between living organisms and their physical environment. The famous American ecologist Odum gave the following definition of ecology - this is the relationship between living organisms and their abiotic and biotic environment or "the study of the structure and function of nature" (Odum 1971). In this case, the structure includes distribution patterns and the number of organisms, and the function includes the interactions of populations, including competition, predation, symbiosis, as well as the circulation of nutrients and energy.

Ecology is an interdisciplinary science. Since ecology focuses on the study of higher levels of organization of life on Earth and on the interconnections between organisms and their environment, in its study it is necessary to rely on many other branches of science: geology, geography, meteorology, biology, economics, chemistry and physics. Thus, ecology is considered a holistic science, which covers a large number of disciplines.

For modern ecologists, ecology can be studied at several levels:

- level of population (individuals of the same species);
- level of biocenosis (or community of species);
- ecosystem level;
- biome level;
- level of the biosphere.

The outer layer of planet Earth consists of the following shells: hydrosphere (water), lithosphere (soil and stones) and atmosphere (air). The biosphere (or sphere of life), which is the "fourth shell," is all living matter on the planet or that part of the planet that is occupied by life. The biosphere captures the other three areas, although there are no permanent inhabitants of the atmosphere. In relation to the volume of the Earth, the biosphere is only a very thin surface layer, which extends from 11,000 meters below sea level to 15,000 meters above.

The biosphere contains a large number of elements such as carbon, nitrogen and oxygen. Other elements, such as phosphorus, calcium, and potassium, are also important for life, but are present in smaller amounts. At the level of ecosystems and the biosphere, there is a constant recirculation of these elements, which alternate between their mineral and organic states.

A biome is a homogeneous environmental entity that exists in a vast region such as the tundra or steppe. The biosphere includes all the biomes of the Earth - all places where life is possible - from the highest mountains to the depths of the oceans. Biomes are distributed in latitudes, from the equator to the poles, with differences depending on the physical environment (for example, oceans or mountain ranges) and climate. Species are distributed according to the corresponding biomes depending on their ability to tolerate temperature, dryness, humidity, etc.

Environmental factors that can influence dynamic changes in a population or species in a given ecology or environment are usually divided into two groups: biotic and abiotic.

Biotic factors relate to living organisms and their interactions. A biotic community is a collection of plants, animals, and other living organisms.

Abiotic factors are geological, geographical, hydrological and climatological parameters. A biotope is an ecologically homogeneous region characterized by a certain set of abiotic environmental factors. Specific abiotic factors include:

- water, which at the same time is an integral element of life and the environment;
- air, which provides oxygen, nitrogen, and carbon dioxide to all living organisms, and also spreads pollen and spores;
- soil - a source of nutrients (soil pH, salinity, nitrogen and phosphorus content, the ability to retain water and density affect its fertility and suitability for living);
- temperature, which should not exceed certain limits;
- light that provides energy for the ecosystem through photosynthesis;
- Natural disasters also relate to abiotic factors.

History of the development of ecology. Ecology as a science was formed in the middle of the 19th century. The history of the development of ecology is associated with the emergence and development of human society (Figure 2.1). With the growth of scale and improvement of methods for the removal of natural substances from people, a consciousness of connection with the outside world and dependence on it was developed. The legal norms that existed in Ethiopia during the time of the Aksumite kingdom (IV century AD) are known: river fish, poultry, steppe and forest mammals could not be sold and bought. The inhabitants of the highlands were exempted from grazing and cultivating land, but had to keep the water flow clean [24].

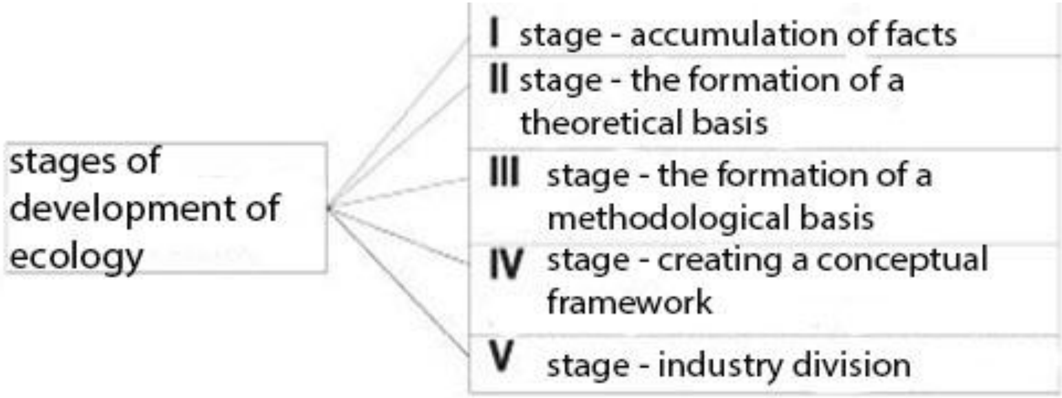


Figure 2.1 - The main stages of the formation of ecology as a science

1. Ancient times. It is said that ecological thought originates from the early teachings of philosophy, ethics, and politics (4th century BC). Aristotle and Feofrast are considered one of the first ecologists who were interested in studying plants and animals. Feofrast described several relationships that exist between living organisms and their environment in the fourth century BC (Ramalai, 1940). Some argue that awareness of species and their relationships began with Aristotle, although his writings on this subject have been largely lost. Aristotle's student Theophrastus described the relationship between plants and animals, but this was more philosophical than scientific point of view [24,25].

2. 18 century. Beginning of the 18th century: two schools of thought dominated the growing scientific study of ecology. The first school of thought is the "Ecological Arcade", which stands for "a simple, modest life for man" and harmonious relations with man and nature. On the other hand, the second school of thought, known as the "Imperial Ecology", believes in the establishment of human domination over nature through a reasonable approach and hard work. Both eyes competed in the early years of the 18th century. In 1758, Carol Linne (Carl von Linne) became a pioneer in the field of taxonomy, the science of the name and classification of organisms. Linnaeus discovered a huge number of plants and animals and recorded them in his book "System of Nature". Linnaeus was a supporter of imperialism, because of its immense popularity, a look at imperial ecology became the dominant view in discipline.

3. 19 век. В течение девятнадцатого века ботаническая география и зоогеография объединились, чтобы сформировать основу биогеографии. Это объясняет причины присутствия определенных видов в указанном месте.

В начале 19-го века были организованы несколько экспедиций для изучения новых земель и добычи природных ресурсов.

1804: Alexander Humboldt in his work discovered many species, especially plants, and attempted to explain their geographical distribution according to geological data. His famous scientific work is called "The Idea of Plant Geography." Many scientists consider Alexander von Humboldt the father of ecology.

1859: This year, Charles Darwin proposed his theory of evolution and adaptation. In accordance with this theory. Such evolutionary changes allow them to better adapt to the environment. Survival by increasing the likelihood of obtaining more offspring.

Charles Darwin's fame is largely due to his idea of natural selection - "survival of the fittest." Along with Alfred Russell Wallace, who determined the role of natural selection in the formation of various organisms, Charles Darwin published all his observations, proposed mechanisms and discoveries in his book "On the Origin of Species Using Natural Selection". With the publication of Charles Darwin's Origin of Species, ecology has moved from a repeating mechanical model to a biological, organic, and therefore evolutionary model. This work describes many observations and proposed mechanisms that clearly fit into the boundaries of modern ecology. Darwin's concept of natural selection, on the other hand, focused mainly on competition. However, many pioneers who founded ecology as a scientific discipline, such as Eugene Warming, A. F. Schimper, Gaston Bonnier, F. A. Forel, S. A. Forbes and Karl Mobius, hardly mentioned Darwin's ideas in their works [5] . One of the reasons is the fact that at that time Darwin's work was not widespread [24-26].

Möbius described in detail the interactions of various organisms living on the coasts, and introduced the concept of "biocenosis", which has become a key term in synecology. Among the interests of Möbius, marine animals occupied one of the main places, it was he who devoted his first scientific work (German Die Fauna der Kieler Bucht, co-authored with Heinrich Adolf Meyer, published in two volumes (1865 and 1872); also in it many problems of the ecology of the seas were reflected [24,25].

1869: Ernst Haeckel coined the term "ecology". Since then, ecology has become a discipline that studies the relationship of organisms with their environment.

1875: Edward Seuss first defined the term biosphere (from Greek bios - life) as a system consisting of living organisms and their environment.

1877. Alfred Russell Wallace, a contemporary and rival to Darwin, was the first to propose the "geography" of animal species. Several authors at the time recognized that the species were not independent of each other, and grouped them into plant, animal species, and then into living creature communities or "biocenosis". This term, which comes from the Greek language, was coined in 1877 by marine biologist Karl Mobius and in essence means "life that has something in common."

1879: Shortly afterwards, symbiosis or living together was described for the first time in a more or less close association or close union of two dissimilar organisms.

A great contribution to the development of ecology as a science was made by Russian scientists K. F. Roulier (1814-1858), N. A. Severtsov (1827-1885), V. V. Dokuchaev (1846-1903), who explained the basic principles, laws, used in ecology. Over the last 6 years of his life, Severtsov has published several works: "On the bird's flight paths through Turkestan", "On the crosses in the group of ducks", "Distribution of birds in the Palearctic region". In his scientific activity, Severtsov is, firstly, as a traveler-researcher, independently exploring a huge section of Central Asia and discovering a lot of new things here, and as a scientist: he processed very large material and made very general and carefully verified conclusions based on these observations [24.25].

V.V. Dokuchaev discovered the laws of genesis (origin) and geographical location of soils. He pointed to the special position of the soil in nature, which is determined by the fact that both mineral and organic compounds participate in its composition. He proved that an integral part of the soil - the living phase - consists of living organisms: the root systems of plants, soil animals, microorganisms. Vasily Vasilievich first established that the soil is an independent natural body, qualitatively different from all other bodies of nature [25].

In 1895 Eugene Warming (1841-1924) - Danish ecologist introduced the discipline of biogeography. Biogeography studies the geographical distribution of living things. In this discipline, abiotic factors are studied, such as wind, fire, temperature, etc.

The study of ecology was greatly improved thanks to the discovery of the nitrogen cycle by Antoine Lavoisier and Theodore de Saussure. Nitrogen is considered one of the essential nutrients essential for the survival of all living organisms, and the discovery of how it is cyclically processed into various forms has paved the way for a better understanding of nutrient absorption in living organisms.

After observing the fact that life developed only within the strict limits of each component that makes up the atmosphere, hydrosphere and lithosphere, the Austrian geologist Eduard Suess proposed the term biosphere in 1875. He used the name biosphere for conditions conducive to life, which include flora, fauna, minerals, material cycles, and so on.

In general, the modern movement towards ecology through botanical geography (which led to plant ecology) developed earlier than animal ecology. During the eighteenth and early nineteenth centuries, great maritime powers such as Great Britain, Spain, and Portugal undertook many world research expeditions. Many scientists, including botanists, such as the German researcher Alexander von Humboldt, joined these expeditions. Humboldt is often considered the father of ecology. He was the first to study the relationship between organisms and their environment. He identified existing relationships between observed plant species and climate and described vegetation zones using latitude and height, a discipline now called geobotany.

Environmental damage was recorded in the eighteenth century, as the development of new territories by people affected deforestation. Beginning in the nineteenth century, when the industrial revolution took place, there was an increasing concern about the environmental impact of human activities.

4. 20th century. Human ecology began in the 1920s, thanks to the study of changes in the sequence of vegetation in cities. These studies have recognized that people who colonized all continents of the Earth are the main environmental factor. Mankind is significantly changing the environment through the development of habitat (in particular, urban planning), through intensive activities such as logging and fishing, as well as as a result of side effects of agriculture, mining and other industries. The development of human ecology has led to an increase in the role of environmental science in the design and management of cities.

At the turn of the twentieth century, Henry Chandler Coles was one of the founders of a new study of “dynamic ecology,” conducting environmental continuity studies in sand dunes. Here, Coles found evidence of ecological continuity of vegetation and soil depending on age. Environmental continuity is the process by which the natural community moves from a simpler level of organization to a more complex community.

1920: a study of human ecology. The purpose of this discipline was to increase the role of environmental science in the management of cities and places of residence.

1926: Vladimir Ivanovich Vernadsky in his book “Biosphere” redefined the biosphere as a global ecological system uniting all living things and their interconnections, including their interaction with elements of the lithosphere, geosphere, hydrosphere and atmosphere, and described the basic principles of biogeochemical cycles.

1935: British ecologist Arthur Tansley coined the term “ecosystem” as a biological community of interacting organisms and their physical environment. Thanks to his work, ecology has become the science of ecosystems - an interactive system created between a biocenosis (a group of living creatures) and their biotope (the environment in which they live).

1940: Patrick Moore studied the interdependence of organisms, especially freshwater ecosystems. She has developed methods for measuring flow health.

1950: The harmful effects of pollution on ecosystems became known to people.

1953: The Tanley ecosystem concept was adopted by the energetic and influential biology teacher Eugene Odum. Together with their brother Howard Odum, they wrote a textbook, which (since 1953) trained several generations of biologists and ecologists in North America, and now the textbook is very popular at universities.

1960: Environmental discipline gained wide publicity due to widespread concern for the environment.

1970: James Lovelock coined the term *Gaia*, or the idea that the whole earth is one living creature and will ensure its survival, even if people destroy themselves.

1971: UNESCO launched the Man and the Biosphere research program to raise people's awareness of their relationship with nature.

1978: conservation biology created as a discipline focused on environmental management.

Currently, the desire to continue environmental research is fueled by the desire of man to restore and preserve the ecology of the planet.

Sections of ecology. Ecology is a broad science that can be divided into main and secondary disciplines. The main disciplines include (figure 2.2):

- physiological ecology (or ecophysiology), which studies the effect of biotic and abiotic environments on human physiology and human adaptation to their environment;
- behavioral ecology, which studies the ecological and evolutionary foundations of animal behavior and the functions of adaptation to certain ecological niches;
- population ecology (autecology), which studies the dynamics of populations within species and the interaction of populations with environmental factors;
- community ecology (synecology), which studies the interaction between species within the ecological community;
- an ecological ecosystem that studies the flows of energy and matter within and between ecosystems;
- medical ecology, which studies the problems associated with human health as a result of environmental violations;
- landscape ecology, which studies the interaction between the individual elements of the landscape and spatial structures, including the role of human exposure;
- global ecology, which considers environmental issues at the global level;
- evolutionary ecology, which studies the history of the evolution of species and their interactions.

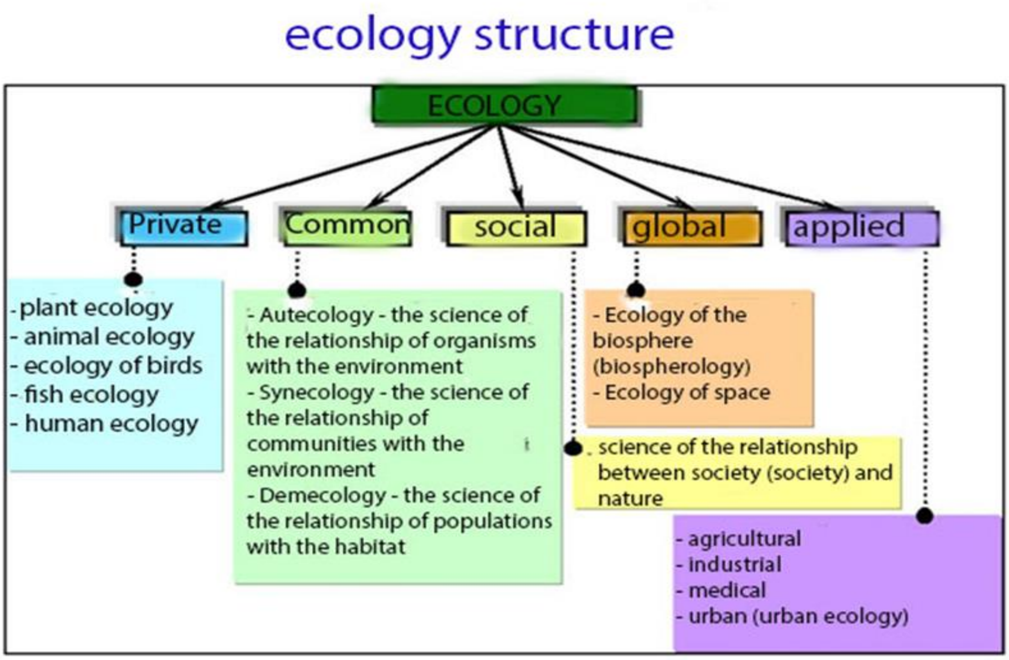


Figure 2.2 - Sections of ecology

Ecology can also be subdivided on the basis of target groups: animal ecology, plant ecology, insect ecology, human ecology, etc. [25,26].

2.2 Global problems of mankind

The international community has seriously started talking about global issues since the mid-60s of the twentieth century. They began to include environmental degradation and a population explosion, the threat of depletion of natural resources in the world and a shortage of sources of energy and food in the world, and a growing gap between rich and poor countries (Figure 2.3) [27].

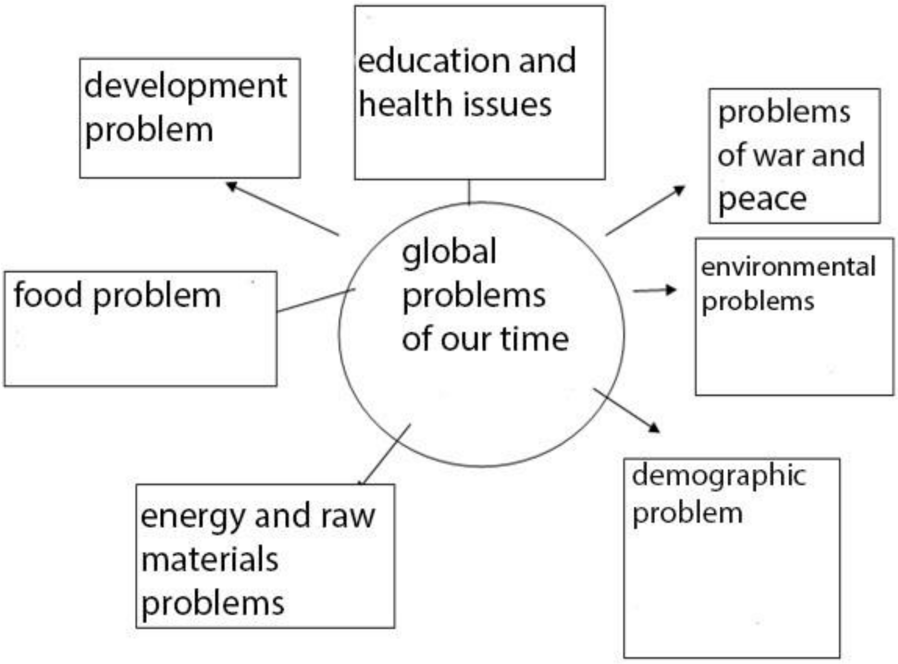


Figure 2.3 - Global problems of mankind

Mankind has made significant progress in understanding global problems, and governments, international organizations and social movements have gained considerable experience in eliminating and preventing a number of dangerous phenomena. The globalization of the world economy, the revolution in the field of telecommunications and information technologies, the development of regional integration create favorable conditions for more effective actions in the sphere of relations "man - society - nature" [27].

In 1942, the famous Russian-American sociologist and culturologist Pitirim Sorokin wrote in his book “Man and Society in Disaster”: “Disasters are not an exceptional evil: along with their destructive and harmful actions, they also play a constructive and positive role in the history of culture and creative activity of man. For mankind, disasters are of great educational importance” [28].

At the beginning of the 21st century, the aggravation of global problems raised a new question about the present and future of human civilization, making the conclusion about the possibility of learning from disasters quite controversial.

The threat of a global planetary catastrophe, the extinction of mankind itself as a species as a result of either a nuclear war, or the degradation of the natural environment, the planet's biosphere under the influence of anthropogenic loads, or aggravation of other contradictions of this magnitude began to increase. Moreover, over the past quarter century, despite the efforts made at various levels, not a single global threat, with the exception of the nuclear one, has been eliminated; they have not even been able to mitigate or move aside [27,28].

The main problems facing humanity are phenomena that encompass the world as a whole and pose a threat to the entire population of the Earth, requiring for their solution combined efforts, joint actions of all states and peoples.

The global problems of our time are different in their nature, these are:

- the threat of nuclear war, an accident at a nuclear power plant;
- demographic growth;
- energy and food problems;
- urbanization and its consequences;
- major environmental issues, including climate change, depletion of the ozone layer, lack of fresh water, water pollution, the harmful effects of pesticides on human health, acid rain, and the reduction of biological diversity [4,27,28].

The most important global problem remains the problem of peace and disarmament. In 1945, after the Second World War ended, over 200 armed conflicts occurred in the world, according to the UN. These conflicts cost the lives of more than 20 million people, of which more than 80% are civilians. In the second half of the XX century. In connection with the further improvement of nuclear weapons and rocket technology, the accumulation of other weapons of mass destruction (chemical and biological), a real possibility arose of destroying entire countries and continents in the event of the outbreak of World War III. Moreover, global stockpiles of weapons of mass destruction are enough to repeatedly destroy all life on Earth. The total world stockpile of nuclear weapons is about 15 thousand megatons, which is approximately equal to more than 1 million bombs, similar to the one that was dropped on Hiroshima [4,27,29].

Despite this, countries, as before, spend huge amounts of money on weapons (Figure 2.4). More is spent on weapons than on people. The world's military expenditures amount to $ 800 billion annually. $ 30 billion worth of weapons are delivered to developing countries each year. And although nuclear weapons are no longer used, the desire of individual states for possession of weapons of mass destruction is uncontrolled by the international community. Now there are at least seven "nuclear states", including those that conflict with each other (India and Pakistan). A number of countries are actively working to create nuclear weapons [27-29].

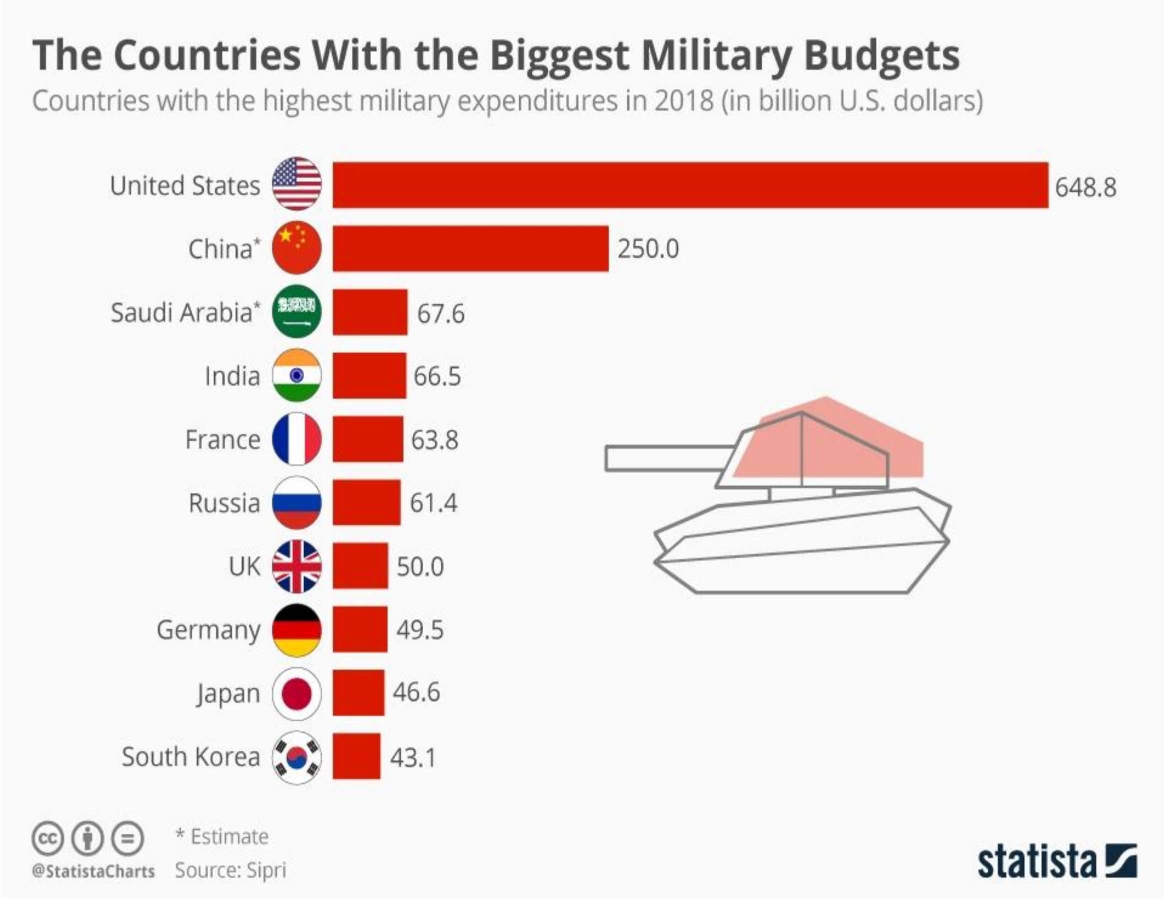


Figure 2.4 - Annual military spending of some countries, dollars [27,29]

It should be noted that the beginning of the XXI century was affected by a new problem - the problem of the fight against international terrorism.

The demographic problem in different countries has its own characteristics. In most European countries, the problem is the depopulation and aging of the nation due to excess mortality over fertility. Such a drop in population growth was called the demographic crisis. In contrast, a demographic “explosion” (Figure 2.5) characterizes many developing countries. This was called the phenomenon of a sharp increase in population growth, which creates many undesirable consequences, such as: difficulties in the economic development of states, aggravation of poverty and environmental problems, and the like. In order to solve the demographic problem, the UN adopted the "World Population Action Plan", according to which governments are invited to pursue an active population policy. Many believe that the desired result in reducing fertility can be achieved by revolutionizing the culture and customs of humanity [30].

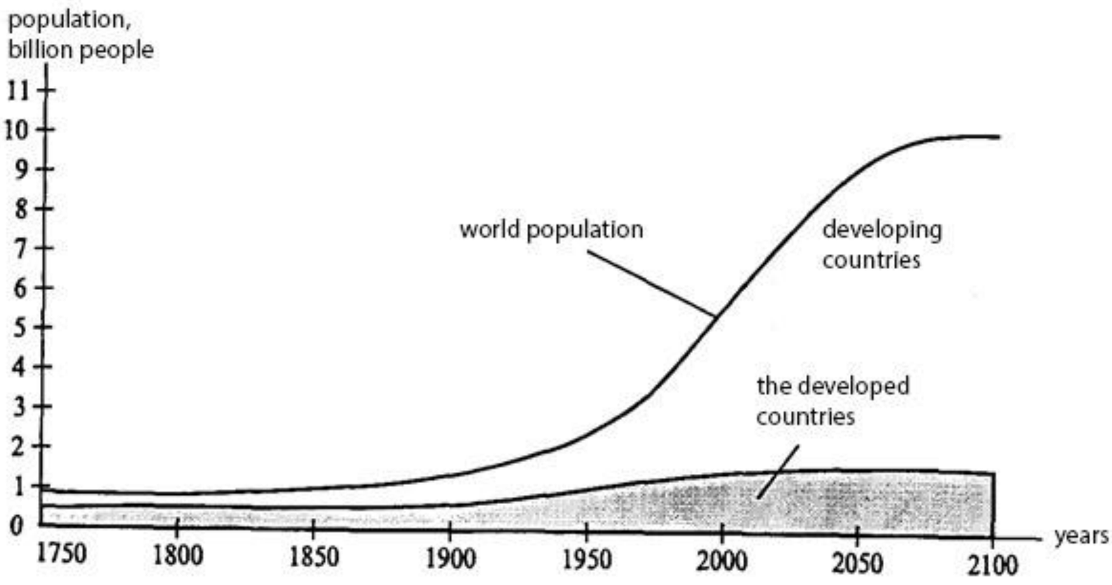


Figure 2.5 - Population growth by years

Energy and raw material problems are to provide humanity with energy and mineral resources. Its exacerbation in the second half of the twentieth century is due to several reasons. Among them are the relative limitations of the proven reserves of oil, natural gas and some other types of fuel and raw materials, the depletion of long-exploited deposits of natural resources, the deterioration of the mining and geological conditions of their production, the widening of the territorial gap between the areas of production and consumption, the promotion of the mining industry in areas of new development with extreme environmental conditions. Currently, it is necessary to rationally use exhaustible and reproduce alternative energy sources, introduce energy and resource-saving technologies [6,22,27].

The food problem is manifested in the fact that 2/3 of humanity are experiencing a constant shortage of food. In addition, nutrition is often not high-calorie and has an irrational structure (lack of vitamins and proteins of animal origin). At the same time, the world as a whole produces enough food, but the geography of its production does not coincide with the geography of consumption. North America and Western Europe have a surplus of food, but developing countries are not able to procure enough [27,28,30].

The most reliable way to solve the global food problem is to increase food production in the starving countries of Asia, Africa and Latin America. It is possible in two ways. One of them - extensive - provides for the further expansion of arable, grazing and other lands. According to the FAO (UN Food and Agriculture Organization), there is still a lot of land for agricultural use. About 1,560 million hectares can be added to the current 1.4 billion hectares of arable land. More than half of the available additional land is in Africa and Latin America. These regions account for most of the land that is best suited for growing crops with rain irrigation. The main solution to the food problem is an intensive way - increasing the biological productivity of existing land. The intensification of agriculture in developing countries is associated with biotechnology, the use of new high-yielding varieties (the so-called green revolution) and new methods of tillage, the further development of mechanization, chemicalization, melioration [16,21,23].

Another major problem in the world is the problem of poverty, which refers to the impossibility of providing the simplest and most accessible conditions for most people in a given country. High levels of poverty, especially in developing countries, pose a serious danger not only to national, but also to global sustainable development [27,31].

The following types of poverty levels are distinguished:

- national;
- international.

National poverty level is the proportion of the population living below the national poverty line. In most countries of the world, the national poverty line means income below the subsistence level, i.e. not allowing to cover the cost of a consumer basket - a set of the most necessary goods and services by the standards of a given country in a given time period. In many developed countries, people with incomes of 40-50% of the country's average income are considered poor [27,31].

International poverty is income that provides less than $ 2 per day. They also determine the international level of extreme poverty (or, in other words, extreme poverty) - income that provides consumption of less than $ 1 per day [31].

According to World Bank estimates, the total number of poor, i.e. living on less than $ 2 per day, makes up 2.5-3 billion people in the world. Including the total number of people living in extreme poverty (less than $ 1 per day) - 1-1.2 billion people. In other words, 40-48% of the world's population are poor and 16-19% are super-poor (Figure 2.6) [31].

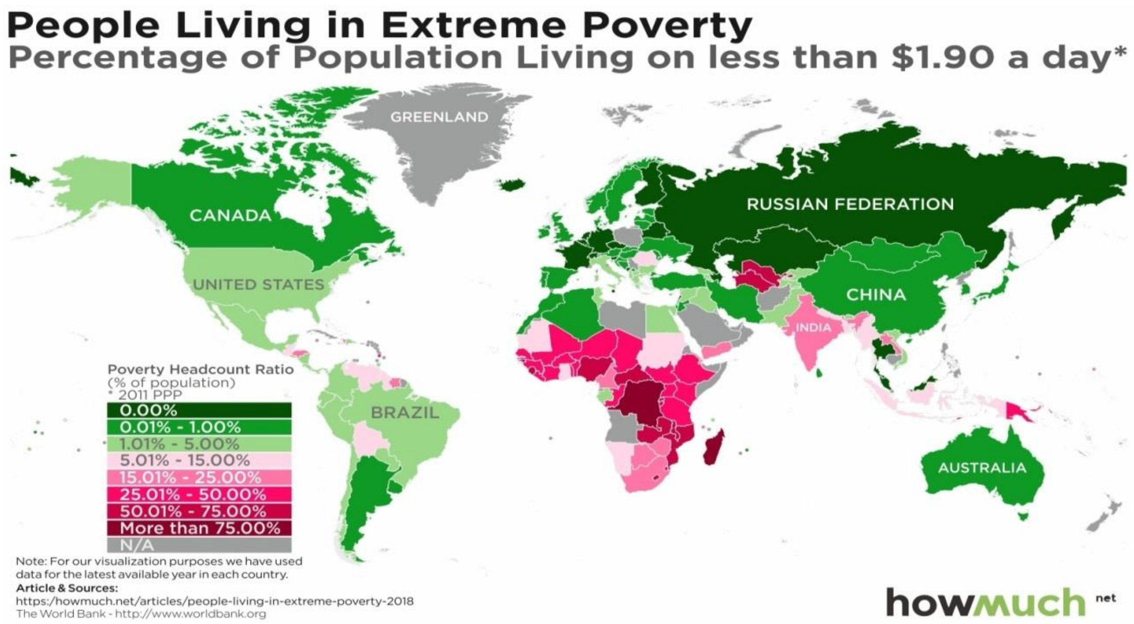


Figure 2.6 - Map of extreme poverty in the world according to the World Bank according to data for 2019

Since the 80s XX century at the beginning of the 21st century the number of people living in extreme poverty declined by about 200 million. This was mainly due to a decrease in the number of super-poor in China. Since the beginning of the 90s. there is a tendency to reduce the number of super-poor in another multi-populated state - India. At the same time, in sub-Saharan Africa over the past 20 years, on the contrary, there has been a steady increase in the number of super-poor [31].

The distribution of the poorest people by region of the world since 1980 has not changed significantly. Two-thirds of the world's poorest people still live in East and South Asia, and one-fourth in sub-Saharan Africa. Most of the poor are concentrated in rural areas of developing countries.

In some developing countries, the problem of poverty has long reached a critical level. For example, at the beginning of the XXI century. less than $ 1 per day has forced 76% of the population of Zambia, 71% of Nigeria, 61% of Madagascar, 58% of Tanzania, 54% of Haiti [30,31].

The most important factor in solving the poverty problem is economic growth, since it is economic growth that leads to an increase in gross national income, through which the consumption fund is formed. At the same time, in the fight against poverty, state assistance to the poor is also important, although its increase leads to a decrease in the severity of the poverty problem, but not to its solution. As the experience of developed countries shows, against the background of the growth of this assistance, the so-called stagnant poverty of that part of the able-bodied population, which are desperate to find work and therefore psychologically oriented only to state assistance, can increase. As a result, targeted payments of benefits to the poor should be accompanied by a set of socio-economic measures aimed at their involvement in labor activities (vocational training and retraining programs, assistance in finding jobs, etc.) [27,30,31].

The global poverty problem is particularly acute because many developing countries, due to low incomes, do not yet have sufficient opportunities to alleviate poverty. That is why the elimination of the centers of poverty in the world economy requires wide international support [31].

Global environmental problems affect the interests of people around the world, since they pose a real threat to the future of mankind. Solving these problems requires international cooperation and timely fulfillment of obligations to restore the environment [27].

2.3 Key environmental issues

The main environmental problems are described in the materials of the UN Conference on the Environment, which was held in Rio de Janeiro in 1992, which brought together representatives from 179 states. During the conference, it was noted that international cooperation should be aimed at preserving the environment and creating a healthy economy for all peoples of the world. The modern negative factors affecting the biosphere should be attributed (Figure 2.7) [32]:

1) The Earth’s atmosphere is experiencing to an increasing extent:

- exposure to gases causing a greenhouse effect leading to climate change;
- the emergence of new chemicals that deplete the ozone layer of the atmosphere and pollute it;
- acid precipitation, damaging the earth, water, living organisms;
- increased energy consumption, air emissions, wastewater discharges.

2) Irrational use of resources:

- an increase in land requirements leads to competition and conflict;
- soil degradation caused by excessive grazing and intensive economic activity.

3) Forest destruction: predatory logging, reduction of plant and animal diversity, expansion of agricultural land.

4) Devastation and drought due to livestock overcrowding, climate change, loss of biological species.

5) Reduction of biodiversity due to the destruction of human habitat, the disappearance of biological resources of natural ecosystems.

6) Pollution of the oceans. Ocean waters experience environmental stress as a result of pollution by sewage, garbage, metals, radioactive waste for disposal, overfishing, etc.

7) Irrational use of fresh water. In many parts of the world, the population suffers from a shortage of fresh water, there is pollution of water by sewage, waste, chemical fertilizers.

8) Waste generation and its negative impact. A growing amount of waste negatively affects not only the quality of the environment, but also on all living organisms. Waste pollutes water, air, soil in vast areas [32].

Greenhouse effect, climate change. The most striking evidence of the warming of the Earth’s climate is the recording of the readings of thermometers located around the world. Reliable confirmation is also preserved records of thermometers from the late 19th century in some parts of the world. Today, the value of air temperature is controlled in many thousands of places, both on land and on the surface of the ocean. Indirect estimates of temperature changes, as well as tree growth rings, ice cores, help determine recent temperature changes in the context of the past. According to indirect estimates, it was found that the 30-year period from 1983 to 2012 was the warmest over the past 800 years (Figure 2.8).

A wide range of other observations confirm the fact of warming in the entire climate system. For example, the lower atmosphere and the upper layers of the ocean became warmer, the size of snow and ice cover decreases in the northern hemisphere, the ice cover of Greenland decreases, and sea level rises. These measurements are made using various monitoring systems, which further confirms the reality of the Earth’s climate warming.

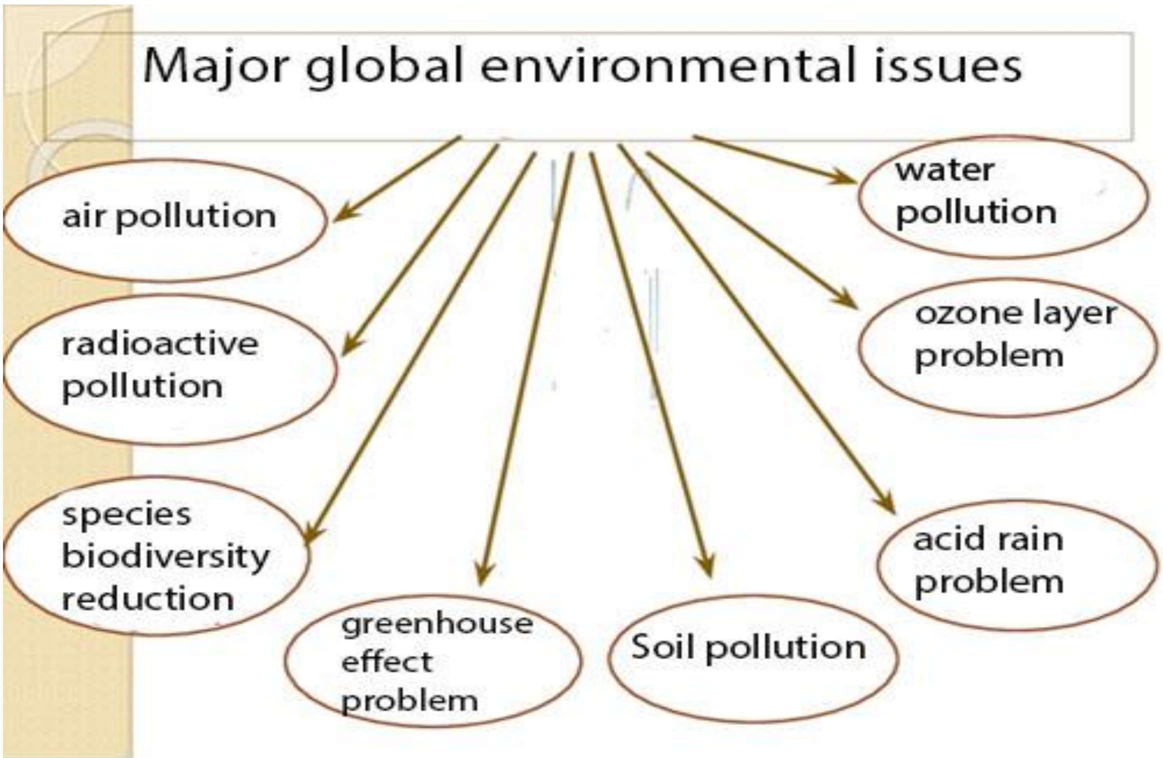


Figure 2.7 - The main environmental problems

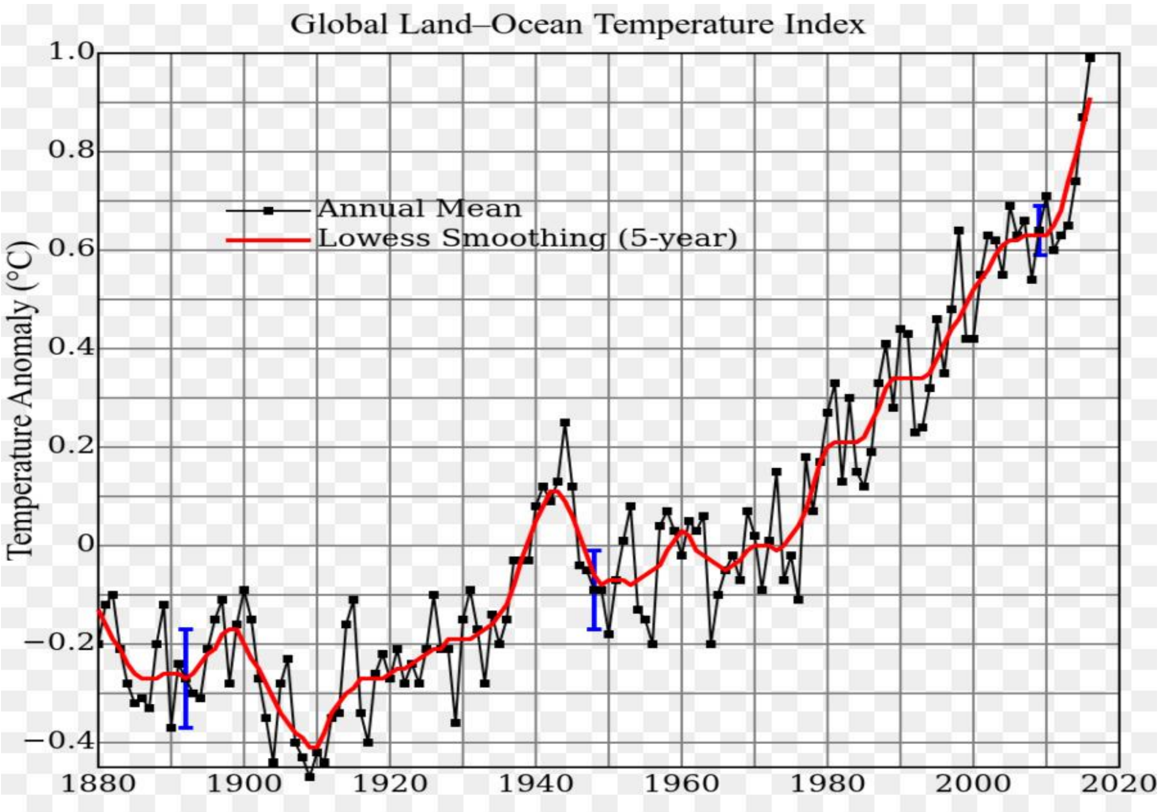


Figure 2.8 - Change in the average annual temperature of the Earth's surface by years

Significant global climate changes in the Earth’s recent geological past are ice age cycles, which are long cold periods followed by shorter warm ones. Similar natural cycles are repeated approximately every 100,000 years. Basically, their manifestation is affected by changes in the Earth’s orbit, because of which the distribution of the energy of the Sun changes depending on the latitude and time of the year on Earth.

However, according to scientists, these changes are not enough to entail an increase in the temperature observed today. Basically, they lead to changes in the size of the ice sheets, an excess of CO2 and other greenhouse gases, which increase the initial temperature change and complete the global transition from warm to cold periods or vice versa.

According to recent estimates, the increase in average global temperature since the end of the last ice age is 4-5 ° C. The CO_2 concentration over the past 200 years has increased by 40%, mainly due to changes in the planet’s energy budget as a result of anthropogenic activities. If the growth of CO_2 content is not restrained, then by the end of this century or soon after it, warming will come, equivalent to the scale of the ice age. The observed rate of increase in the temperature of the surface of the planet is more than ten times the rate of warming that has occurred since the last ice age, the fastest known sustained global change.

Since the mid-1800s, scientists have established that carbon dioxide CO_2 is one of the main greenhouse gases and is an important component in the energy balance of the Earth. Direct measurements of CO_2 in air, in air, in ice show that over the period from 1800 to 2012 its concentration in the atmosphere increased by about 40%. Measurements of various forms of carbon indicate that carbon dioxide increases are associated with human activities. Also, the concentration of other greenhouse gases (especially methane and nitrous oxide) increases as a result of human activities.

Expected climate change is the result of greenhouse gases trapping heat. A fundamental understanding of the physical behavior of greenhouse gases proves that the observed climate changes cannot be attributed to their natural sources of emissions. Natural causes include fluctuations in solar radiation and the Earth’s orbit around the Sun, volcanic eruptions and internal fluctuations in the climate system (such as El Niño and La Niña). Calculations using climate models (see Information block, p. 20) were used to simulate what would happen to global temperatures if only natural factors influenced the climate system. These simulations give a slight warming or even a slight cooling during the 20th century. Only when the models take into account the human influence on the composition of the atmosphere, the resulting changes in temperature are consistent with the observed changes.

The greenhouse effect is the retention of a significant amount of solar thermal energy on the earth's surface. The concept of the greenhouse effect was formulated as early as 1863 by Tyndall. In 1896, Arrhenius showed that carbon dioxide, which constitutes an insignificant part of the atmosphere (approximately 0.03%), maintains its temperature 5-6 ° C higher than if this gas were absent. In 1927, the French physicist J. Fourier came to the conclusion that the Earth's atmosphere performs a kind of glass function in a greenhouse, i.e. air passes solar heat, preventing it from retreating back into space (Fig. 2.4). This assumption turned out to be true. In 1938, Callender first suggested the possible impact of anthropogenic carbon dioxide emissions on the climate. In the 70s it was proved that other gases in smaller quantities than carbon dioxide give a tangible greenhouse effect [24,25].

The impact on the global climate of the greenhouse effect is as follows (Figure 2.9):

1. There is a constant and increasing increase in emissions of greenhouse gases, primarily carbon dioxide. The sources of which are the burning of coal and other carbon-containing fuels, oil, gas, gasoline, etc. Emissions of other "greenhouse" gases, namely methane, nitrogen oxides, halagenic hydrocarbons, are growing even more rapidly.

2. As a result of air emissions on the planet, the average annual temperature has continued to increase. According to some estimates, in the 1890s it amounted to 14.5 ° C for the world as a whole, and to 15.2 ° C in the 1980s. During 1940-1970, the indicator remained stable, but now there is a rapid pace of increase. According to forecasts in 2030-2050. the average annual temperature may turn out to be 2-4.5 ° C higher than the current one, i.e. it will be warmer on Earth than in the past 2 million years. Moreover, the rate of warming in the first half of the XXI century may become 5-10 times higher than in the last century [24,25].

3. The effects of warming on the populations and economies of different countries may turn out to be different and have both negative and positive sides. Globally, the extremely high rates of change that are currently being forecast are fraught with difficulties or even the inability to adapt quickly enough to new conditions.

The increase in temperature on the globe as a result of the greenhouse effect will entail an unprecedented environmental, economic and social explosion.

The water level in the oceans can rise by 1-2 meters due to sea water and the melting of polar ice. As a result, by 2100, about 1% of Egypt’s territory will be under water, 6 - of the Netherlands, 17.5 - of Bangladeshi, 80% of the Majuro Atoll, which is part of the Marshall Islands [24,25,33].

With increasing temperature on the planet:

- droughts and typhoons will become commonplace;

- the ice cover of the Arctic will be reduced by 15%;

- in the Northern Hemisphere, the ice cover of rivers and lakes will be reduced by two weeks;

- ice cover will melt in the mountains of South America, Africa, China;

- a complex ecological system will be in the stage of destruction, which will entail a catastrophic decrease in the genetic diversity of plants and animals.

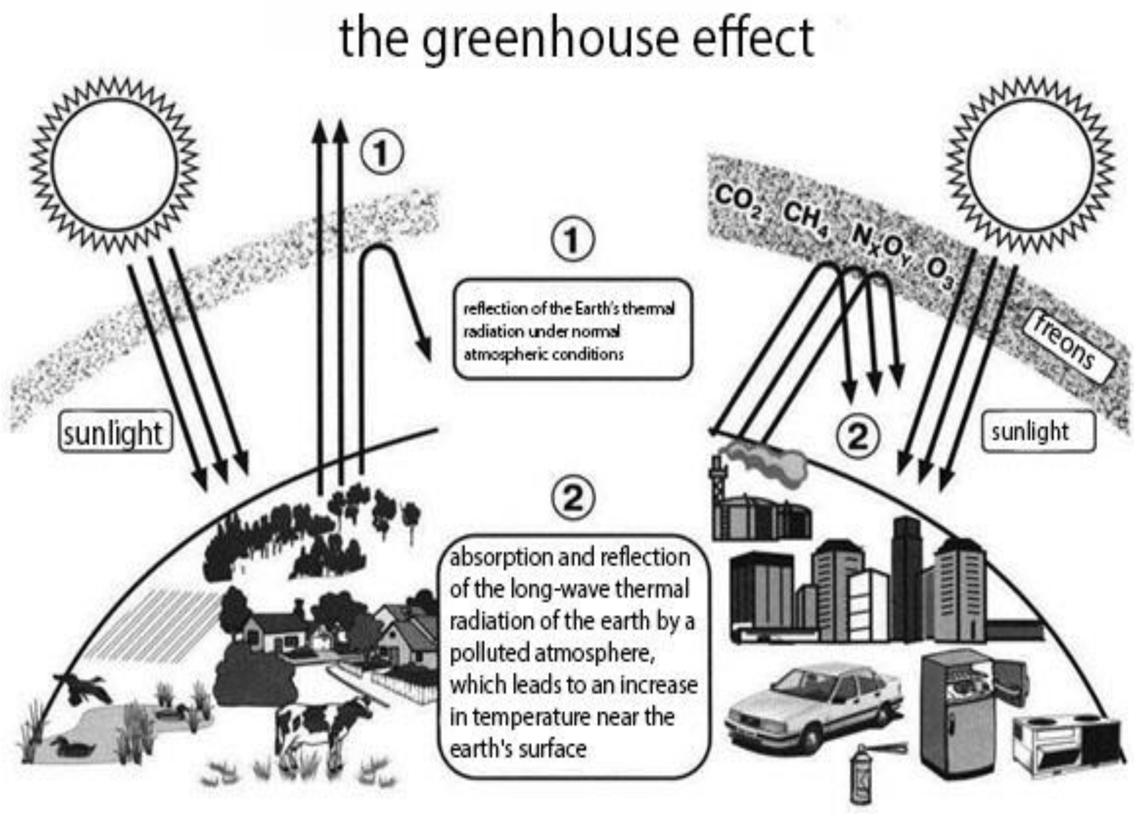


Figure 2.9 - Scheme of the greenhouse effect

In 1988, the World Meteorological Organization (WMO) and the United Nations Environment Program (UNEP) established the Intergovernmental Panel on Climate Change (IPCC). The goal of the IPCC is to provide governments with scientific information that they can use to develop climate policies. The IPCC reports are also a key contribution to international climate change negotiations. The IPCC currently has 195 members. With regard to climate assessment reports, IPCC scientists voluntarily spend their time evaluating thousands of scientific articles published each year to provide a comprehensive summary of what is known about the causes of climate change, its consequences and future risks, and how adaptation and mitigation can reduce risks.

In their report, experts argue that anthropogenic greenhouse gas emissions have increased since the pre-industrial era, due in large part to economic growth and population growth, and now they are higher than ever. This has led to atmospheric concentrations of carbon dioxide, methane and nitrous oxide, which are unprecedented in at least the past 800,000 years. Their effects, along with the effects of other anthropogenic factors, have been found throughout the climate system and are likely to be the dominant cause of observed warming since the mid-20th century.

The IPCC is currently preparing the sixth six-year climate assessment report. During this cycle, the Group will prepare three special reports, including a methodological report on national greenhouse gas inventories [34].

Depletion of the ozone layer. The ozone layer is a layer in the Earth's atmosphere that contains relatively high concentrations of ozone (O3). The ozone layer absorbs 93-99% of solar high-frequency ultraviolet light, which potentially damages life on Earth [23,24]. Most ozone is present mainly in the lower part of the stratosphere about 10–50 km above the Earth, although its thickness varies depending on the season and geographical location [25]. The presence of the ozone layer in the atmosphere of the earth was discovered in 1913 by French physicists Charles Fabry and Henri Boisson. Its properties were investigated in detail by the British meteorologist G. M. B. Dobson, who developed a simple spectrophotometer (Dobson meter) for measuring stratospheric ozone from the ground. Between 1928 and 1958, Dobson created a worldwide network of ozone monitoring stations, which continues to operate today.

Without ozone, life on Earth for all living things would be impossible. The first stage of development of a unicellular organism occurred in an oxygen-free environment that existed on the earth more than 3,000 million years ago. As the primitive forms of plant life multiplied and developed, they began to secrete small amounts of oxygen through the photosynthesis reaction (which turns carbon dioxide into oxygen). The accumulation of oxygen in the atmosphere led to the formation of the ozone layer in the upper atmosphere (stratosphere). This layer filters out the incoming radiation from the ultraviolet spectrum that damages the cells. Thus, the formation of the ozone layer led to the formation of more complex life forms. Ozone is a form of oxygen. The oxygen we breathe is in the form of oxygen molecules (O_2) - the two oxygen atoms bonded together are colorless and odorless. Ozone consists of three oxygen atoms bonded together (O_3), is colorless and has a very pungent odor. Of the 10 million air molecules, about 2 million are normal oxygen, but only 3 are ozone. Most ozone is produced naturally in the upper atmosphere or in the stratosphere. Ozone is also found in very small amounts in the lowest parts of the atmosphere, an area known as the troposphere. It is produced at ground level as a result of the reaction between sunlight, volatile organic compounds (VOCs) and nitrogen oxides (NOx), some of which are produced as a result of human activities, such as driving cars.

Ground-level ozone is a component of urban smog and is harmful to human health. Despite the fact that both types of ozone contain the same molecules, their presence in different parts of the atmosphere has very different consequences [23,26,27]. Stratospheric ozone blocks harmful solar radiation and all life on Earth has adapted to filtered solar radiation. In contrast, surface ozone is a pollutant. It absorbs a certain amount of incoming solar radiation, but cannot compensate for the loss of ozone in the stratosphere.

The main ozone-depleting substances include chlorofluorocarbons (CFCs), carbon tetrachloride, hydrochlorofluorocarbons (HCFCs) and methyl chloroform. Halons, sometimes known as brominated fluorocarbons, also contribute greatly to the depletion of the ozone layer (Figure 2.10). Reactions with these gases usually occur through catalytic processes. The catalytic reaction cycle is a set of chemical reactions that lead to the destruction of many ozone molecules, while the molecule that started the reaction is reformed to continue the process. Due to catalytic reactions, a single chlorine atom can destroy on average about a thousand ozone molecules before it turns into a form that is harmless to ozone [28,29].

The danger of depletion of the ozone layer as a result of human activity was first declared in the late 1960s. We have every reason to destroy the ozone layer and lead to a global environmental crisis.

At the University of California, Irvine, scientists F. Sherwood Rowland and Mario J. Molina found that chlorofluorocarbons (CFCs) destroy the atmospheric ozone layer, which blocks the harmful ultraviolet rays of the sun. The American Society of Chemists has called this discovery a national historical reference to phase out CFC use. When scientists reported their results in 1974, CFCs were widely used as refrigerants and as propellants in aerosol cans. A statement by Rowland and Moline convinced skeptical industrialists, politicians and the public of the dangers of using CFCs. Further propaganda of scientists about their discovery, the discovery by other researchers of the depletion of the ozone layer over the Antarctic, led to the worldwide abandonment of CFCs and the development of safer alternatives. “For work on atmospheric chemistry, especially in connection with the formation and destruction of ozone”, Rowland and Molina were awarded the Nobel Prize in chemistry in 1995 [30,31].

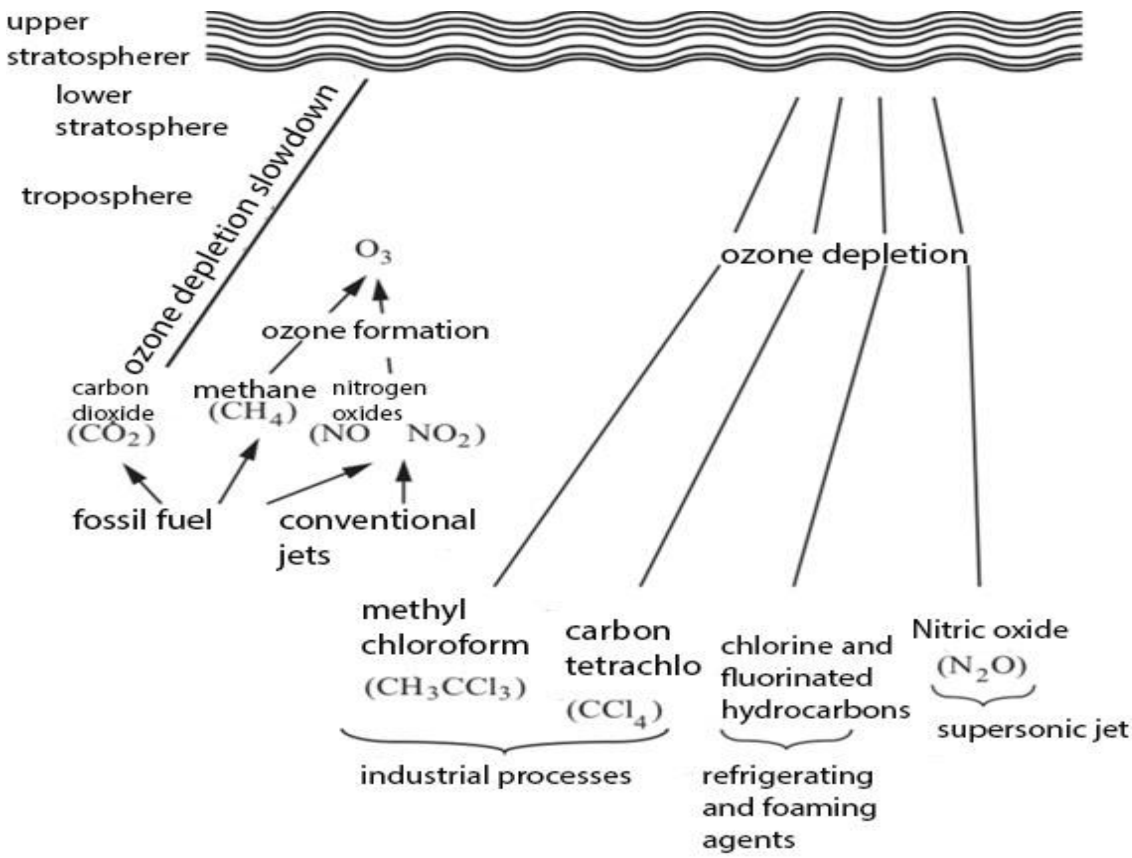


Figure 2.10 - The destruction of the ozone layer

In the mid-1980s, governments in many countries readily responded to the emerging problem of ozone depletion. In 1985, Vienna (Austria) adopted the

Convention for the Protection of the Ozone Layer. In 1987 the Montreal Protocol was adopted, as a result of which a gradual phase-out of the main ozone-depleting gases began.

In 1992, under the auspices of the UN, the UN Framework Convention on Climate Change was adopted at a conference in Rio de Janeiro (Brazil), to which more than 180 states are currently parties, and in 1997 in Kyoto (Japan) the Kyoto Protocol obliging developed countries and countries with economies in transition to reduce or stabilize greenhouse gas emissions. In 2011, the Kyoto Protocol was extended for 5 years [2,4,33].

However, the problem has not yet been completely resolved. First, there are a number of artificial ozone-depleting gases, including some of these chemicals, designed to replace early chlorofluorocarbons. The problem was compounded by the interconnectedness between the warming of the lower atmosphere (the greenhouse effect) and the depletion of the ozone layer of the stratosphere.

The decline in biodiversity in the world, as well as the economic and environmental consequences associated with it, is currently of great concern throughout the world. “Biodiversity is the diversity, variability of living organisms from all sources and ecological complexes that they comprise, from birds in the air, fish in the sea and microorganisms in the soil to the genetic diversity of crops and ecosystem diversity” [33]. The components of biodiversity are all the different forms of life on Earth, including ecosystems, animals, plants, fungi, microorganisms, and genetic diversity.

Biodiversity evolves slowly and naturally from the very beginning of life. Human activity also shapes the biodiversity of our planet. In the past, when the natural abundance on Earth seemed limitless, few people worried about the impact of human activity on the global stock of biodiversity. Only recently has a significant degree of involvement of human activity been recognized in the extinction of species and in environmental changes (Figure 2.11). A United Nations report says that studies of various groups of animals, birds, and insects show that about 20–25 percent of rainforest species can disappear over the next quarter century, which is 10,000 times the historical rate of extinction (UNEP, 1995) [33].

Biodiversity is necessary for humanity for many reasons, the most important:

- biodiversity supports ecosystem functions (such as the carbon cycle, catchment flows of surface and groundwater, soil protection and enrichment, regulation of surface temperature, etc.);
- biodiversity represents aesthetic, scientific, cultural and other values;
- biodiversity is the source of many products in the world, including food, fiber, pharmaceutical products, chemicals and is the main source of information for biotechnology;
- biodiversity forms the basis for crop varieties and livestock, improving existing varieties and developing new ones;
- the uniqueness and beauty of diverse ecological systems is important for a wide range of recreational uses and for ecological tourism.

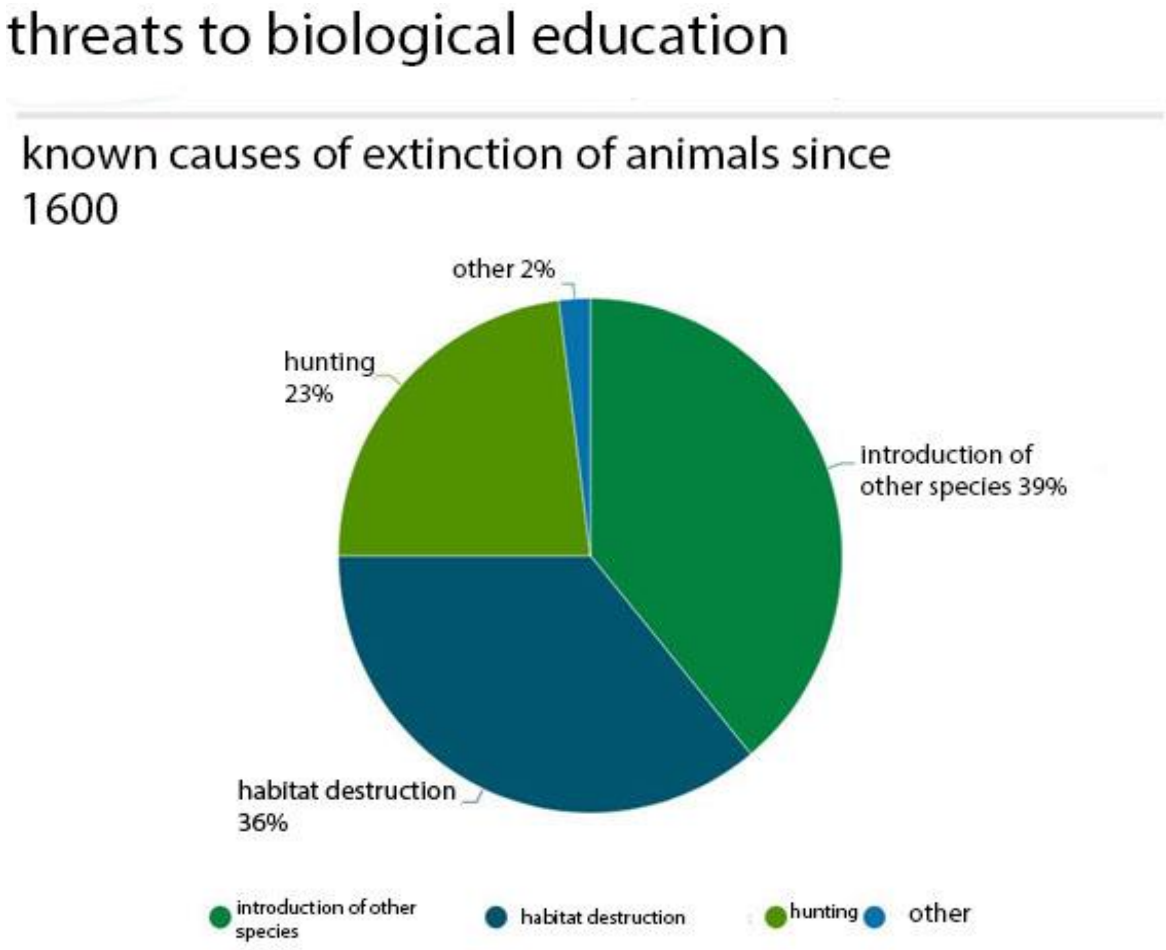


Figure 2.11 - The main causes of biodiversity decline

Ecosystems, species and genetic resources should be used for the benefit of people, but in a way that does not lead to a reduction in biodiversity. The conservation of biological diversity is a common task of mankind. On June 5, 1992, the Convention on Biological Diversity was adopted at the Earth Summit in Rio de Janeiro. The Convention covers biodiversity at all levels: ecosystems, species and genetic resources. It also covers biotechnology, including through the Cartagena Protocol on Biosafety. The ecosystem approach, an integrated resource management strategy is the basis for action under the Convention.

With the adoption of the Convention on Biological Diversity, international attention has been focused on the practical implementation of strategies for its conservation and sustainable use. The Convention on Biodiversity recognizes that the causes of the loss of species and ecosystems are diffuse and cover many different sectors. To address the root causes of this problem, the convention emphasizes the need for multilateral processes aimed at protecting biodiversity at the genetic, species and ecosystem levels. The Convention defines incentive measures as a special mechanism that helps guide actions at the national level and contribute to the achievement of the conservation and sustainability goals set out in the convention. Incentive measures are described in Article 11 of the Convention: “Each Contracting Party shall, as far as possible and appropriate, take reasonable measures that promote the conservation and sustainable use of components of biological diversity”

Significant investment is required to conserve biodiversity, but this will bring significant environmental, economic and social benefits [26,27].

Another major environmental problem is *desertification and land degradation.*

Land degradation in arid, semi-arid and dry sub-humid regions caused by various factors, including climate change and human activities, is called desertification (Anonymous, 1992). This is a slow process of land degradation, which degrades the quality of the land, leads to a decrease in its productivity and, thus, affects the standard of living of people.

According to UNEP (United Nations Environment Program) (1997), some 5172 million hectares of the world's regions (or 39.7% of the world's land area) are drylands and are subject to desertification. Of the total arid land, arid lands (excluding hyperarid regions) occupy 26% of the area, semi-arid 38% and dry sub-humid 21%. It has been estimated that about 1035 million ha (or 20% of the total area) are affected by desertification, while 467 million ha are water erosive and 432 million ha are wind eroded (Thomas, 1995). Deserts are part of the “drylands” and are limited to five main zones:

- The Sonora Desert in northwestern Mexico and its continuation in desert basins in the southwestern United States;
- Atacama Desert, a thin coastal strip extending west of the Andes from Southern Ecuador to Central Chile;
- an extensive belt stretching from the Atlantic Ocean to China, including the Sahara, the Arabian Desert, the desert of Iran and the former USSR, the Thar desert in India, as well as the Takla Makan and Gobi deserts in China and Mangolia;
- Kalahari and the arid lands surrounding it in southern Africa;
- most of the continent of Australia.

Desertification is also a process of land degradation in arid, semi-arid and sub-humid areas due to various factors, including climate change and human activities. In other words, desertification is the process of transition of the state of the earth from one type of biome to a desert biome due to various changes. The huge problem that many countries face is that desertification is taking place on large tracts of land.

According to UNESCO, one third of the world's surface is threatened by desertification, which affects the livelihoods of millions of people. Desertification is another major environmental problem and a major obstacle to meeting basic human needs in drylands. Desertification affects the topsoil, groundwater reserves, surface runoff, population, animals and plants. Water scarcity in arid areas limits the production of wood, crops, feed, and other services that ecosystems provide to our community.

The causes of desertification. Overgrazing is a major cause of desertification worldwide. Other factors causing desertification include urbanization, climate change, excessive groundwater drift, deforestation, natural disasters, and tillage in agriculture, making it more vulnerable to wind.

Let us consider in more detail the main causes of desertification:

1. Overgrazing: a huge problem for many areas that are beginning to turn into desert biomes. If a large number of animals are grazing in certain places, this leads to difficulties in the growth of plants, which harms the biome and deprives it of the previous amount of flora.

2. Deforestation occurs when people develop new territories for living, to meet the needs for wood, construction of houses and other purposes. Deforestation plays a significant role in the dynamics of desertification processes. Without plants (especially trees), the rest of the biome cannot exist.

3. Farm activities. Some farmers do not know how to use land efficiently. Before moving to another piece of land, they essentially strip the land of all fertile properties. As a result, desertification is a consequence of the predatory use of land in agriculture.

4. Urbanization and other types of development. The development of new territories for settlement leads to the extinction of many plant species. It is also associated with the effect of chemicals on the soil that people use. As more and more areas become urbanized, fewer places remain for growing plants, which leads to desertification of the planet as a whole.

5. Changing of the climate. Climate change plays a huge role in the desertification process. Days are getting warmer, respectively, periods of drought are becoming more frequent and desertification is becoming more noticeable. If mankind does not take measures to curb global warming, then soon huge areas of land will become a desert, some of these areas may become uninhabited.

6. Mining. When natural resources, such as natural gas, oil, coal, etc., are found in certain areas of the earth people begin their production to the complete devastation of deposits. This also leads to the deprivation of nutrients in the soil, which in turn leads to the extinction of vegetation and over time, the process of transformation into a desert biome begins.

7. Natural disasters. Desertification processes begin on earth as a result of natural disasters, mainly due to drought. In this case, a person cannot change the course of events of natural phenomena, but at the same time, you can try to rehabilitate the earth after it has already been damaged by nature.

Combating desertification.

1. Farm policy changes. At the legislative level, solve the issue of agriculture in certain territories, about permissible conditions for rational land use.

2. Education. Education is an important tool that needs to help people understand how to better use land for farming. By teaching the population sustainable land practices, more land will be saved from becoming a desert.

3. Scientific advances in engineering and technology. In cases where it is difficult to prevent desertification, research and technological advances are needed that push the boundaries of what we do not currently know.

4. Cooperation on land rehabilitation at local, regional and international levels. There are many ways to rehabilitate the land where desertification processes occur, but this requires material costs and time. Together, people will be able to save land from extinction.

Acid precipitation. Almost 70% of the Earth's surface is covered with water. Part of this water enters the atmosphere as a result of evaporation, and then, making a cycle, ultimately falls out of the atmosphere in liquid or solid form, returning to the planetary reservoir. While in the atmosphere, water can interact with a number of elements or compounds. Acidification of precipitation can occur through the release of acid-forming compounds into the atmosphere due to natural processes: for example, intense volcanic activity. However, over the past few hundred years, human industrial activity has been the main source of acid precipitation. More than 90% of sulfur-containing compounds in the atmosphere are present as a result of human activities, such as the burning of fossil fuels in power plants, factories and as a result of emissions from vehicles. Overly acidic precipitation has become a serious problem in some parts of the world.

Acid pollutants can be deposited on Earth from the atmosphere in both wet and dry form. The general term used to describe this process is acid deposition. The term acid rain is used to describe the wet forms of acid pollution that can be detected in rain, snow, snow, fog, hail and cloudy drops. The acidity of substances dissolved in water is usually measured by pH (defined as the negative logarithm of the concentration of hydrogen ions). According to this measurement scale, solutions with a pH of less than 7.0 are acidic, while solutions with a pH of more than 7.0 are alkaline. [PH scale range from 0 to 14; pH 7.0 is defined as neutral.]

Typically, the PH level of precipitation ranges from 5.0 to 5.6 due to natural atmospheric reactions involving carbon dioxide. Precipitation is considered acidic when its pH is below 5.6, which means acidity is 25 times that of pure water). The most common contaminants that form acid precipitates are sulfur and nitrogen. Sulfur and nitrogen molecules react with oxygen and form acidic compounds sulfur dioxide and nitrogen oxides. As a result of the following reactions, nitrogen or sulfuric acids are formed:

1. Sulfur dioxide and water vapor in the atmosphere combine in sulfuric acid:

$$SO_2 + H_2O \rightarrow H_2SO_3.$$

Sulfuric acid then reacts with ozone in the atmosphere to form sulfuric acid and oxygen.

$$2H_2SO_3 + 2O_3 \longrightarrow 2H_2SO_4 + 2O_2$$

2. In the atmosphere, nitric oxide reacts with oxygen to form nitrogen dioxide.

$$2NO + O_2 \rightarrow 2NO_2$$

Nitrogen dioxide then reacts with water vapor to form a mixture of nitric and nitrous acids:

$$4NO_2 + 2H_20 \rightarrow 2HNO_2 + 2HNO_3$$

Constant acid precipitation leads to acidification of the soil and water bodies. When precipitation becomes excessively acidic, their chemical properties become harmful to living organisms.

The first step in reducing the volume of these atmospheric pollutants is to determine their source (s). To do this, conduct air sampling in several places at a certain time. Using data on wind speed and wind direction, you can calculate the distance traveled by air currents. This path is called the air flow path [35].

Methods of dealing with acid precipitation.

1. Purification of exhaust gases before emissions from exhaust pipes and chimneys. Most of the electricity needed to meet modern energy needs comes from burning fossil fuels (oil, natural gas and coal). Flushing coal, using low sulfur coal, and using purifiers can provide a technical solution to reduce SO_2 emissions. Heat and power plants can also switch to using fuels that emit much less SO_2, such as natural gas and other environmentally friendly fuels

NO_x emissions are mainly generated from the burning of automobile fuels. The use of catalytic converters and other cleaning devices can reduce emissions. Improving the quality of benzine will also reduce NO_x emissions.

2. Recovery of damaged environments. The use of limestone or lime (liming) allows you to restore the damage caused by acid rain to lakes, rivers and streams. The addition of lime to acidic surface water balances the acidity. This process is widely used in Sweden to maintain the optimum pH level of water.

3. Alternative energy sources. In addition to fossil fuels, there is a wide range of alternative energy sources that can generate electricity. These include wind energy, geothermal energy, solar energy, hydropower and nuclear energy. The only solution is to use sustainable energy that can protect the future.

4. Individual, national, state and international activities. Millions of people directly and indirectly contribute to SO2 and NOx emissions. To solve the problem of reducing emissions into the environment, it is necessary in the classroom at schools, colleges, and higher education institutions to talk about the need and importance of energy conservation and about ways to reduce emissions, such as:

- turning off the lights or electrical appliances while they are not being used;
- use of public transport, hybrid vehicles, electric cars;
- the use of energy-efficient electrical appliances.

Solving the problem of depletion of natural resources is a very important task. Resource provision depends not only on the rate of consumption of natural resources by humans, but also on the state of the environment.

Natural resources are called natural fossils, natural bodies and natural phenomena that a person uses for his existence and improve the quality of life. Natural resources are divided into two large groups: inexhaustible and exhaustible (Figure 2.12).

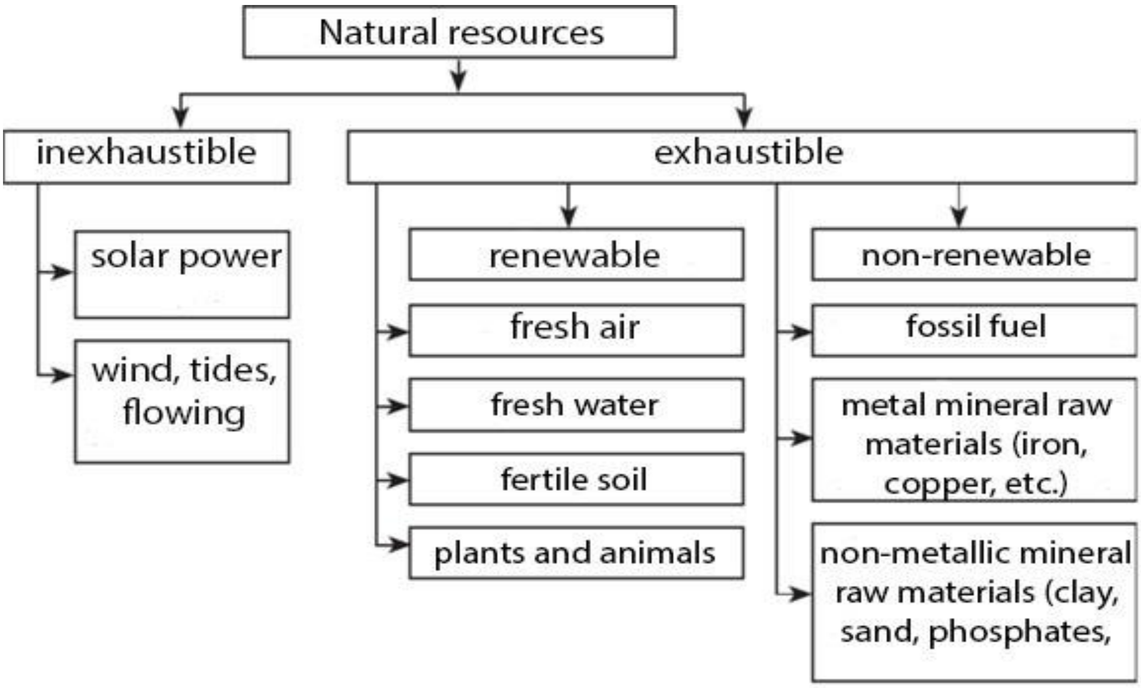


Figure 2.12 - Classification of natural resources

Natural resources are divided into three main types:

- inexhaustible resources (for example, solar energy and wind) the use of which does not lead to their reduction;
- renewable resources (for example, trees and crops), the rate of use of which is less than or equal to the rate of replenishment;
- non-renewable resources such as fossil fuels and minerals. This type of resource is formed as a result of slow geological processes, so their use reduces available reserves.

Resources such as clean water, fertile soils and biodiversity, given the time needed to restore them, can also be considered non-renewable.

The Club of Rome first drew attention to the depletion of resources in the early 1970s. At that time, emphasis was placed on the depletion of fossil and mineral resources. It was assumed that various important natural resources, such as oil and various metal ores, would be exhausted over several decades. The discovery of new deposits, technological advances, and falling energy prices made it possible to recover ores with a lower grade, and the estimated remaining life of some resources was significantly extended.

Sooner or later, at the current level of consumption, the reserves of certain resources will be exhausted.

The challenge facing the world is to reduce the consumption of fossil fuels by 4–10 times and reduce the rate of the greenhouse effect. This requires fundamental changes in environmental management, such as:

- limiting the loss of materials and energy in the production and consumption chains;
- more efficient use of resources in the economy (recycling and cascading);
- the use of alternative raw materials and resources.

The basic principles of environmental management are as follows:

1) increase the efficiency of resource use, organize control and accounting of natural resources, create resource-saving technologies;

2) introduce technologies that reduce waste generation, as well as work on the creation of non-waste production.

The term “resource efficiency” means a reduction in the use of resources at a certain level of economic production. If costs are reduced for a given level of production, productivity will increase accordingly. Thus, resource efficiency combines environmental sustainability and economic goals [29,33].

Questions for self-control:

1. What is the object and subject of environmental research?
2. Describe biotic and abiotic factors.
3. When did the first information about the relationship between living organisms and the environment appear?
4. What is the role of Charles Darwin's work in development and ecology?
5. The main works and discoveries of the 19th century, which influenced the formation of ecology as a science.
6. Describe the role of environmental science in the 20th century.
7. What are the main sections of ecology?
8. What is the problem of peace and disarmament?
9. What are the features of the demographic problem?
10. What is the essence of the food problem?
11. What are the consequences of exacerbating poverty?
12. What is the environmental impact of the greenhouse effect?
13. Describe the effects of ozone depletion on people, living organisms, and the environment.
14. How will biodiversity decline affect ecosystems?
15. What are the causes of desertification?
16. What desertification control activities do you know?
17. What are the reasons for the formation of "acid" precipitation?
18. Give a classification of natural resources.

3 Environmental protection

3.1 Protection of atmospheric air from pollution

Air occupies an important place among the conditions necessary for life. The air masses around the Earth are a mixture of several gases and are called the atmosphere. The atmosphere prevents the penetration of ultraviolet rays that are harmful to life, and thanks to it, a favorable temperature is maintained for living organisms.

The total mass of the atmosphere is 5,15 - 10^{15} tons. At an altitude of 10 to 50 km, with a maximum concentration at an altitude of 20-25 km, a layer of ozone is located that protects the Earth from excessive ultraviolet radiation, fatal to organisms [35].

The atmosphere is a mixture of various gases, including water vapor and dust particles. Nitrogen and oxygen are the two main atmospheric gases. The composition of the atmosphere and the percentage are given in table 3.1 [35].

The amount of ozone gas in the atmosphere is very small. It forms the ozone layer in the atmosphere and protects living things by absorbing the ultraviolet rays of the sun.

Table 3.1 - The composition of the atmosphere

Percentage of gases in the atmosphere	
Nitrogen	78,1%
Oxygen	20,9%
Carbon dioxide	0,9%
Hydrogen	0,03%
Neon	0,01%
Helium	0,0018%
Ozone	0,0005%
Other	0,00006%

The gaseous form of water present in the atmosphere is called water vapor. Water vapor is the source of all types of precipitation. Its maximum amount in the atmosphere can be up to 4 percent. The maximum amount of water vapor is in areas with high humidity, and the smallest amount is in dry regions.

Suspended particles (dust) are usually found in the lower atmosphere. These particles are sand, soot and ocean salts. Suspended particles are involved in the process of condensation of water vapor. During condensation, water vapor condenses in the form of droplets around dust particles in the atmosphere. Through this process, clouds form and precipitation becomes possible.

The atmosphere performs important functions to maintain life on Earth:

- contains oxygen necessary for the life of living organisms;
- contains carbon dioxide necessary for photosynthesis of plants.
- dust particles present in the atmosphere create conditions for precipitation;

- the amount of water vapor in the atmosphere is constantly changing and directly affects plants and living things.

- ozone protects all types of life on earth from the harmful ultraviolet rays of the sun.

Atmospheric air also carries out the most complex protective ecological function, protecting the Earth from absolutely cold Cosmos and the flow of solar radiation, a mass of meteorites is delayed.

The atmosphere has the ability to cleanse itself. It occurs when aerosols are washed out from the atmosphere by precipitation, turbulent mixing of the surface air layer, deposition of contaminated substances on the surface of the earth, etc. However, in modern conditions, the capabilities of natural systems of self-purification of the atmosphere are seriously undermined. Under the massive onslaught of anthropogenic pollution, very undesirable environmental consequences began to appear in the atmosphere, including global ones [35].

3.1.1 Aerosol emission characteristics

Air pollution is any atmospheric condition in which certain substances are present in such concentrations that they can have an adverse effect on humans and the environment. These substances include gases (SO_x, NO_x, CO, HC_s, etc.), solid particles (smoke, dust, vapors, aerosols), radioactive substances, and many others.

Pollutants enter the atmosphere as a result of natural and man-made processes. Substances that naturally enter the atmosphere (with the exception of intense extreme natural events) usually have low (background) concentrations. Thus, a specific substance can be considered as an air pollutant only if its concentration is relatively high compared to the background value.

Air pollution is a serious problem in most countries of the world, as it directly affects the health of people, animals and plant health. Polluted atmospheric air causes deterioration in the properties of building materials, poor visibility and a drop in the quality of life in general. Industrial development is associated with the emission of large quantities of gaseous and solid particles into the atmosphere, which are generated both in industrial production and as a result of burning fossil fuels for energy and transport.

Air pollutants can be primary (with direct release of harmful substances into the atmosphere) or secondary. Secondary air pollutants arise from chemical reactions of primary pollutants in the atmosphere, often involving natural environmental components such as oxygen and water.

According to the state of aggregation, harmful substances in the air basin can be:

- in a gaseous state (sulfur dioxide, nitrogen oxides, carbon monoxide, hydrocarbons, volatile organic compounds and carbon and non-carbon primary particles, etc.);

- in a liquid state (acids, alkalis, solutions of salts, etc.);

- solid particles (carcinogens, lead and its compounds, organic and inorganic dust, soot, tarry substances and others).

In addition to the physical state of the pollutants, it is important to consider the geographical location of the emission sources. The extent of air pollution depending on the atmospheric lifetime of specific air components is local, urban, regional and global. Emission sources can also be classified on a geographical scale (point, linear or territorial sources) [3,23,25].

Aerosol is a dispersed complex, where the medium is air (gas), and the phase is solid particles. In the air basin, aerosol is in the form of fog and smoke. Most aerosols in the atmosphere appear when solid particles interact with water vapor or liquid particles. The average particle size of aerosols is 1-5 microns [36].

Dust is a dispersed aerosol in which solid particles are present, regardless of their dispersed composition.

Fog is a gaseous medium composed of tiny droplets of water or ice crystals suspended in the air on or near the surface of the Earth.

To improve dust collection processes, it is very important to know the physicochemical properties of mists and dust: fractional composition, particle charge, wettability, etc.

According to [36], “the entire range of particle sizes is divided into fractions. Under the fraction understand the mass (counting) fraction of particles contained in a certain range of particle sizes. For example, the following dust particle size scale is used: 1- 1.3 - 1.6 - 2.0 - 2.5 - 3.2 - 4.0 - 5.0 - 6.3 - 8.0 - 13 -16 - 20 - 25 - 32 - 40 - 50 - 63 microns.

According to the dispersion of dust, they are classified into 5 groups:

- I - very the coarse dust, d_{50} >140 microns;
- II - coarse dust, d_{50} = 40…140 microns;
- III – medium dust, d_{50} = 10…40 microns;
- IV - fine dust, d_{50} = l…10 microns;
- V - very fine dust, d_{50}=l microns».

When choosing a purification apparatus, it is also important to know the density of the particles, since the deposition efficiency in cyclones, sedimentation tanks, etc.

The greater the value of the particle sticking index, the greater the likelihood that the structural parts of the dust collecting apparatus may become clogged, and also these particles will settle on the gas ducts. It is important to know that particle cohesion increases with decreasing particle size and with increasing humidity.

3.1.2 Classification of methods and apparatus for aerosol cleaning

The dust removal process in general includes the following main steps:

- preventing the spread of the “original” aerodisperse system in the air of the working area and increasing the stability of this system in the direction of a strictly limited pre-allocated area (dust collection process);
- the destruction of dust aerosol, consisting in the release of dust from the air (dust cleaning process);

- a further decrease in the stability of the dust aerosol preserved after the implementation of the previous stages, which consists in intensifying the distribution of dust particles remaining in the air and aeration of the dispersed medium in the surface layer of the atmosphere (dust dispersion process) [3,25,36].

Dust removal process includes three elements:

- dust collection (DC);
- dust cleaning (DC);
- dust dispersion (DD).

Each element of the system can be implemented by different methods (aerodynamic, hydrodynamic, electromagnetic, thermophysical, mechanical, etc.), which are determined by the nature of the directed external influences on the dust aerosol. Any method can be implemented in various ways (irrigation, foam, steam, fog, etc.), and the method - by technical means.

The most complete classification of devices is based on the use of the following dust removal methods:

- physical methods include: mechanical (aerodynamic, hydrodynamic, filtration), electrical, magnetic, acoustic, optical, ionizing, thermal;
- chemical;
- physicochemical;
- biochemical;
- physical-biochemical [36].

Basically, they are based on one (or several) of the following dedusting processes: sedimentation, coagulation, disposal, disinfection, incineration and capture.

Dry, wet and electrical methods are used to neutralize aerosols (dusts and mists).

Wet methods for cleaning solid and liquid aerosols have a significant drawback - the need to separate the trapped contaminant from the trapping liquid. For this reason, wet methods should be used only in the absence of other cleaning methods, giving preference to methods with a minimum flow rate [3,25,36].

The gravitational sedimentation. Aerosol particles are precipitated from a stream of contaminated air by gravity. For this, it is necessary to create an appropriate mode of movement of contaminated air in the apparatus, taking into account the particle size and density.

Инерционное осаждение. Inertial deposition is based on the fact that aerosol particles and a weighing medium, due to a significant difference in densities, have different inertia. Aerosol particles, moving by inertia, are separated from the gas medium.

Precipitation by centrifugal force. Occurs during the curvilinear movement of a contaminated air-gas stream. Under the action of the emerging centrifugal forces, aerosol particles are discarded to the periphery of the apparatus and deposited [36].

Gearing effect. Aerosol particles suspended in an air (gas) environment are trapped in narrow winding channels and pores when an air-gas stream passes through filter materials.

Wet cleaning. Wetting the surface of the elements of the apparatus with water or other liquid helps to retain aerosol particles on this surface.

Precipitation in an electric field. Passing an electric field, aerosol particles receive a charge. Moving to the electrodes of the opposite sign, they are deposited on them.

In the practice of trapping aerosol particles, other methods find application: enlargement of particles in an acoustic field, thermophoresis, photophoresis, exposure to a magnetic field, biological treatment [36].

3.1.3 The main characteristics of the devices for aerosol cleaning

The main characteristics of the equipment for cleaning aerosols from suspended particles include the efficiency (degree) of air purification from dust, which is also sometimes called the efficiency of the apparatus, although this does not reflect its physical meaning; hydraulic resistance; cleaning cost. The general parameters of dust collectors include their clean gas performance and energy intensity, determined by the amount of energy spent on cleaning 1000 m^3 of gas [36].

In assessing the effectiveness of the dust collectors take into account:

- the total dust removal efficiency, or the amount of dust trapped in the dust collector, relative to the amount of dust contained in the purified gas;
- fractional efficiency, which determines the completeness of capture of particles of certain sizes; it is expressed as the percentage of dust particles of certain sizes separated in the dust collector;
- residual dust content in the gas when it leaves the dust collector;
- energy consumption, and when selecting one or another type of dust collector - the frequency distribution of the dispersion of fractions [36].

The main indicator characterizing the operation of dust cleaning devices in specific cases of their use is the coefficient (degree) of cleaning (dust removal efficiency),% [36]:

$$\xi = \frac{\mathrm{M}_{entry} - \mathrm{M}_{exit}}{\mathrm{M}_{entry}} \cdot 100\% \qquad (3.1)$$

where M_{entry}, M_{exit} — the mass of dust particles contained in the gases, respectively, at the inlet to the apparatus (i.e., before cleaning), trapped in the apparatus and at the outlet of the apparatus after cleaning.

When installing several devices in series (cascade, or multi-stage cleaning), used to more fully dedust air, the total cleaning efficiency is determined by the formula

$$\varepsilon = [1 - (1 - \varepsilon_1) \cdot (1 - \varepsilon_2) ... (1 - \varepsilon_n)] \cdot 100\ \% \qquad (3.2)$$

where ε_1, ε_2... ε_n — is the cleaning efficiency of each of the devices included in the cascade (in fractions of a unit) [36].

Fractional efficiency shows the fraction of captured dust for each fraction. This allows you to choose dust removal equipment in accordance with the fractional composition of dust. Fractional purification efficiency is expressed by the ratio

$$\text{e}_{\Phi} = \frac{m_{t.f.}}{\text{M}_{i,f.}}. \quad (3.3)$$

where $m_{t.f.}$- trapped dust fraction; $\text{M}_{i,f.}$— the amount of fraction entering in the dust apparatus [36].

As an indicator of the energy balance, by analogy with the coefficient of performance use energy coefficient of performance (ECP).

$$\text{ECP}= \frac{\text{E}_u}{E} \quad (3.4)$$

where E_{u} — useful energy; E — all energy spent in the dust removal process [36].

3.1.4 Mechanical cleaning devices

The term "mechanical precipitators" is usually used to refer to devices in which particles are deposited by either gravity or inertia, or both. In gravitational precipitators, particles are precipitated from a gas stream by their own weight. In inertial precipitators, the flow of particles suspended in a gas suddenly undergoes a change in direction of motion. The resulting inertial forces tend to throw particles out of the stream. Cyclone precipitators using centrifugal inertia are an important particular case of inertial precipitators [25,36].

For sedimentation by gravity, the gas is usually slowly passed through a large chamber, with the particles being able to settle in the hopper at the bottom. The distance required for particle deposition can be reduced by dividing the chamber space with several horizontal parallel pallets.

Gravity chambers can be equipped with reflective baffles to change the direction of gas movement and to attract inertia forces to increase the precipitation.

In cyclone precipitators, the gas rotates or swirls to expose the particles to centrifugal force. This is achieved either by the tangential introduction of the flow into the circular chamber, or by passing gas past the blades radially oriented with respect to the flow axis [3,36].

Devices of all these types are characterized by the simplicity of the design of work. They are relatively cheap compared to other types of precipitants. Energy costs for work are also relatively small, due to the small pressure drop during gas flow through the device.

The simplest separator of solid suspended particles is a dust precipitation chamber (Fig. 3.1), in which a dusty gas stream moves at a low speed, making gravity precipitation (sedimentation) of the transported suspension possible. To achieve acceptable efficiency of gas cleaning with these devices, it is necessary that the particles were in the dust precipitation apparatus for as long as possible, and the speed of the dust flow was insignificant. Therefore, this equipment belongs to the category of extensive equipment, the working volumes of such devices are very significant, which requires large production areas. Industrial dust collectors are used as gas pre-treatment devices, for example, for separating large particles and unloading apparatuses of subsequent stages. In this regard, this equipment is used only in the first stages of gas purification systems for the deposition of large particles (more than 100 microns). Typically, the average flow rate of gases in dust collecting chambers is 0.2 ... 1 m/s, and in dust bags - 1 ... 1.5 m/s [36].

The greatest distribution in dust cleaning systems has received cyclones (Fig. 3.2). Cyclones are widely used for dust removal of ventilation and technological emissions in all sectors of the economy. In practice, a particle capture system is created by imparting a dusty flow to a swirling or rotational motion limited by cylindrical walls. Particles are deposited when dropped onto walls. Such a device is called a cyclone [36].

Cyclones are divided into high-performance cyclones and high-efficiency cyclones. The former are usually large in diameter and provide for the cleaning of significant quantities of air. The second - a relatively small diameter (up to 500 ... 600 mm). Very often a group installation of these cyclones is used, connected in parallel through the air.

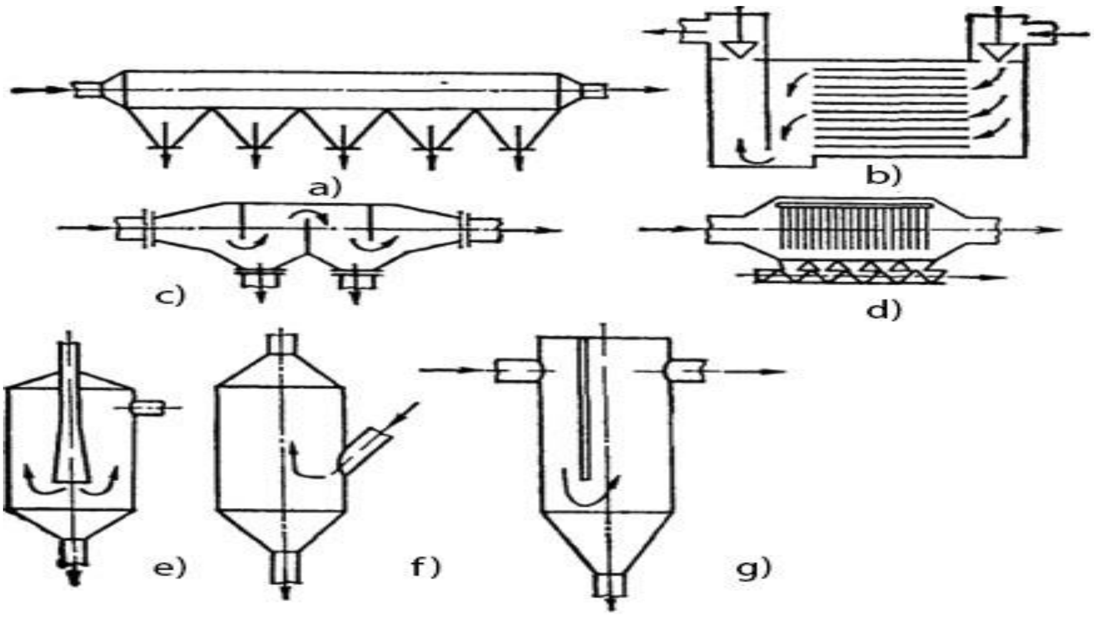


Figure 3.1 - Dust precipitation chambers and the simplest dust precipitators of inertial action:
a – simple dust collecting chamber; b – multi-shelf chamber;
c – chamber with partitions; d – chamber with chain or wire curtains; e – dust "bag" with a central gas supply; f - dust "bag" with lateral gas supply; g – precipitant with baffle plate

The efficiency of gas purification in cyclones is mainly determined by the dispersed composition and density of particles of captured dust, as well as the viscosity of the gas, depending on its temperature. By reducing the diameter of the cyclone and increasing to a certain limit the gas velocity in the cyclone, the cleaning efficiency increases. Therefore, the diameters of commercially available cyclones do not exceed 5 m [36].

Cyclones, as a rule, are used for rough and medium purification of air from dry non-sticking dust. It is generally accepted that they have a relatively small fractional efficiency in the field of dust fractions up to 5 ... 10 microns in size, which is their main disadvantage. However, cyclones, especially high-efficiency cyclones, capture not so small a portion of dust up to 10 microns in size - up to 80 percent or more.

Dusty air enters the cyclone through the pipe, cleaned - is removed through the exhaust pipe. Depending on the method of supplying air to the cyclone, cyclones with tangential and spiral air supply are distinguished.

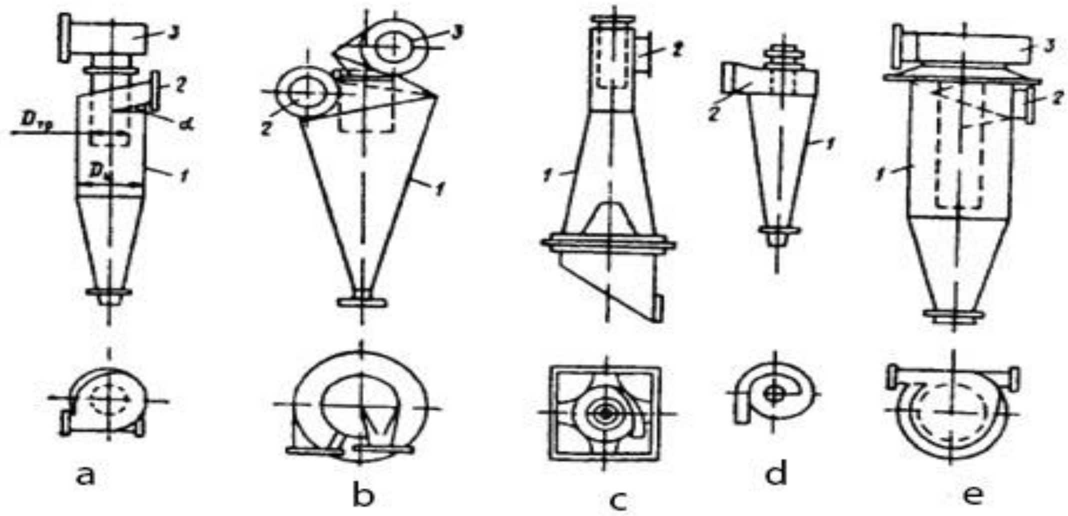


Figure 3.2 - The main types of structures of cyclones:
a – NIIOGaz cyclone; b – SIOT; c – VCNIIOT; d – SK-CN-34;
e – LIOT; 1 – body; 2 – input branch pipe; 3 – exit snail

Spiral feed cyclones have higher cleaning efficiency, all other things being equal. A stream of dusty air enters the cyclone body usually at a speed of 14 ... 20 m / s. Particles suspended in the flow inside the cyclone are affected by the inertia force, which tends to displace them from curved streamlines along tangent lines directed at a certain angle downward and toward the body wall. Particles in contact with the inner surface of the wall, under the influence of gravity, inertia and a falling gas stream, slide down and fall into the dust collector (bunker). Particles that do not reach the wall continue to move along curved streamlines and can be carried out of the cyclone by a gas stream, which can capture a certain amount of particles deposited in the bunker [36].

3.1.5 Filtration separators for air purification

In filtration separators, air (gas) is cleaned of aerosol contaminants (dust, soot, drip moisture) when a contaminated stream passes through a layer of porous material. As a filter layer, fabrics, coke, gravel, etc. are used. Filtration of dispersion and condensation aerosols in a porous medium provides a high degree of deposition of suspended particles with any size, up to close to molecular ones. The dispersed admixture is captured when the aerosol stream bends around obstacles formed on its way by the structural elements of the porous layer [3,36].

The filtration process is based on many physical phenomena (the engagement effect, including the sieve effect, - aerosol particles are delayed in pores and channels having a cross section smaller than the particle size; the action of inertia forces - when the dusty stream moves in a different direction, the particles deviate from this direction and precipitate; Brownian motion - to a large extent determines the movement of finely dispersed submicron particles; the action of gravitational forces, electrostatic forces - aerosol particles and filter material can have electric charges or be neutral).

The following mechanisms of particle deposition on obstacles are considered essential for filtering: contact (engagement), screening (screening, sieve effect), inertial trapping, gravitational and diffusion deposition, and electrostatic interaction.

Most filters have high cleaning efficiency. Filters are used both at high and at low temperatures of the medium being cleaned, at various concentrations of suspended particles in the air.

Filtering devices have the following disadvantages: the cost of cleaning filters is higher than in most other dust collectors, in particular in cyclones. This is due to the greater structural complexity of the filters compared to other devices, high energy consumption.

According to the type of structural elements of the porous layer are distinguished:

- fibrous;
- fabric;
- grainy [36].

Fibrous filters are designed to capture particles of finely dispersed and especially finely dispersed dust at its concentration in the cleaned air (gas) in the range of 0.5 ... 5 mg/m^3.

Fiber filters can be divided into fine fiber, deep and coarse fiber filters.

Fine fiber filters (Fig. 3.3) have fiber diameters of less than 5 microns and are used to trap fine dust and other aerosol particles with a size of 0.05 ... 0.1 microns with a submicron particle efficiency of at least 99%. PF (Petryanov filter) is used as a filter material [36].

Coarse fiber filters (Fig. 3.4) are usually installed in front of fine fiber filters for pre-treatment of air (gases). Due to this, the cleaning cost is reduced, since the cost of coarse fiber filters is almost 10 times lower than fine fiber filters, it is easier to replace or regenerate them. The prefilter filter material consists of a mixture of fibers with a diameter of 1 to 20 microns [36].

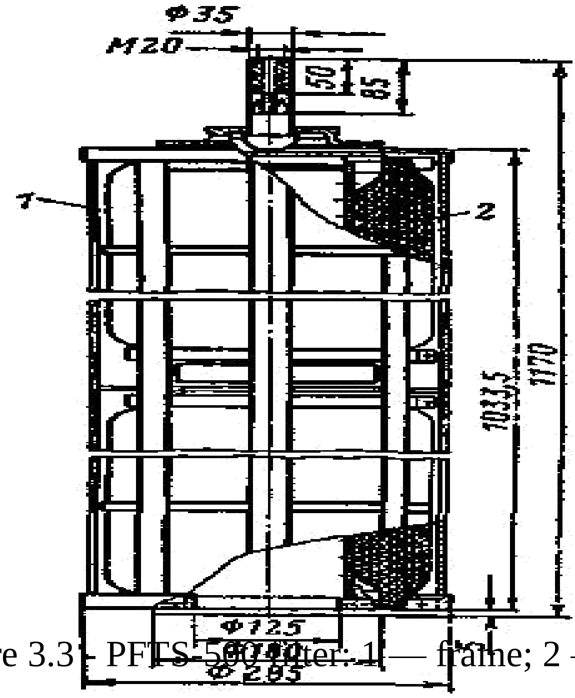


Figure 3.3 – PFTS-500 filter: 1 — frame; 2 — filter bag.

Widespread fabric filters. Bag fabric filters are used to clean large volumes of air (gases) with a significant concentration of dust. The filtering elements in these devices are sleeves made of special filter cloth.

Bag filters (Fig. 3.5) provide a fine air purification from dust particles having a size of less than 1 micron. Along with cyclones, bag filters are one of the main types of dust-collecting equipment and are widely used at the enterprises of ferrous and non-ferrous metallurgy, chemical industry, building materials industry, food industry, power plants, etc.

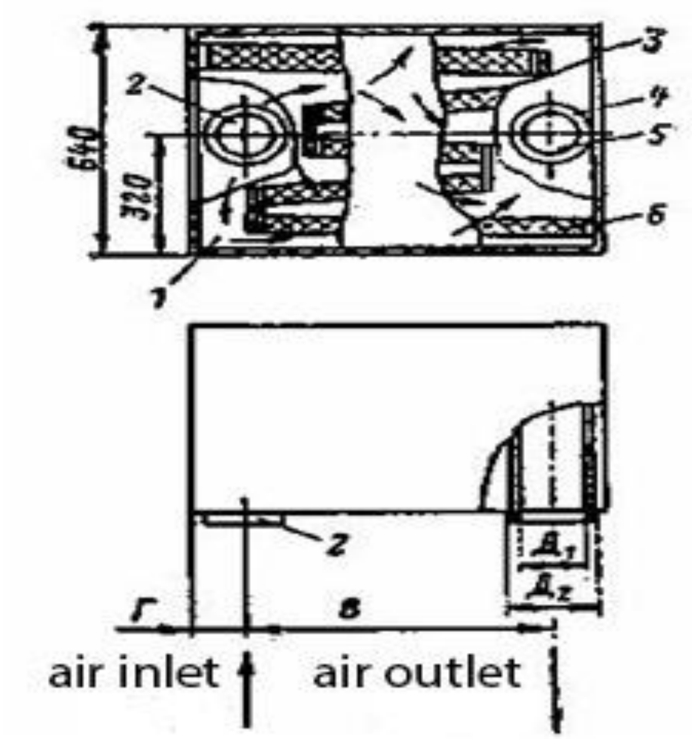


Figure 3.4 - Coarse filter FG:
1 - camera; 2 – input hole; 3 - body; 4 – output hole;
5 - sealing ring; 6 - filter element.

The regeneration of the filter cloth of the sleeves is carried out by mechanical or aerodynamic action on the filter cloth in order to destroy and remove the layer of settled dust [36].

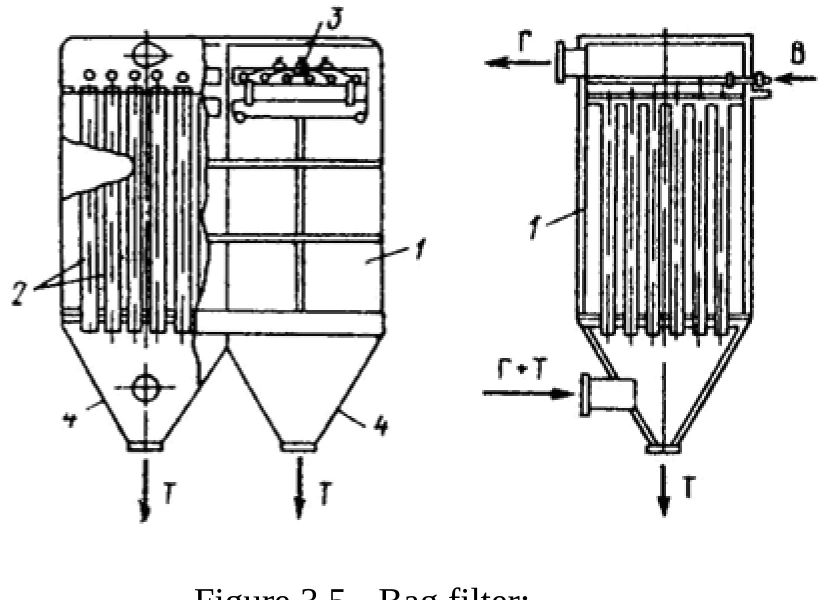


Figure 3.5 - Bag filter:
1 – body; 2 – filter bags; 3 – collector of compressed air;
4 – dust collector.

3.1.6 Apparatus wet cleaning

The wet dust collection process is based on the contact of a dusty gas stream with a liquid that traps suspended particles and carries them out of the apparatus in the form of sludge. The method of wet cleaning of gases from dust is considered quite simple and at the same time a very effective way of dedusting.

Scrubbers Scrubbers - wet dust collectors with a body in the form of a vertical column, hollow or with a nozzle. A dusty stream passes through the scrubber and liquid is introduced into the apparatus [4,36].

In wet scrubbers, a close, violent contact of gas and liquid is realized, accompanied by the generation of liquid droplets. Capture of droplets with gas can cause fluid to escape from the scrubber to the superheater, duct, fan, chimney, and then to the atmosphere. If measures are not taken to separate the fluid entrained by the flow, this can cause corrosion, erosion, clogging, damage to fans, and emissions of contaminants.

In wet scrubbers designed for dust collection, water is most often used as an irrigation liquid. Its flow rate for different types of apparatus can vary from 0.1 to 10 m3 per 1000 m3 of gas processed. Wet dust collectors have several advantages over other types of apparatus:

- characterized by a relatively low cost and higher efficiency of trapping suspended particles in comparison with dry mechanical dust collectors;
- can be used to clean gases from particles up to 0.1 microns in size (for example, Venturi scrubbers);
- have high cleaning efficiency as bag filters and electrostatic precipitators, can be used at high temperatures and high humidity of gases, in case of danger of fire and explosions of purified gases, as mixing heat exchangers [36].

The listed advantages of wet dust collecting apparatuses make it possible to widely use them in dust cleaning systems of drying plants, especially second-stage cleaning.

However, the wet dedusting method has several disadvantages:

- he captured product is emitted in the form of sludge, which is associated with the need for wastewater treatment and, therefore, the cleaning process becomes more expensive;
- when the purified gases are cooled to a temperature close to the dew point, as well as during mechanical removal of droplets of liquid from the gas cleaning apparatus, dust can be deposited in gas pipelines, ventilation systems, and smoke exhausters. In addition, mud spray leads to irretrievable losses of irrigation fluid;
- In case of cleaning aggressive gases, equipment and communications must be protected with anti-corrosion materials.

The following hardware mechanisms for wet aerosol capture processes are available:

- trapping droplets of fluid moving through a gas;
- trapping by cylinders (usually solid, such as wires);
- capture by liquid films (usually flowing over hard surfaces);

- trapping in gas bubbles (usually rising in liquids);
- capture on impact of gas jets on liquid or solid surfaces [36].

Depending on the method of organization of the contact surface of the phases and the principle of action, wet dust collectors can be divided into the following groups:

- hollow gas washers (hollow scrubbers etc.);
- nozzle scrubbers;
- bubbling and foam apparatus;
- inertial shock devices rotoclones);
- apparatuses centrifugal action;
- high-speed аппараты (Venturi scrubber) [3,36].

Before deciding on the use of a wet cleaning method, it is necessary to carefully analyze the properties of the processed emissions. It is necessary to take into account the solubility, reactivity (the possibility of the formation of explosive, corrosive substances and secondary pollutants), the corrosion activity of the components of the pollutant and the carrier gas. For solid pollutants, it is important to know such parameters as: wettability, curability, adhesion, for liquid - wettability, density, phase transition parameters.

Hollow gas washers (Fig. 3.6) implement the simplest wet cleaning scheme with the organization of washing dusty gas streams in gas ducts (ducts) or individual chambers (containers) of various shapes. Irrigating liquid in them is supplied in the opposite direction or across the gas stream. The size of the droplets should be at least 500 μm, and the gas flow velocity should not exceed (0.8 ... 1.2) m / s so that the entrainment of liquid from the contact zone was insignificant [36].

Foam dust collectors are apparatuses, the body of which is divided by a grid with evenly spaced small holes (Fig. 3.7). The dusty stream enters under the grate; the cleaned stream is removed from the upper part of the housing. Water flows to the grill from above. Depending on the design of the dust collector, water from the surface of the grate is discharged through openings in the grate and partially through a drain, or only through openings. The diameter of the holes in the grill 3 ... 8 mm.

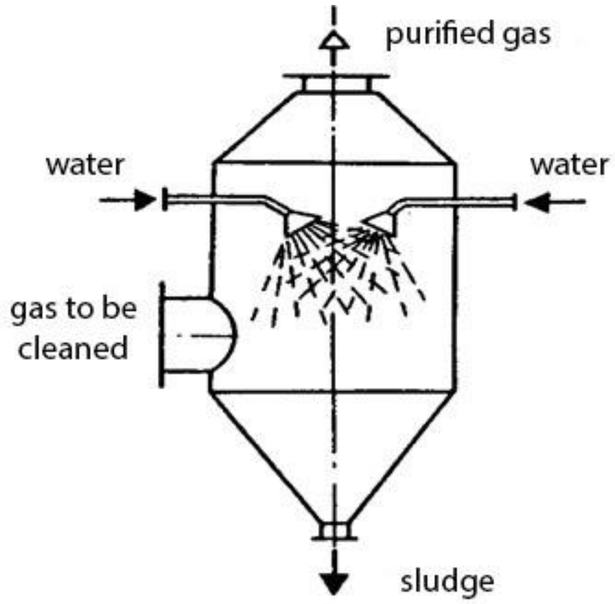


Figure 3.6 - Diagram of a hollow scrubber

Among wet dust collectors, installations with a Venturi pipe have the greatest efficiency in cleaning gases (air) from fine dust.

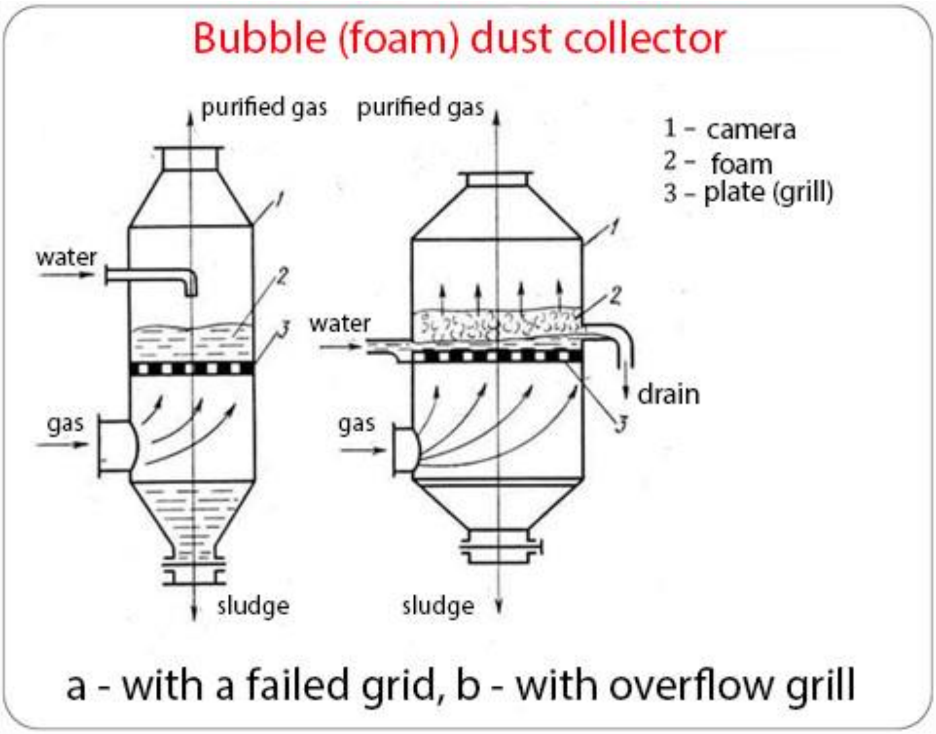
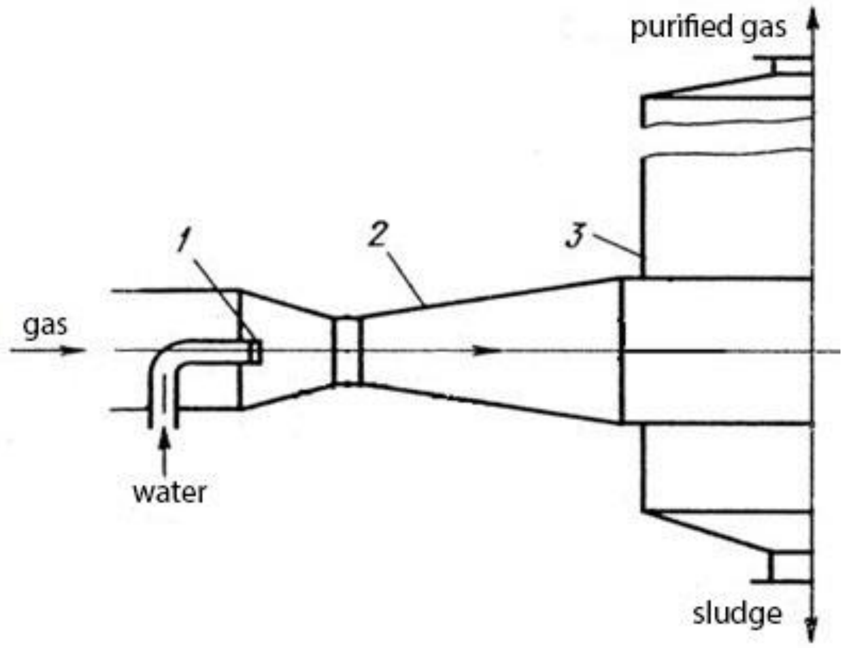


Figure 3.7 - Diagram of a foam dust collector

Higher dust collection efficiency compared to hollow scrubbers is achieved in Venturi scrubbers by creating a developed phase contact surface, which also requires significantly higher energy costs. A Venturi scrubber is an apparatus consisting of a spray tube for grinding liquid under the action of an air (gas) stream moving at high speed and a droplet eliminator (Fig. 3.8). The main part of the scrubber is a Venturi nozzle 2, into the confuser part of which a dusty gas stream is supplied and irrigation fluid is sent through centrifugal nozzles 1. In the confuser part of the nozzle, gas accelerates from the inlet speed (w = 15 ... 20 m/s) to a speed in the narrow section of the nozzle of 40 ... 200 m/s and more. The process of deposition of dust particles on liquid droplets is due to the mass of the liquid developed by the surface of the droplets with a high relative velocity of the liquid particles and dust in the confuser part of the nozzle. The cleaning efficiency largely depends on the uniform distribution of the liquid over the cross section of the confuser part of the nozzle. In the pipe diffuser, pressure increases and the flow velocity decreases to 15 ... 20 m / s, which contributes to the coagulation of small particles. From the diffuser, the gas stream carries droplets of liquid with dust particles settled on them into the droplet eliminator 3, where the separation of suspended particles [36].



1- Figure 3.8 - Venturi Scrubber
2- injector, 2 – Venturi nozzle, 3 – drop catcher

3.2 Protecting water from pollution

3.2.1 Sources of hydrosphere pollution

All bodies of water or water sources are affected by:
- conditions for the formation of surface or underground water flow;
- various natural phenomena;
- industry;
- industrial and municipal construction;
- transport;
- household and human activities.

The consequence of these influences is the introduction into the aquatic environment of new substances unusual for it - pollutants that impair water quality [3,25,26].

Pollution that enters the aquatic environment is classified according to approaches, criteria and objectives. So, chemical, biological and physical pollution is usually distinguished (Fig. 3.9).

Chemical pollution is a change in the natural chemical properties of water by increasing the content of harmful impurities in it, both inorganic and organic.

The first is inorganic chemicals. The main inorganic (mineral) pollutants of fresh and marine waters are a variety of chemical compounds that are toxic to the inhabitants of the aquatic environment. These are compounds of arsenic, lead, cadmium, mercury, chromium, copper, fluorine. Most of them fall into the water as a result of human activity. Heavy metals are absorbed by phytoplankton and then passed along the food chain to more highly organized organisms. [3,25].

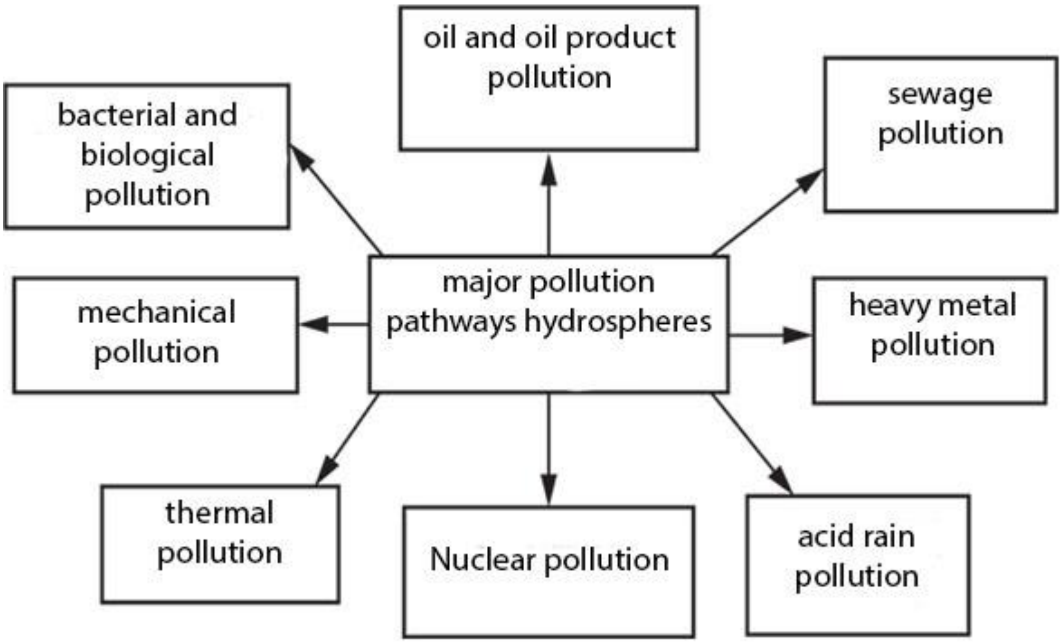


Figure 3.9 - The main paths of pollution of the hydrosphere

Secondly, these are organic chemical compounds in a soluble state. Among the soluble substances introduced into the ocean from land, organic residues are of great importance for the inhabitants of the aquatic environment.

Biological pollution is associated with the presence of biological impurities in drinking water, that is, microorganisms that cause disease.

Household liquid waste is dangerous not only because it is the source of certain human diseases (typhoid fever, dysentery, cholera), but also because it requires a lot of oxygen for its decomposition. If domestic wastewater enters the reservoir in very large quantities, then the content of soluble oxygen may fall below the level necessary for the life of marine and freshwater organisms.

At the beginning of our century, a significant step forward was made in improving the quality of water purification by chlorination. Due to the chlorination of water and pasteurization of milk, a sharp decrease in mortality due to typhoid fever has become possible [3,25].

Physical pollution is insoluble particles of various origin present in water.

The pollution of the hydrosphere with oil products is important. Due to its physicochemical properties, oil products quickly spread over the surface of the water, forming the thinnest films with a thickness of up to a fraction of a millimeter, which retain, especially on a calm surface, high stability.

Oil and petroleum products are the most common pollutants in the oceans. Oil is a viscous oily liquid that has a dark brown color and has a weak fluorescence. Oil consists primarily of saturated aliphatic and aromatic hydrocarbons. The main components of oil - hydrocarbons (up to 98%) - are divided into 4 classes:

a) paraffins (alkenes) - (up to 90% of the total composition) - stable substances whose molecules are expressed by a straight and branched chain of carbon atoms. Light paraffins have maximum volatility and solubility in water.

b) cycloparaffins (30 ... 60% of the total composition) are saturated cyclic compounds with 5-6 carbon atoms in the ring. In addition to cyclopentane and cyclohexane, bicyclic and polycyclic compounds of this group are found in oil. These compounds are very stable and poorly biodegradable.

c) aromatic hydrocarbons - (20 ... 40% of the total composition) - unsaturated cyclic compounds of the benzene series containing 6 less carbon atoms in the ring than cycloparaffins. The oil contains volatile compounds with a single ring molecule (benzene, toluene, xylene), then bicyclic (naphthalene), polycyclic (pyrene).

d) olefins (alkenes) - (up to 10% of the total composition) are unsaturated non-cyclic compounds with one or two hydrogen atoms at each carbon atom in a molecule having a straight or branched chain [37].

Detergents (synthetic surfactants) belong to the group of substances that lower the surface tension of water. They are part of synthetic detergents, widely used in everyday life and industry.

Surfactants enter mainland waters and the marine environment along with wastewater. Synthetic detergents contain:

- sodium polyphosphates in which detergents are dissolved;
- a number of additional ingredients that are toxic to aquatic organisms: flavors, bleaching agents (persulfates, perborates), soda ash, carboxymethyl cellulose, sodium silicates.

Carcinogenic substances are chemically homogeneous compounds that exhibit transforming activity and the ability to cause carcinogenic, teratogenic (impaired embryonic development processes) or mutagenic changes in the body [3,37].

Carcinogenic substances include:

- chlorinated aliphatic hydrocarbons;
- vinylchloride;

- polycyclic aromatic hydrocarbons (PAH).

The maximum amount of PAHs in modern bottom sediments of the World Ocean (more than 100 μg / kg dry matter mass) was found in tectonically active zones subject to deep thermal exposure [37].

The main anthropogenic sources of PAHs in the environment are the pyrolysis of organic substances during the combustion of various materials, wood and fuel.

Heavy metals (mercury, lead, cadmium, zinc, copper, arsenic) are common and highly toxic substances. They are widely used in various industrial plants, therefore, despite the treatment measures, the content of heavy metal compounds in industrial wastewater is quite high. Large masses of these compounds enter the ocean through the atmosphere [37].

Thermal pollution of the surface of water bodies and coastal marine areas occurs as a result of the discharge of heated wastewater by power plants and other industrial enterprises. The discharge of heated water in many cases causes an increase in the temperature of water in water bodies by 6 ... 8 ° C. The solubility of oxygen decreases, and its consumption increases, since with increasing temperature the activity of aerobic bacteria that decompose organic matter increases. Species diversity of phytoplankton and the entire algae flora is increasing.

One of the main sources of water pollution is industrial wastewater. The most dangerous water pollutants are salts of heavy metals, phenols, organic poisons, petroleum products, bacteria-rich biogenic organics, synthetic detergents [37].

3.2.2 Methods and means for wastewater treatment from impurities

Wastewater of industrial enterprises is purified by mechanical, physico-chemical and biological methods. The choice of the purification scheme is determined by a number of factors, including indicators of the treated effluent, the possibility of utilizing impurities and reusing water for industrial needs, the condition of the reservoir, the quality of the water in it, etc.

Due to the strong pollution of wastewater from industrial enterprises, their purification from impurities is carried out in several stages. In all cases of wastewater treatment, the first stage is mechanical cleaning, designed to remove the largest mechanical impurities, suspensions and dispersed colloidal particles. Subsequent purification of chemicals is carried out by various methods: physicochemical (flotation, absorption, ion exchange; distillation, reverse osmosis and ultrafiltration, etc.), chemical (reagent cleaning), electrochemical (electrochemical oxidation and reduction, electrodialysis, electrocoagulation, electroflotation, etc.), biological. If there are very harmful substances in wastewater, thermal methods are used to eliminate impurities [37]. As a rule, in many cases it is necessary to apply a combination of these methods. The most commonly used methods should include:

- for suspended and emulsified impurities - sedimentation, flotation, filtration, clarification, centrifugation (for coarse particles); coagulation, flocculation, electrical deposition methods (for finely dispersed and colloidal particles);

- for purification from inorganic compounds - distillation, ion exchange, reverse osmosis, ultrafiltration, reagent deposition, deposition methods, electrical methods;

- for purification from organic compounds - extraction, absorption, flotation, ion exchange, reagent methods (regeneration methods); biological oxidation, ozonation, chlorination, electrochemical oxidation (destructive methods);

- for cleaning from gases and vapors - blowing, evacuation, heating, reagent methods;

- for the destruction of harmful substances - thermal decomposition [37].

Different enterprises use different methods of wastewater treatment. At petrochemical plants (in the production of synthetic alcohol, phenol, acetone, synthetic fatty acids, rubber, etc.), the main places for the formation of contaminated wastewater are hydrocarbon pyrolysis shops, ethylene hydration, and alcohol rectification. Wastewater of the hydrocarbon pyrolysis workshop contains ethylene, propylene, butane, isobutane, benzene, toluene, xylene, naphthalene. Alcohol, acetaldehyde, polymerization products, resin are present in the wastewater of the ethylene hydration and alcohol rectification workshop. When applying biological treatment methods, the content of organic substances (benzene, toluene, xylene, naphthalene, etc.) in wastewater is significantly reduced. The choice of method for the neutralization of industrial wastewater depending on their composition and concentration of pollutants is given in table 3.1.

Table 3.1 - Recommended methods for decontamination of wastewater [37]

<table>
<tr><td rowspan="4">The concentration of pollutants, mg/l</td><td colspan="4">Methods for treating wastewater containing substances</td></tr>
<tr><td colspan="3">mostly organic with a boiling temperature,°C</td><td rowspan="2">predominantly inorganic</td></tr>
<tr><td><120</td><td>120-250</td><td>>250</td></tr>
<tr><td colspan="2">Biological, chemical, sorption</td><td>chemical, sorption</td><td>Mechanical, chemical, sorption</td></tr>
<tr><td>500 - 5000</td><td>chemical (ozonation, chlorination), sorption, liquid phase oxidation with biological treatment, burning in furnaces</td><td>Chemical, sorption, extraction, liquid phase oxidation with biological treatment, burning in furnaces</td><td>sorption, biological post-treatment liquid phase oxidation, burning in furnaces</td><td>Mechanical, sorption, evaporation</td></tr>
<tr><td>5000 - 30000</td><td colspan="3">Chemical, extraction, liquid-phase oxidation with biological treatment, burning in furnaces</td><td>Mechanical, evaporation, discharge into the sea, burial in the ground, drying in a fluidized bed</td></tr>
<tr><td>>30000</td><td colspan="3">Extraction, liquid phase oxidation with various purification methods, burning in furnaces</td><td>same</td></tr>
</table>

3.2.3 Mechanical cleaning devices of wastewater

Mechanical treatment is used to isolate undissolved mineral and organic impurities from wastewater. The purpose of mechanical treatment is to prepare wastewater, if necessary, for a biological, physicochemical or other method of deeper treatment. Mechanical cleaning at modern treatment plants consists of filtering through grates, sand collection, settling and filtering. The types and sizes of these structures depend mainly on the composition, properties and consumption of industrial wastewater, as well as on methods for their further processing [37].

As a rule, mechanical treatment is a preliminary, rarely the final stage for the treatment of industrial wastewater. It provides the release of suspended solids from these waters up to 90 ... 95% and the reduction of organic pollution (in terms of biological indicator of oxygen) up to 20 ... 25%.

A high effect of wastewater treatment is achieved by various methods of intensification of gravity sedimentation - pre-aeration, biocoagulation, clarification in a suspended layer (clarifiers) or in a thin layer (thin-layer settlers), as well as using hydrocyclones [37].

Figure 3.10 shows a scheme of mechanical wastewater treatment with the following composition of the main structures: grilles 2 for trapping large contaminants of organic and mineral origin, sand traps 3 for separating heavy mineral impurities (mainly sand), averagers 5 for wastewater flow rate and concentration of their contaminants, settling tanks or clarifiers 6 for separating insoluble impurities, filters 7 for more complete clarification of water and facilities for sludge treatment [37].

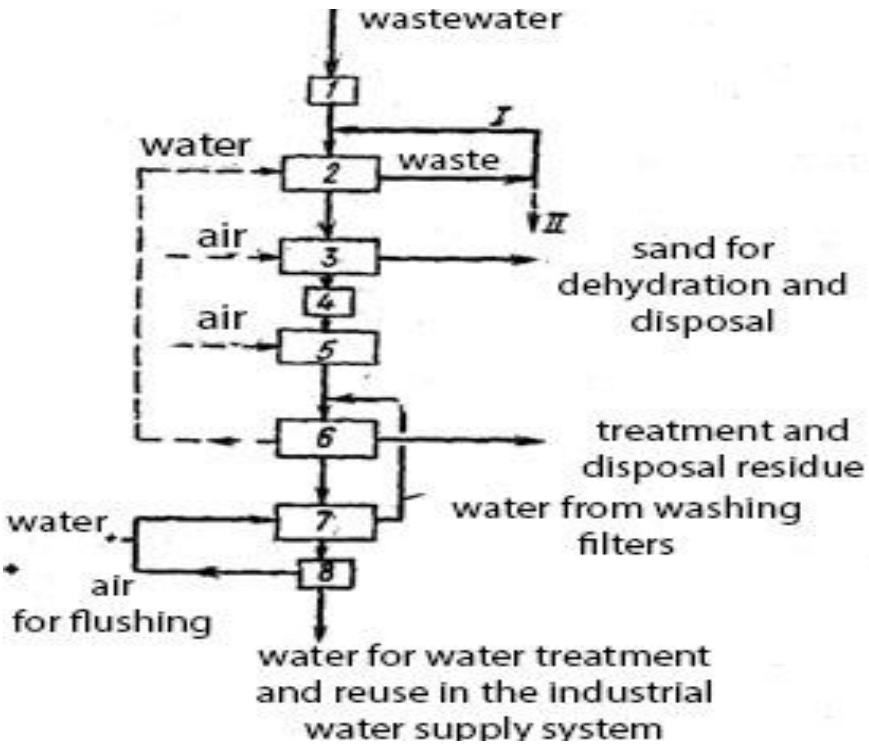


Figure 3.10 - Scheme of mechanical wastewater treatment:

I- option with crushing waste and discharging it into the sewer; II - option for waste disposal in containers for disposal; 1 - receiving chamber; 2 – mechanical lattices with separate crushers or crusher lattice; 3 - sand traps; 4 - water measuring device; 5 - averagers; 6 - sump or sump - clarifier; 7 - drum nets and sand filters or frame-only filters; 8 - pumping station

In some cases, mechanical treatment is the only and sufficient way to extract mechanical impurities from industrial wastewater and prepare them for reuse in water recycling systems.

However, some industries require water with a lower content of suspended solids than the content provided by mechanical treatment; therefore, additional physicochemical and biological treatment, as well as an even deeper treatment of industrial wastewater are required. Chlorination is required when reusing biologically treated wastewater in accordance with sanitary standards [37].

The sump is the main construction of mechanical wastewater treatment; it is used to remove precipitating or pop-up coarse particles. There are primary sumps that are installed in front of biological or physico-chemical treatment facilities, and secondary sumps for the allocation of activated sludge or bioten. Depending on the direction of movement of the water flow, the settlers are divided into horizontal, vertical and radial. The choice of the type and design of sedimentation tanks depends on the quantity and composition of industrial wastewater entering the treatment, the characteristics of the formed sludge (compaction, transportability). In each case, the choice of type of sedimentation tanks should be determined as a result of a technical and economic comparison of several options. To calculate sedimentation tanks, the following data are required:

- the amount of wastewater Q, m^3/s, according to the maximum inflow;

- concentration of suspended solids C_1, mg/l, heavy and light (oil and oil products) mechanical impurities;

- the required degree of purification, or the permissible content of suspended solids in clarified water, C_r mg/l, taken in accordance with sanitary standards or due to technological requirements (for example, when calculating the primary settling tanks located in front of aeration tanks for full cleaning or biofilters, when C_r should be equal 100 ... 150 mg/l) [37].

The principle of operation of hydrocyclones is based on the separation of solid particles in a rotating fluid flow. The particle separation rate in the centrifugal field of a hydrocyclone can exceed hundreds of times the rate of equivalent particle deposition in the gravitational field.

The main advantages of hydrocyclones include:

- high specific productivity of the processed suspension;

- relatively low costs for the construction and operation of installations;

- the lack of rotating mechanisms designed to generate centrifugal force; centrifugal field is created by tangential input of wastewater [37].

The intensification of the sedimentation of suspended particles from wastewater is carried out by the action of centrifugal and centripetal forces in them in low-pressure (open) and pressure hydrocyclones. The rotational movement of the liquid in the hydrocyclone, leading to the separation of particles, is ensured by the tangential supply of water to the cylindrical body. The rotation of the flow contributes to the agglomeration of particles and increase their hydraulic size. Wastewater under pressure enters through a tangentially located input into the upper part of the cylinder and acquires a rotational movement. The resulting centrifugal forces move the impurity particles to the walls of the apparatus along a spiral path down to the outlet pipe. Purified water is removed through the upper pipe. Figure 3.11 shows a diagram of an open hydrocyclone [37].

Electromagnetic filters (Fig. 3.12) are intended for the purification or deep purification of wastewater from mechanical impurities containing more than 25% ferromagnetic impurities, with an initial concentration of solid particles up to 200 mg/l and oils up to 50 mg/l. The filter consists of a housing, a magnetic system, which is an inductor with magnetic cores, between which there is a filtering granular load of ferromagnetic material, as well as devices for supplying and discharging waste water. As filter elements in electromagnetic filters, granular loading from ferromagnetic materials with a particle size of 1 ... 3 mm was used. Filtration of the treated wastewater is carried out when a magnetic field of a certain intensity is applied, as a result of which the granular load is compacted and, as a result of a decrease in porosity, acquires a high filtering capacity, which makes it possible to delay non-magnetic components from the composition of suspended solids (scale) along with magnetic filters [37].

Before washing, it is necessary to demagnetize the filter load, for which a current of the opposite direction is passed through the magnetizing coils. After demagnetization of the load, the scraper mechanism is turned on, and washing water is supplied to the filter.

The efficiency of wastewater treatment from ferromagnetic and non-magnetic impurities is 95 ... 98 and 40 ... 60%, respectively.

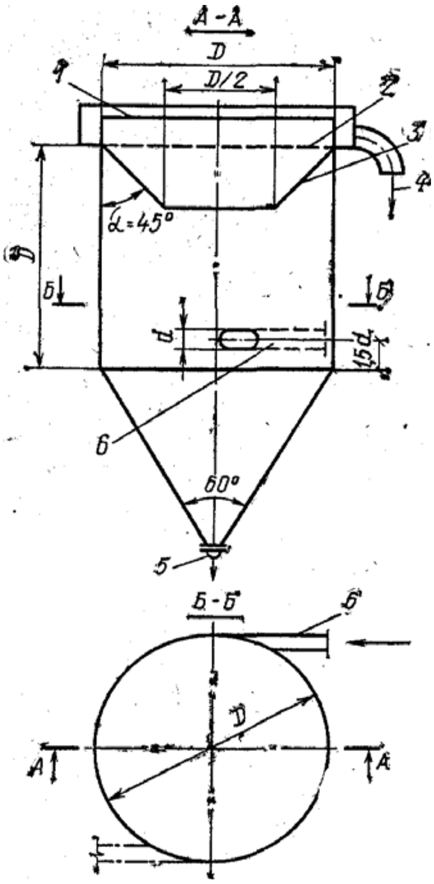


Figure 3.11 - Open hydrocyclone with a conical diaphragm:
1 - peripheral weir; 2, 3 - respectively flat and conical diaphragm; 4 — drainage of clarified water; 5 - hole for removing sludge; 6 - supply of wastewater

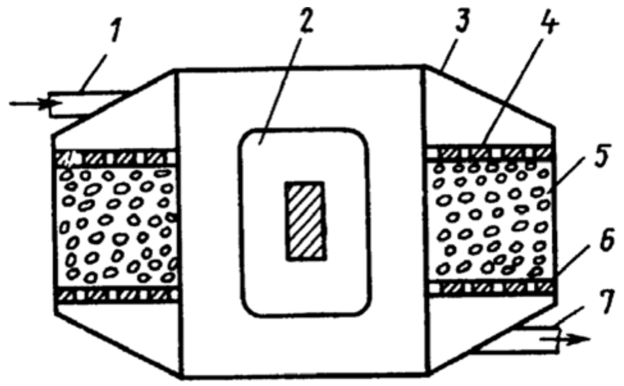


Figure 3.12 - The scheme of the electromagnetic filter:
1 - 1 - pipeline of the source wastewater; 2 - coil of inductance;
3 - non-magnetic housing; 4 - bounding grid;
5 - filter loading;
6 - support grid; 7 - purified water pipeline

3.2.4 Apparatus for physico-chemical wastewater treatment

Physicochemicals are used both independently and in combination with mechanical, chemical and biological methods. Physicochemical cleaning methods include coagulation, flocculation, sorption, flotation, extraction, ion exchange, hyperfiltration, dialysis, evaporation, evaporation, evaporation, crystallization, magnetic treatment, as well as methods associated with applying an electric field (electrocoagulation, electroflotation) [3,25].

Coagulation is the coalescence of particles of the colloidal system during their collisions in the process of thermal motion, mixing or directional movement in an external force fieldAs a result of coagulation, aggregates are formed - larger (secondary) particles, consisting of an accumulation of small (primary) particles. Primary particles in such aggregates are connected by intermolecular interaction forces directly or through a layer of the surrounding (dispersion) medium. Coagulation is accompanied by a progressive enlargement of particles and a decrease in their total number in the volume of a dispersion medium (in our case, liquid). Adhesion of homogeneous particles is called homocoagulation, and heterogeneous particles are called heterocoagulation [37].

One of the types of coagulation is flocculation, in which small particles in suspension, under the influence of specially added substances (flocculants) form intensively settling loose flocculent clusters.

The effectiveness of coagulation cleaning depends on many factors: the type of colloidal particles; their concentration and degree of dispersion; the presence of electrolytes and other impurities in wastewater; values of electrokinetic potential.

As coagulants, aluminum salts, iron salts, as well as mixtures of $Al_2(SO_4)_3$ and $FeCl_3$ salts in a ratio of 1:1 to 1:2 and aluminum-containing waste, pickling solutions, slags, pastes and mixtures are used [37].

Flotation is the process of molecular adhesion of particles of floated material to the interface between two phases, usually a gas (usually air) and a liquid, due to excess free energy of the surface boundary layers, as well as surface wetting phenomena.

Flotation units are used to remove oils, oil products, fats, resins, hydroxides, surfactants and other organic substances, solid particles with a hydraulic particle size of less than 0.01 mm / s, polymers, fibrous materials, and also for the separation of sludge mixtures from wastewater [37].

The process of wastewater treatment by flotation consists in the formation of “particle-bubble” complexes, the emergence of these complexes and the removal of the resulting foam layer from the surface of the treated liquid. When designing flotators for wastewater treatment with a flow rate of up to 100 m^3/h, rectangular chambers with a depth of 1 ... 1.5 m are accepted, with a flow rate of more than 100 m^3/h - radial flotators (Fig. 3.13) with a depth of at least 3 m [37].

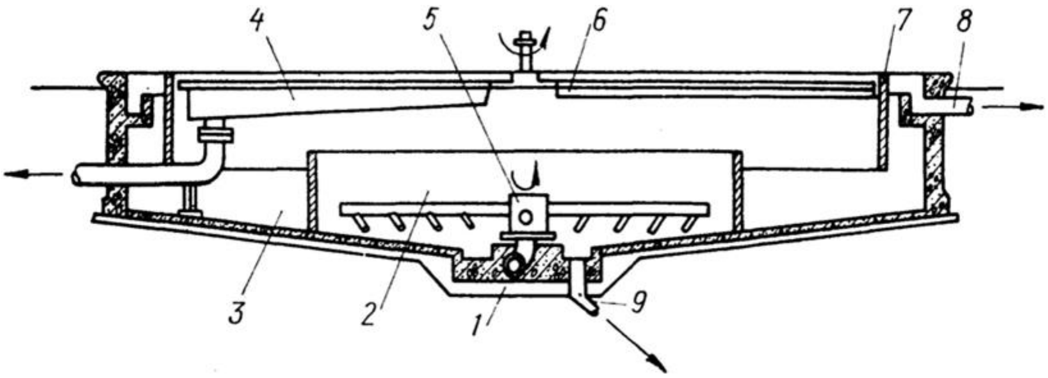


Figure 3.13 - Radial flotator
1 - water supply for cleaning; 2 - reception department; 3 - flotation chamber; 4 - sludge trap with release; 5 - rotating water distributor; 6 - a mechanism for raking foam; 7 - annular partition; 8 - drainage of purified water; 9 - release of sediment

Devices that carry out certain processes of electrochemical effects on aqueous solutions have a common name - electrolyzers. The general circuit diagram of such devices is presented in Figure 3.14.

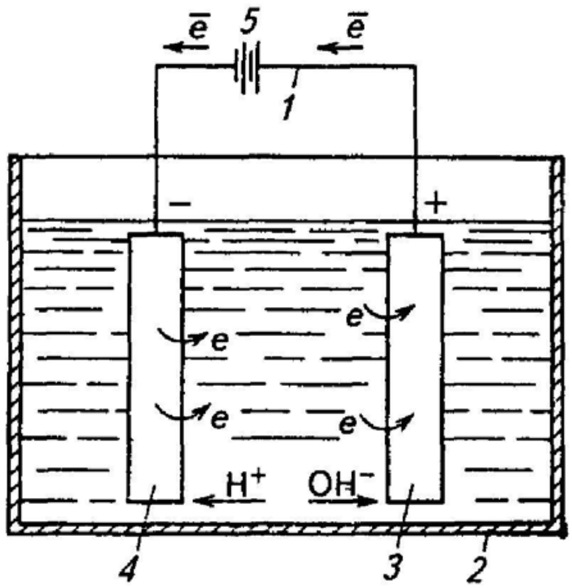


Figure 3.14 - Scheme of the electrolyzer:
1 - external circuit; 2 - tank; 3 - anode; 4 - cathode; 5 - current source

Water enters the tank 2, in which two electrodes 3, 4 are immersed, connected to the current source 5. Under the influence of an electric field, positively charged ions migrate to the negative electrode - the cathode, and negatively charged ions - to the positive electrode - the anode. At the electrodes, an electron transition occurs. The cathode gives electrons to the solution, and processes associated with the attachment of electrons to the reacting particles occur in the electrode space - restoration [37].

3.2.5 Apparatus for chemical wastewater treatment

The main methods of chemical treatment of industrial wastewater are neutralization and oxidation.

Chemical treatment can be used as an independent method before supplying industrial wastewater to the recycled water supply system, as well as before discharging them into a body of water or into a city sewer network. The use of chemical treatment in some cases is advisable (as a preliminary) before biological or physico-chemical treatment.

Neutralization is carried out by mixing acidic and alkaline wastewater, adding reagents, filtering acidic waters through neutralizing materials and absorbing acidic gases by alkaline waters or absorbing ammonia by acidic waters. In practice, the reagent is introduced in excess (10% more than the calculated amount) [37,38].

The neutralization reaction is a chemical reaction between substances having the properties of an acid and a base, which leads to the loss of the characteristic properties of both compounds. The most typical neutralization reaction in aqueous solutions occurs between hydrated hydrogen ions and hydroxide ions, respectively contained in strong acids and bases: $H^{+}+OH^{-} = H_2O$. As a result, the concentration of each of these ions becomes equal to that which is characteristic of water itself (about 10-7), i.e. the active reaction of the aqueous medium approaches pH =7. When draining wastewater into a pond or into a city sewer network, mixtures with pH = 6.5 ... 8.5 should be considered almost neutral. Therefore, wastewater with a pH of less than 6.5 and more than 8.5 should be neutralized.

For chemical cleaning, the following methods of neutralization are used:

a) mutual neutralization of acid and alkaline wastewater;

b) neutralization with reagents (acid solutions, quicklime CaO, slaked lime $Ca(OH)_2$, soda ash Na_2CO_3, caustic soda NaOH, ammonia NH_3OH);

в) filtering through neutralizing materials [lime, limestone CaO_3, dolomite $CaCO_3{\cdot}MgCO_3$, magnesite $MgCO_3$, calcined magnesite MgO, chalk $CaCO_3$ (96…99 %)];

г) neutralization of alkaline wastewater.

Reagent wastewater neutralization processes are carried out at neutralization plants (рис. 3.15).

The choice of reagent to neutralize acidic wastewater depends on the type of acid and its concentration, as well as on the solubility of salts formed as a result of a chemical reaction. To neutralize mineral acids, any alkaline reagent is used, but most often lime and calcium or magnesium carbonates in the form of a suspension. Lime for neutralization is used in the form of lime milk of 5% concentration or in the form of a powder [37,38].

The oxidative purification method is used to neutralize wastewater containing toxic impurities (cyanides, complex cyanides of copper and zinc) or compounds that are inappropriate to recover from wastewater, as well as to be treated by other methods. Chlorine, calcium and sodium hypochlorite, bleach, chlorine dioxide, ozone, industrial oxygen and oxygen, pyrolusite, hydrogen peroxide, manganese oxides, permanganate and potassium dichromate are used as oxidizing agents [37].

Neutralization of wastewater with chlorine or its compounds is one of the most common methods for their purification from toxic cyanides, as well as from such organic and inorganic compounds as hydrogen sulfide, hydrosulfide, sulfide, methyl mercaptan, etc.

Ozone is a strong oxidizing agent and has the ability to destroy many organic substances and impurities in aqueous solutions at normal temperature. At a pressure of 0.1 MPa and a temperature of 0 ° C, the solubility of ozone in water is 0.4 g / l. The rate of decomposition in an aqueous solution increases with increasing salinity, pH and water temperature [38].

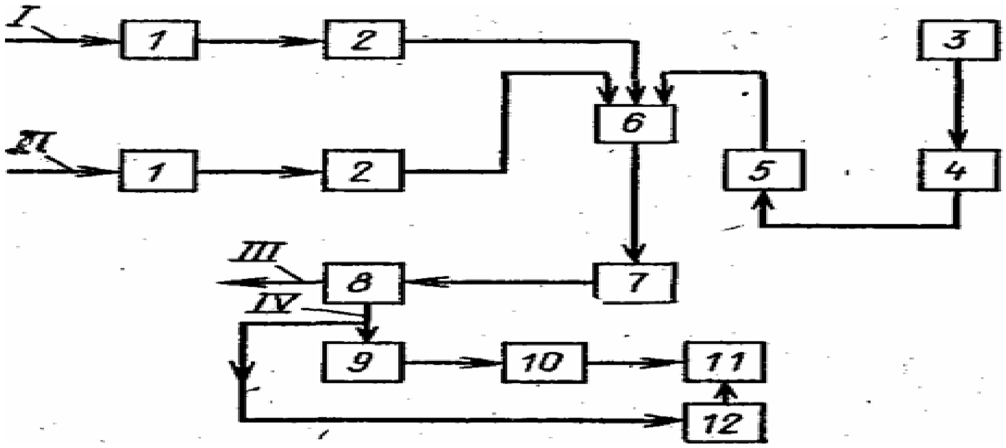


Figure 3.15 - Schematic diagram of a reagent neutralization station:
I, II - supply of acidic and alkaline wastewater, respectively; III, IV - neutralized wastewater and sludge discharge: 1 - sand traps; 2 - averagers; 3 - storage of reagents; 4 - solution tanks; 5 - dispenser; 6 - mixer; 7 - neutralizer; 8 - sump; 9 - sediment compactor; 10 - vacuum filter; 11 - accumulator of dehydrated sediments; 12 - playground for sludge

Ozonation is used to treat wastewater from phenols, petroleum products, hydrogen sulfide, arsenic compounds, surfactants, cyanides, dyes, carcinogenic aromatic hydrocarbons, pesticides, and others. To oxidize these substances, an ozone-air mixture is introduced into water. The solubility of ozone in water depends on the pH of the water. In a slightly alkaline environment, ozone dissociates very quickly, and in an acid one it exhibits great stability.

During wastewater treatment, ozone supplied to the reaction chamber in the form of an ozone-oxygen or ozone-air mixture enters into chemical reactions with substances polluting wastewater [37].

A schematic diagram of an ozonizer with horizontal tubular electrodes is shown in Figure 3.16.

A discharge is formed in a narrow gas space between two electrodes, to which a voltage of 5 ... 25 thousand volts is supplied. Air moves along the axis of the ozonizing elements in the annular space between the concentrically arranged electrodes. Oxygen molecules are crushed under the action of electric discharges, and the formed atoms easily attach to whole molecules due to their molecular affinity, forming an ozone molecule [37]:

$$O + O_2 \leftrightarrow O_3$$

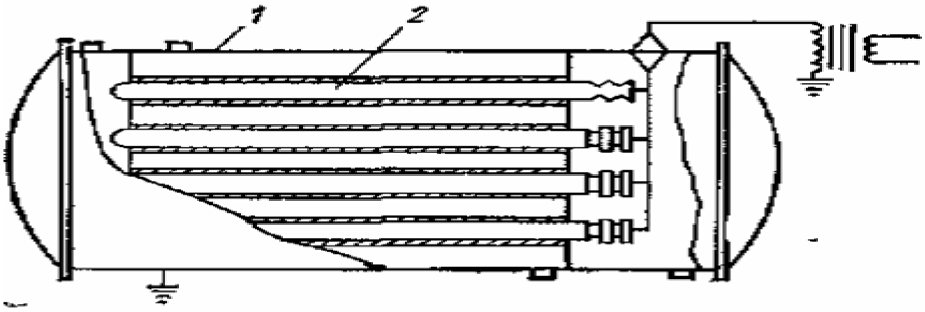


Figure 3.16 - Ozonator with horizontal tubular electrodes:
1- housing, 2- tubular element

3.2.6 Apparatus for biological wastewater treatment

Biological oxidation is a widely used in practice method of treating industrial wastewater, which allows them to be cleaned of many organic impurities. Biological oxidation is carried out by a community of microorganisms (biocenosis), which includes many different bacteria, protozoa and a number of more highly organized organisms-algae, fungi, etc.

Aerobic biological treatment of large quantities of wastewater is usually carried out in aeration tanks (Fig. 3.17) - capacitive flowing structures with activated sludge freely floating in the volume of treated water, whose bio-population uses wastewater pollution for its life.

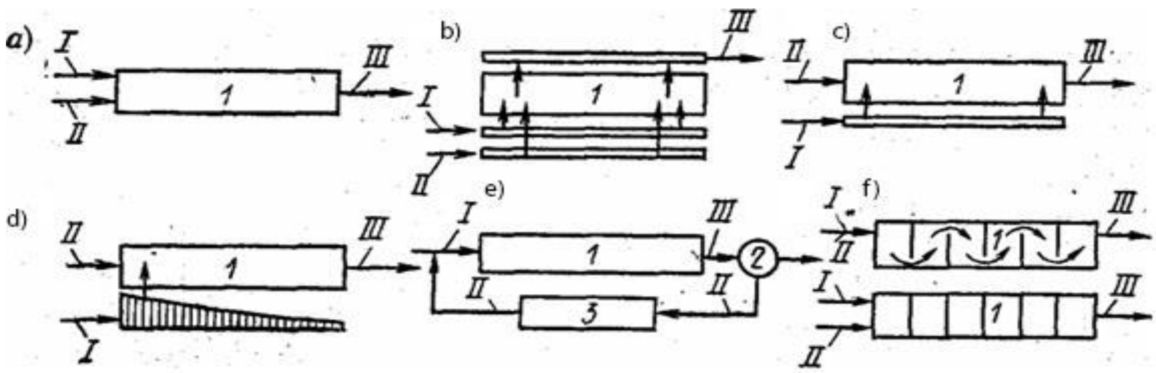


Figure 3.17 - Schemes of aeration tanks:
a - displacers; *b* - mixers; *c* - with dispersed water inlet;
d - with an unevenly distributed fluid flow type ANR;
e - with regenerators; *f* - cellular type;
I - wastewater; II - activated sludge; III - sludge mixture;
1 - aeration tank; 2 - secondary sump; 3 – regenerator

A prerequisite for the effectiveness of biological metabolic processes in the aeration tank is to provide them with oxygen dissolved in water, which is achieved by aeration and mixing of a mixture of water and activated sludge with pneumatic, mechanical or mixed type devices [3,37].

Biotenki-biofilters (Fig. 3.18) consist of a housing and tray elements located in a checkerboard pattern above each other in a checkerboard pattern. The treated wastewater enters the upper part of the biotank and, filling the tanks located above, flows down. In this case, the wastewater washes the outer parts of the elements on which the biofilm is formed. The biomass of activated sludge formed in the elements themselves is mixed and saturated with oxygen due to the movement of the treated wastewater. Biotenk in conjunction with a biofilter provides a high degree of purification (up to biological indicator of oxygen 5 of about 30 mg/l) with a load of biological indicator of oxygen of about 1.5 kg/(m^3·day) [37].

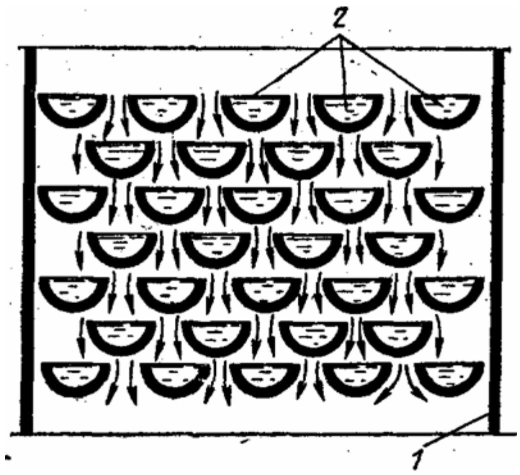


Figure 3.18 - Bioten scheme:
1 - case; 2 - loading elements

In biofilters, biodegradable organic substances of liquid waste are sorbed and oxidized under aerobic conditions of populations of heterotrophic optional bacteria forming a biological film on the surface of the nozzle (loading material, substrate). To irrigate the nozzle, contaminated water is periodically or continuously supplied to the upper part of the structure through stationary sprinklers (sprinklers) or reactive rotating water distributors. The active part of the biofilm extends to a depth of 70 ... 100 microns. Anaerobic conditions are created in the layers of the film adjacent to the nozzle, organic acids are formed (and CH4 and H2S gases), the pH decreases, and partial death of cells occurs. Under the influence of hydraulic loading, such parts of the film come off the substrate and are carried out with water [37].

The most important component of a biofilter is loading material. According to the type of loading material, all biofilters are divided into two categories: with volumetric and flat loading.

Biological ponds are artificially created reservoirs in which natural processes are used to treat wastewater.

These ponds can be used both for treatment and for deep treatment of wastewater that has undergone biological treatment. In oxidizing ponds, the processing of organic and a number of other wastewater and waste impurities is provided by anaerobic decomposition of sediment in the bottom zone and the oxidation of dissolved and colloidal organic substances during aerobic metabolism of bacteria in the middle part of the water volume. The products of these processes are utilized by algae growing near the surface and producing oxygen to ensure aerobic degradation of organic substances. [37].

In aerobic ponds highly loaded with organic components, photosynthesis is the main source of oxygen for the biological decomposition of organic waste. In this case, an intensive growth of algae occurs, into the protoplasm of which the bulk of the organic matter of wastewater passes. Algae is isolated from the pond drainage by filtration (for example, through a mesh microfilter) or by methods of physicochemical deposition.

In the oxidation processes, an important role is played by aquatic vegetation, which helps to reduce the number of nutrients, and regulates the oxygen regime of the reservoir.

There are ponds with natural and artificial aeration. The most effective oxidation processes in ponds take place in the summer, in addition, at this time the water leaving the pond does not contain pathogenic microflora. In the cold season, ponds operate primarily as capacitive structures for collecting sediment, rather than as biological reactors [37,38].

Questions for self-control:

1. What gases are part of the atmosphere?
2. What are the functions of the atmosphere to sustain life on Earth?
3. What is called air pollution?
4. Which pollutants are primary and which are secondary?
5. What are the main stages and methods of dust removal of air?
6. What characteristics of aerosol cleaners are used to evaluate their effectiveness?
7. List the devices that use mechanical aerosol cleaning.
8. What are the advantages and disadvantages of wet cleaners?
9. What are the main types of water pollution?
10. What methods of wastewater treatment are used in industrial enterprises?
11. What is the mechanical treatment of wastewater?
12. What is the physical-chemical treatment of wastewater?
13. What is the chemical treatment of wastewater?
14. What is the biological treatment of wastewater?

4 Sustainable Development Policy in Kazakhstan

4.1 The main objectives of sustainable development

The Republic of Kazakhstan is a full-fledged participant in the international community and and has committed itself to fulfill the tasks set in Agenda 21 (Rio de Janeiro, 1992) and the declarations of the Millennium Summit (New York, 2000) and the World Summit Sustainable Development (Johannesburg, 2002). The Republic of Kazakhstan has taken a number of measures towards achieving sustainable development. Kazakhstan is a member and an active participant in the UN Commission on Sustainable Development, the “Environment for Europe” and “Environment and Sustainable Development for Asia” processes, the regional Eurasian network of the World Business Council for Sustainable Development.

Kazakhstan adopted the Development Strategy of Kazakhstan until 2030, the Strategic Development Plan of the Republic of Kazakhstan until 2010, the Strategy for Industrial and Innovative Development of the Republic of Kazakhstan until 2015, the Concept of Environmental Safety of the Republic of Kazakhstan for 2004-2015, the Strategy for the Territorial Development of the Republic of Kazakhstan until 2015, The Council on Sustainable Development of the Republic of Kazakhstan and the JSC “Sustainable Development Fund“ Kazyna ”were created.

The Republic of Kazakhstan plays a special role in ensuring the environmental stability of the Eurasian continent. As a political, cultural and economic bridge between Europe and Asia, Kazakhstan has a similar connecting function in the development of landscape and ecological systems on the continent. The size of the territory of Kazakhstan, the variety of climatic conditions, and the features of the water balance of the region entail a significant dependence of the environmental situation throughout Eurasia. The political situation in Kazakhstan shows the whole world a unique example of stability, interfaith harmony, the development of democracy and public institutions in the interests of all citizens of the countries [39,40].

In September 2015, as part of the 70th UN General Assembly at the UN summit on the adoption of the post-2015 Development Agenda, Kazakhstan and other UN member states signed a new document for further global development, emphasizing that the goals and objectives of the Sustainable Goals Development Goals (SDGs) fully coincide with Kazakhstan's priorities and objectives [39].

Sustainable Development Goals are a comprehensive universal set of goals and indicators until 2030, aimed at improving the quality of life of citizens, socio-economic development and environmental sustainability of states.

Sustainable Development Goals consist of 17 goals to be achieved by 2030, as well as 169 goals and 242 indicators associated with them.

The Sustainable Development Goals are designed to help achieve sustainable development through the unification of three components: economic, social and environmental. The close relationship between the three components of sustainable development is particularly relevant in modern conditions, when the serious consequences of climate change and the need to preserve limited natural resources and the transition to a green economy become apparent [39,40].

Holding the international exhibition “EXPO-2017” and creating, with the assistance of the UN, the Center for Green Technologies and investment projects “Energy of the Future” on the basis of the exhibition are Kazakhstan's substantive contribution to international efforts to achieve the goals of sustainable development.

For Kazakhstan, the introduction of the methodology and indicators of sustainable development goals provides the opportunity for systemic adaptation of the strategic planning and monitoring system of the Republic of Kazakhstan to international standards, taking into account the harmony of Kazakhstan's program documents, primarily the “Strategy-2050” and the programs arising from it [39].

In general, the SDGs, or the so-called 2030 Agenda, are in many respects consistent with Kazakhstan’s development efforts and can serve as a useful and convincing political basis for achieving them, as well as for monitoring and evaluating progress towards the SDGs.

The mission of international experts of the United Nations Development Program in order to quickly comprehensively assess Kazakhstan’s readiness for the implementation and monitoring of the SDGs, held in November 2016, revealed a rather high degree of inclusion of the SDG targets in national and sectoral plans - 61% of the SDG targets are already covered by national strategic documents [39].

Kazakhstan is part of the High-level Group for Partnership, Coordination and Capacity-building for the provision of statistics for the 2030 Agenda for Sustainable Development, consisting of Member States, including UN regional and international agencies as observers.

A specially created interdepartmental Working Group on the implementation of indicators for monitoring the SDGs is developing a system of indicators that includes both global and national indicators, taking into account the priorities of Kazakhstan.

In general, the systematic implementation of the SDGs in Kazakhstan will undoubtedly give a positive multiplier effect, in particular [39]:

- facilitating the process of becoming one of the 30 most competitive countries in the world by achieving the indicators of the Organization for Economic Cooperation and Development (OECD) through the implementation of the SDG;
- giving an additional impetus to processes such as increasing human potential, attracting foreign technology and experience, advanced training in the field of processing large data arrays (Big Data);
- the implementation of the SDGs is becoming one of the factors of investment attractiveness for large international corporations for which the model of socially responsible business and its relevance to the SDGs is an important component of their image [39].

«Sustainable Development Goals until 2030:

Goal 1. End poverty in all its forms everywhere.

Goal 2. End hunger, ensure food security and improve nutrition, and promote sustainable agriculture.

Goal 3. Ensuring a healthy lifestyle and promoting well-being for all at all ages.

Goal 4. Ensure inclusive and equitable quality education and promote lifelong learning for all.

Goal 5. Ensure gender equality and empowerment of all women and girls.

Goal 6. Ensure the availability and sustainable use of water and sanitation for all.

Goal 7. Ensure access to affordable, reliable, sustainable and modern energy for all.

Goal 8. Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all.

Goal 9. Create resilient infrastructure, promote inclusive and sustainable industrialization and innovation.

Goal 10. Reduce inequality within and between countries

Goal 11. Ensuring openness, security, resilience and environmental sustainability of cities and settlements.

Goal 12. Ensure the transition to rational patterns of consumption and production.

Goal 13. Take urgent action to combat climate change and its effects.

Goal 14. Conservation and rational use of oceans, seas and marine resources for sustainable development.

Goal 15. Protect and restore land ecosystems and promote their rational use, sustainable forest management, combating desertification, ending and reversing land degradation, and ending the loss of biological diversity.

Goal 16. Contribute to building a peaceful and open society for sustainable development, ensuring access to justice for all and creating effective, accountable and inclusive institutions at all levels.

Goal 17. Strengthen the means of implementation and revitalize the Global Partnership for Sustainable Development" [39].

Kazakhstan is taking steps to move towards a more sustainable development model, which were outlined in two main strategic documents: "Kazakhstan-2050" 2012 and the "Green Economy Concept" (KZE) 2013, which determined the path to long-term growth based on climate technologies, energy conservation measures, as well as restoration and rational use of natural resources. The "Green Economy Concept" provides for the modernization of a deteriorating environmental infrastructure, contains ambitious goals for generating electricity, mining, developing industry and agriculture, using soil and water resources. The concept determines that "... as a result of the successful achievement of these goals, the country will restore water and land resources by 2030, the efficiency of resource use will be on par with the average indicators of OECD countries and other developed countries" [39].

Table 4.1 summarizes the main goals and indicators of sustainable development, which were taken into account when preparing the Concept for the transition of the Republic of Kazakhstan to the "green economy" (table 4.1).

Table 4.1 - “Goals and target indicators of sustainable development” [39]

Sector	Goal description	2020	2030	2050
Water resources	Elimination of water scarcity at the national level	Provide the population with water	Provide agriculture with water (by 2040)	Solve once and for all water supply problems
	Elimination of water scarcity at the basin level	The fastest coverage of the deficit in the basins as a whole (by 2025)	No deficit in each basin	
Agriculture	Labor productivity in agriculture	increase in 3 times		
	Wheat crop (t/ha)	1,4	2,0	
	water consumption for irrigation (m^3/m)	450	330	
Energy efficiency	Reducing the energy intensity of GDP from the level of 2008	25% (10% by 2015)	30%	50%
Electrical power	The share of alternative sources[1] in power generation	Solar and wind: at least 3% by 2020	30%	50%
	Share of gas power plants in electricity generation	20%[2]	25%[2]	30%
	Gasification of the regions	Akmola and Karaganda regions	Northern and Eastern regions	
	Reduction of carbon dioxide emissions in the power industry relative to the current level	2012 level	-15%	-40%
Air pollution	Emissions of sulfur and nitrogen oxides into the environment		European level of emissions	
Disposal waste	Number of people with access to solid waste removal		100%	
	Sanitary storage of garbage		95%	
	The proportion of recycled waste		40%	50%

“Note: [1]Solar power plants, wind power plants, hydroelectric power stations, nuclear power plants; [2]with the transfer of thermal power plants in major cities to gas in the presence of affordable gas volumes and an acceptable gas price” [39].

4.2 Water resources

The President of the Republic of Kazakhstan in his message “Kazakhstan-2050 Strategy” points to the emergence of a global threat related to pollution and lack of fresh water.

The state has set a goal of providing a stable water supply for the needs of people and agriculture. An important condition is the conservation of water resources, protection against pollution, the development of ecotourism [39,40].

Water bodies of the Republic of Kazakhstan are subject to risks associated with a high level of evaporation of water from the surface of the seas and lakes. In this regard, a large amount of water is required to maintain aquatic ecosystems. In addition, many transboundary rivers of Kazakhstan, being an inflow for many water resources, are significantly reduced in volume (Fig. 4.1) [39].

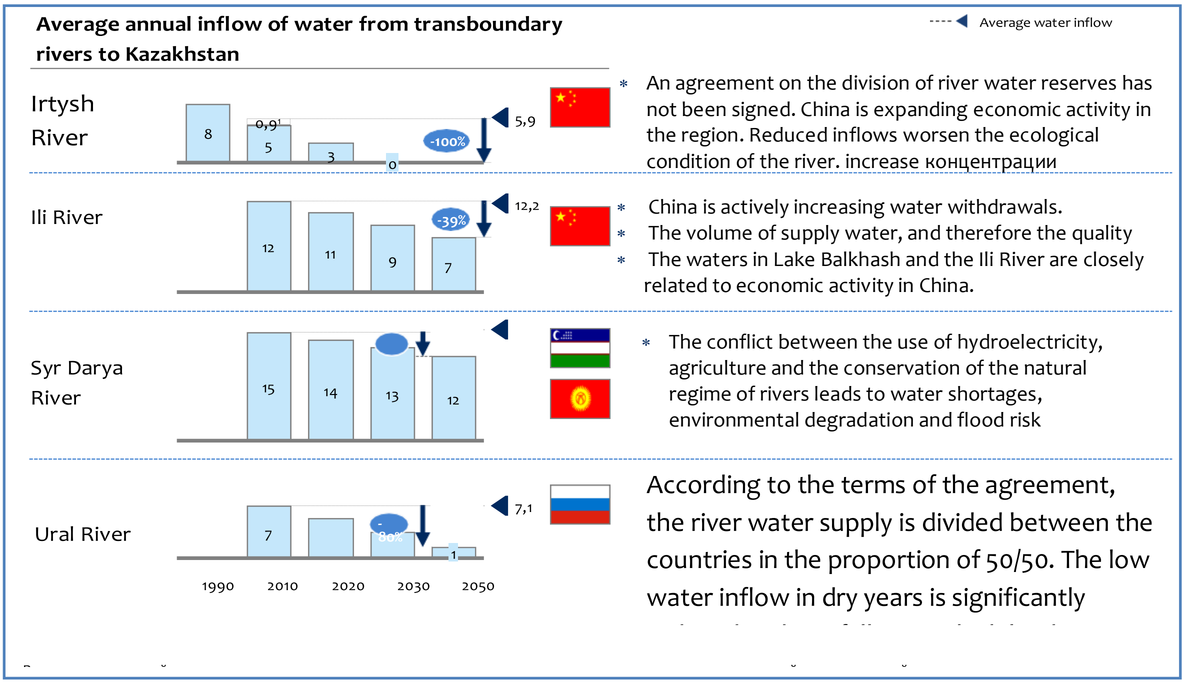


Figure 4.1 - Analysis of changes in the volume of inflow of transboundary rivers of Kazakhstan [39]

If the state does not take any measures to preserve and restore water resources, this may lead to the following consequences:

- degradation of rivers and lakes, especially the Northern Aral, Lake. Balkhash, p. Or as a result of lower revenues and water pollution;
- to create a system for rationing water consumption in hydropower, in agriculture;
- to possible interruptions in water supply;
- creation and introduction of additional sources of water supply (for example, reuse of water) and in connection with this material costs for the construction of additional pipelines, installations for water treatment.

This means that the threat of water scarcity is one of the barriers to sustainable development in Kazakhstan.

In the industrial sector, it is necessary to implement the following measures to increase the efficiency of water resources use:

- economical use of water through the introduction of energy efficiency technologies, which will reduce water consumption by about 20%;

- the use of wastewater for water supply of economic objects, as well as the use of recycled water supply;

- increased requirements for standards for water treatment.

Measures to improve the efficiency of water use in the communal sector:

- increased requirements for water conservation standards in the production of household appliances and plumbing fixtures, and devices;

- timely elimination of leaks and accounting for ode consumption in the communal and housing sectors.

It is necessary to come to a consensus with neighboring states on the environmentally sound management of water resources, since there is a problem in the country with the use of transboundary rivers [39].

To timely solve the problems associated with the depletion of water bodies in Kazakhstan, the following measures should be implemented:

- development of recommendations for the sustainable use of groundwater;

- the construction of reservoirs and storage reservoirs for collecting water effluents resulting from prolonged rainfall, melting snow, floods, etc. with the possibility of their use in dry periods;

- the construction of wastewater treatment facilities, including salt water;

- revival of water basins, cleaning of lakes, rivers from silt and other sediments.

In addition to measures to combat water scarcity include the construction of pipelines and canals for transferring water resources to areas suffering from water shortages. "According to the Committee on Water Resources, the additional potential for the transfer of inaccessible water resources is from 10 to 14 billion m^3" [39].

Another serious problem associated with water bodies is their pollution as a result of wastewater discharges, oil spills, the use of pesticides in agriculture, etc.

In this regard, it is necessary to adopt environmental standards, laws, measures to control water quality, following the example of the European Union, which has rich positive experience in their application [39].

To solve the tasks associated with the sustainable use of water bodies, a state program was adopted with a phased schedule of measures for water conservation (Table 4.2).

Table 4.2 - Stages of implementation of the state program of water conservation [39]

Areas of water conservation program	2013-2014	2015-2020	2020-2030
	Designing programs to improve efficiency, processing results and making changes	1. Implementation of a program to improve water use efficiency for agricultural 2. Reduce furrow irrigation to 5% 3. Crop reduction of cotton and rice 4. Implementation of standard quotas 5. Beginning of work of certification body for industrial efficiency	1. Achieving new levels of water efficiency. 2. In agriculture, from 1330 m^3/t to 300 m^3/t. 3. In industry, from 3.5 thousand tenge per m^3 to 5.5 thousand tenge per m^3.
Available water resources	1. Signing of agreements on transboundary rivers 2. Create a map of existing water reserves (groundwater), assess renewability	Implementation of priority investment projects to ensure the sustainability of water reserves	Launch of the Central Asian Development Fund of water-saving technologies for the joint sustainable use of water resources.
Resource management and reflection of the value of water	1. Develop a management structure and build competencies. 2. Gradual elimination of subsidies and introduction of incentive schemes. 3. Preparation of legislative changes that will ensure the effective implementation of the program.	1. The Committee on Water Resources will ensure water supply planning at the intersectoral level, setting quotas. 2. Adoption of laws ensuring the implementation and effectiveness of the proposed measures	Building competencies in the field of large-scale project management.
Safety of water bodies	2013-2014	2015-2020	2020-2030
	Assessment of risks associated with water bodies and development of plans to reduce them.	1. Raising the standard (to international) and strengthening water quality control. 2. Launch of infrastructure projects to reduce emergency risks, providing warning and information systems	Cleaning of historical pollution (remaining from previous periods)

4.3 Agriculture

The Republic of Kazakhstan is rich in land, so it has great potential for agricultural growth. The main task of this sector is its transition to sustainable development, which means maintaining the fertile properties of the earth, creating "green" jobs, increasing the varieties of domestic products and, accordingly, independence from imported products [39,40].

According to 2012 data [6.39], the share of agriculture in Kazakhstan’s GDP was 4%, but this sector is an important component for the country's economy, as it has great potential in providing jobs and the following depends on its development:

- food security of citizens;
- quality and quantity of native products;
- sustainability of the country's water resources.

One of the main problems in agriculture is the lack of financing for their development, "in the light of the lack of solutions for longer-term financing and the current large share of bad debts" [39].

Currently, the sector uses outdated agricultural practices and inefficient irrigation methods, which is why many water basins in the country are experiencing water shortages, which leads to prolonged droughts. Due to the threat of climate warming, over the next decade, the country will face an even greater shortage of water resources and, therefore, this could ruin the agricultural sector. Most of the land is degraded as a result of overgrazing and the close proximity of settlements. Desertification processes occurring on 66% of the country's lands [39] are of concern to scientists and ecologists. Therefore, now it is necessary to apply effective measures for water consumption, irrigation systems, construction of tanks for collecting melt water, etc. [39].

"The program for the development of the agro-industrial complex in the Republic of Kazakhstan for 2013 - 2020," Agribusiness 2020 "was developed in connection with the above problems. Additionally, for the sustainable development of the agricultural sector, the following is needed:

- state support to attract funding sources;
- training farmers in new agricultural techniques, business planning to attract credit organizations and second-tier banks as sources of financing;
- creation of model farms on the principle of concluding agreements between farmers and buyers of their products with the involvement of foreign companies.

4.4 Renewable Energy in Kazakhstan

Sustainable development of the world community primarily involves the absence of energy crises. In turn, the absence of energy crises is possible if all countries have access to energy resources. Traditional energy resources are exhaustible minerals, so other possibilities should be sought. Such opportunities are renewable energy sources and, above all, solar energy and its derivatives: wind energy, hydropower, biomass [4,6,39].

Renewable energy is essential for human life for two reasons:

- depletion of fossil fuels and the dependence of most developed countries from fuel imports (mainly oil);
- significant negative impact of traditional (fuel) energy on the human environment and wildlife.

Energy supply is one of the main indicators of the country's energy security. Kazakhstan is one of the world leaders in terms of variety and quantity of minerals.

Previously, the government was less focused on the development of alternative energy sources. For example, at present, most power plants in Kazakhstan operate on natural gas, coal or petroleum products. However, the crisis in the global economy and the awareness of the need to reduce the energy intensity of the economy and the environmental impact forced the country's leadership to actively focus on creating favorable conditions for the use of renewable energy sources (RES). According to Kazakhstani legislation, renewable energy means: sources of energy that can be renewed by natural processes, including [39]:

- energy of solar radiation;
- wind energy;
- hydrodynamic energy of water;
- geothermal energy (heat of soil, groundwater, rivers and water bodies);

as well as anthropogenic sources of primary energy:

- biomass;
- biogas;
- other fuels from organic waste used in the production of electric and/or thermal energy.

Renewable energy sources include solar and wind power plants, small hydropower plants, biofuel plants, geothermal and some other types of power plants. Given the geographical location and climatic conditions of Kazakhstan, small hydropower plants, solar and wind energy are the most promising renewable energy sources (Fig. 4.2). According to official estimates, the hydropower potential of medium and large rivers is 55 billion kWh, and the potential of small rivers is 7.6 billion kWh per year. At the same time, the potential of solar and wind energy is estimated at about 2.5 billion kWh per year and 1.820 billion kWh per year, respectively. Thus, the total potential of renewable energy sources is 1885 billion kWh per year, which is equivalent to the total capacity of 4.3 GW [6,39].

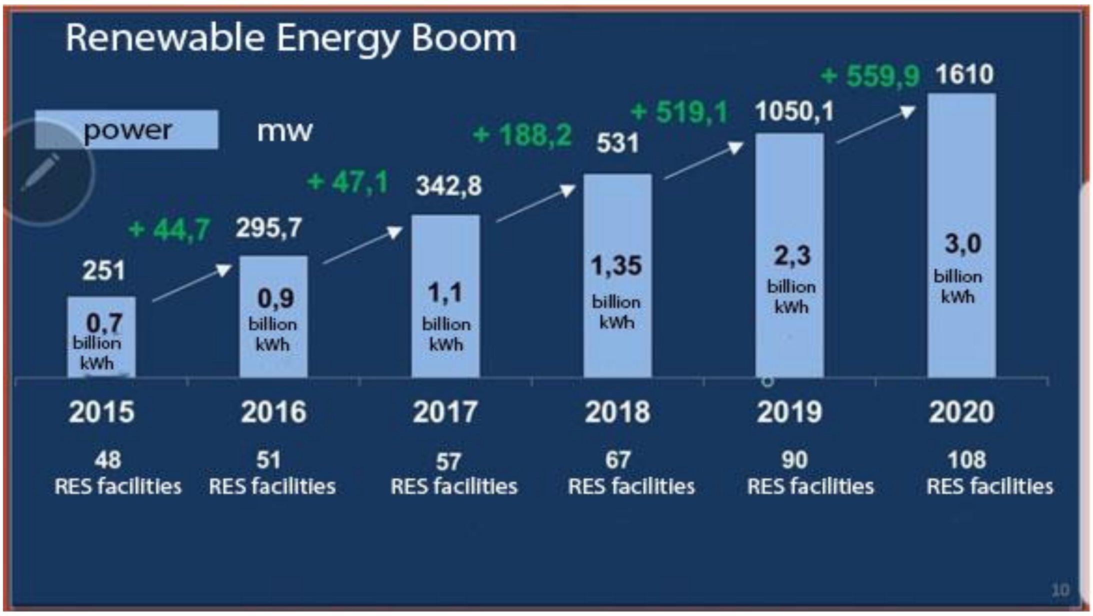


Figure 4.2 - Development of renewable energy in Kazakhstan

The key factors in the development of renewable energy projects in Kazakhstan are:

- government commitment to achieving environmentally friendly sustainable economic growth;

- mechanical aging of the electricity generation infrastructure, which suffers from relatively high (6%) losses in the transmission and distribution of electricity. The development of renewable energy sources can reduce losses by reducing the distance of transmission of electricity;

- Kazakhstan has a relatively high share of the rural population (43%), which currently accounts for about 10% of the country's total electricity consumption. RES can be a convenient source of energy for remote villages and regions;

- high carbon dioxide emissions due to the high dependence on coal for electricity production. The low intensity of carbon emissions from renewable energy sources is an attractive option for the country [39,40].

In 2017, the number of operating RES-based power plants increased to 55 (Fig. 4.3), and their generation capacity increased by 15.5% compared to the same period last year to 341.4 MW in 2017 (169.8 MW for hydroelectric power stations, 112 MW for wind power plants and 59 MW for solar power plants) against 295.7 MW in 2016 (139.9 MW of hydroelectric, 98.2 MW of wind power and 57.3 MW of solar power plants). This growth occurred due to the commissioning of new hydroelectric power stations and a wind power plant of 30 MW and 14 MW, respectively [39].

Electricity generation from renewable sources continues to grow significantly, despite the fact that the share of renewable energy sources in the country's total energy balance remains low.

Despite the considerable potential for the development and implementation of projects in the field of renewable energy, due to the vast territory of the country and various climatic conditions, in Kazakhstan there are still obstacles and barriers to the introduction and development of renewable energy:

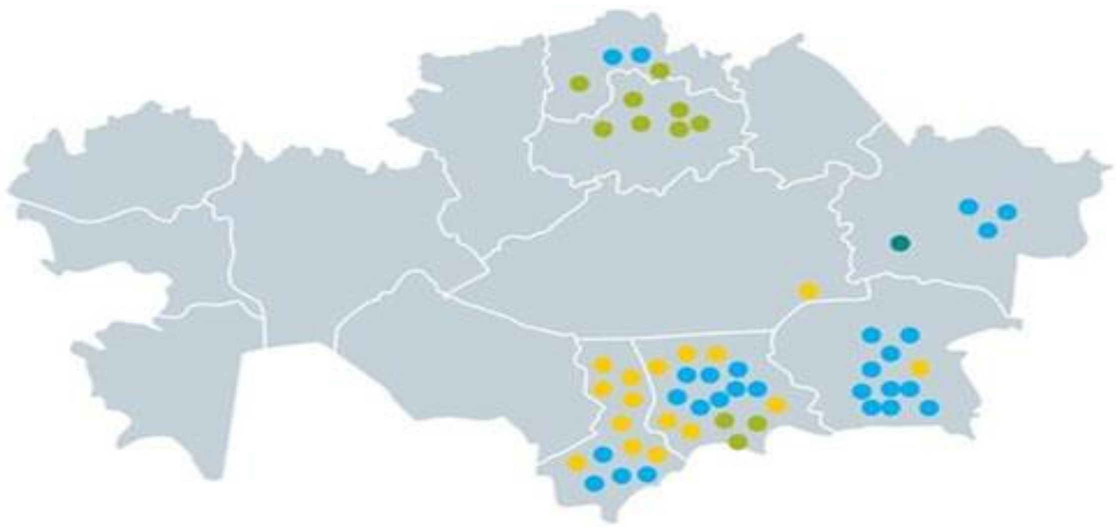


Figure 4.3 - Map of the location of renewable energy stations in Kazakhstan by type (data for 2017)

1. Low prices for electricity obtained by traditional methods.

Today in Kazakhstan, traditional fossil fuel power plants are more competitive in price compared to renewable energy sources. Kazakhstan has the largest recoverable coal reserves in Central Asia; the country is the second largest coal producer in the region. Coal mined in the northern regions is the main source of electricity production [39].

2. Power transmission losses and inefficient technologies.

3. Limited regulatory framework which is necessary to stimulate the use of renewable energy sources.

4. Limited technological base, low awareness and information barriers [39].

Low awareness of the importance, benefits and potential of renewable energy sources among representatives of society and other interested parties is one of the key factors hindering the introduction of renewable energy sources in Kazakhstan.

5. Currency fluctuations and a high-risk business environment.

The country's transition to a free floating exchange rate has limited the potential return on investment and has jeopardized the future development of renewable energy.

6. Limited capacity of the Unified Energy System (UES) of Kazakhstan [39,40,41].

Questions for self-control:

1. List the main goals of sustainable development in Kazakhstan.
2. Describe the relevance and prerequisites for the transition of the Republic of Kazakhstan to sustainable development.

3. What are the consequences of irrational use of water resources in Kazakhstan?

4. What are the causes of changes in the volume of inflow of transboundary rivers of Kazakhstan.

5. What activities should be carried out to increase the efficiency of water resources use?

6. What problems in agriculture do you need to solve for the transition to sustainable development?

7. What activities need to be carried out to develop the agricultural sector?

8. What are the most promising renewable energy sources in Kazakhstan.

9. What are the key factors for the development of renewable energy in the Republic of Kazakhstan?

10. What are the main reasons which impede the development of renewable energy in the Republic of Kazakhstan?

5 Life safety

5.1 Review of the law of the Republic of Kazakhstan “On Civil Protection”, basic concepts in life safety

In the process of life, a person is exposed to various dangers, which are usually understood as phenomena, processes, objects that can, under certain conditions, cause damage to human health directly or indirectly, i.e. cause various undesirable effects.

«The life of a modern person in a civilized society is fraught with many dangers. In the field of production, in transport, in the environment, events always occur that have or may have a harmful effect on human health or may even cause death. Therefore, life “without dangers” is an incorrect idealization, and the term “security” should be understood as a system of measures to protect against dangers, as an opportunity to manage hazards, the ability to prevent dangerous situations. A person can be in emergency situations of peacetime (calamity, accident, disaster) and wartime. In these conditions, civil defense deals with the protection of man and objects [42].

On April 11, 2014, the Law on Civil Protection entered into force in Kazakhstan. “The law regulates public relations, that arise in the course of civil protection measures, and is aimed at preventing and eliminating natural and man-made emergencies and their consequences, providing emergency medical and psychological assistance to the population in the emergency zone, ensuring fire and industrial safety, and also defines the main tasks, organizational principles of the construction and functioning of the civil defense of the Republic Kazakhstan, the formation, storage and use of the state material reserve, the organization and activities of emergency rescue services and units” [43].

The Law “On Civil Protection” has replaced a number of the repealed Laws, such as:

1) “The Law of the Republic of Kazakhstan dated July 5, 1996“ On emergency situations of natural and technogenic nature ”;
2) “The Law of the Republic of Kazakhstan dated November 22, 1996“ On Fire Safety ”;
3) “The Law of the Republic of Kazakhstan dated March 27, 1997“ On emergency rescue services and the status of rescuers ”;
4) “The Law of the Republic of Kazakhstan dated May 7, 1997“ On Civil Defense ”;
5) “The Law of the Republic of Kazakhstan dated November 27, 2000“ On the State Material Reserve ”;
6) “The Law of the Republic of Kazakhstan dated April 3, 2002“ On Industrial Safety at Hazardous Production Facilities ”.

In this Law, all the main tasks and principles on which civil protection is based are indicated.

According to the Law, “the state civil protection system consists of territorial and sectoral subsystems [43]:

- **territorial subsystems** are created at the regional, city and district levels for the prevention and liquidation of emergencies and their consequences, the implementation of civil defense measures within their territories and consist of units corresponding to the administrative-territorial division of these territories.

- **"industry subsystems** are created by central executive bodies to organize work on the implementation of civil protection measures within their competence."

The state civil protection system has three levels:

- republican
- territorial
- object.

These levels consist of:

- management bodies of civil protection;
- control points, operational duty services;
- advisory bodies - commissions for the prevention and elimination of emergency situations;
- forces and means of civil defense;
- communication systems, alerts and information support.

According to the Law on the territory of the Republic of Kazakhstan, there is a *“single duty dispatch service 112”* [43].

Unified duty dispatch service “112” is created in the territorial divisions of the authorized body of the region, city of republican significance, the capital, district, city of regional significance.

The law stipulates that all state bodies, including their territorial divisions, local executive bodies, legal entities operating facilities with a mass presence of people, hazardous production facilities, are obliged to organize the interaction of information and communication networks and automated monitoring systems with a single duty dispatch service “112” [43].

If special work is required to ensure civil protection, then created:

- republican civil protection services,
- regional civil protection services,
- city civil protection services,
- district civil protection services [43].

The competence in the field of civil protection, of all authorized (state) bodies is indicated in Chapter 3 of the Law. State control and supervision in the field of civil protection is carried out by the authorized body in order to comply with the legislation of the Republic of Kazakhstan in the field of civil protection and is carried out in the form of verification and other forms. State control and supervision in the field of civil protection is divided into:

1) state control in the field of civil defense;
2) state control in the field of fire safety;
3) state supervision in the field of industrial safety [43].

In order to protect the population, facilities and territory of the Republic of Kazakhstan, to reduce damage and losses in the event of military conflicts, the following civil defense measures are carried out [44]:

1) in advance:

- development of civil defense plans;

- the creation and development of control systems, alerts and communications and maintaining them in readiness for use;

Creation, staffing, equipment and maintenance of readiness of civil protection forces;

- training of civil protection management bodies and training the population in protection methods and actions in cases of using modern means of destruction;

- construction and accumulation of the fund of protective structures of civil defense, their maintenance in readiness for operation;

- creation, accumulation and timely refreshment of civil defense property;

- planning of evacuation measures;

- planning and implementation of measures for the sustainable functioning of industries and organizations;

2) in case of military conflicts:

- warning of the threat and use of modern weapons, informing the public about the course of action;

- sheltering the population in protective structures of civil defense, if necessary, use of personal protective equipment;

- medical care for the wounded and injured;

- carrying out evacuation measures;

- the creation of additional control points, alerts and communications of civil protection;

- carrying out emergency rescue and emergency operations;

- restoration of broken control systems, alerts and communications;

- restoration of readiness of civil protection units [43].

According to the Law, the objects of civil defense include: control points, separate and built-in shelters, radiation protection shelters, storage facilities for storing civil defense property [43].

Civil defense property includes: personal protective equipment, radiation, chemical reconnaissance and dosimetric monitoring devices, personal medical protective equipment, communication and warning equipment, and other material and technical means.

Emergency services and formations are divided into professional and voluntary emergency rescue services (Chapter 6 of the Law) [43].

Emergency medical and psychological assistance services, fire and rescue, operational rescue, water rescue, aviation rescue, paramilitary and other specialized professional emergency rescue services and units in the field of civil protection are also being created in Kazakhstan [44].

Chapter 7 of the Law is devoted to state control and supervision in the field of civil protection.

Chapter 8 of the law provides a list of civil protection measures taken:

- for the prevention of emergency situations;

- from floods, floods, floods, shallowing of seas and large bodies of water, mudflows, avalanches of snow landslides;

- from emergencies related to the development of mineral deposits.

In order to form and develop a comprehensive scientific basis for civil protection, the authorized body organizes and coordinates research in the field of civil protection (Chapter 9 of the Law).

The main objectives of scientific research in the field of civil protection are to reduce the negative impact of natural and man-made emergencies, develop recommendations on the normative and methodological support for assessing and managing risks in the field of civil protection.

Chapter 10 of the Law specifies the procedure for declaring an emergency of a natural and man-made nature.

So, the Prime Minister of the Republic of Kazakhstan makes an announcement in an emergency of global or regional scale, and by the akims of the administrative-territorial units in emergency situations of a local scale.

The head of emergency response is appointed depending on the scale, which, in turn, organizes and manages emergency rescue and urgent operations, manages the forces and means involved in the liquidation of an emergency of a natural and technogenic nature, and organizes their interaction.

This law obligated central and local executive bodies, organizations in rendering all possible assistance to emergency services and formations following to emergency situations, carrying out emergency response work and returning to the place of deployment.

Central and local executive bodies, within their competence and depending on the nature and scale of emergency situations, carry out activities to restore engineering infrastructure, housing, improve the environment, and provide social and rehabilitation assistance to the population (Chapter 11 of the Law) [44].

This chapter indicates in what cases individuals and legal entities are entitled to demand compensation for damage, as a result of various situations, who pays the damage and in what amount.

According to Art. 60 of the Law, the fire safety system in the Republic of Kazakhstan means the totality of economic, social, organizational, scientific, technical and legal measures, as well as the forces and technical means of the fire service, aimed at preventing fire and harm (damage) from it.

The bodies of the state fire service consist of an authorized body, its structural unit in the field of fire safety, territorial units and state institutions, including educational institutions of the authorized body.

The bodies of the state fire service carry out fire prevention and extinguishing, conduct emergency rescue and emergency operations, state control in the field of fire safety and conduct inquiries in cases of crimes related to fires [43].

This chapter indicates:

- fire extinguishing procedure,

- fire safety requirements in the design, construction, reconstruction and production of technical regulations in the field of fire safety,

- fire safety requirements during operation, storage, transportation, application and implementation of technical regulation objects in the field of fire safety.

Chapter 13 of the Law is devoted to non-state fire service and voluntary fire groups.

The main tasks of the non-state fire service are:

1) prevention and suppression of fires in organizations, settlements and at facilities;

2) emergency rescue operations in organizations, settlements and at facilities

The main tasks of voluntary fire fighting units include:

1) prevention and suppression of steppe fires, as well as fires in organizations and settlements;

2) carrying out emergency rescue operations related to extinguishing steppe fires, as well as fires in organizations and settlements;

3) performance of work and the provision of services in the field of fire safety;

4) training the population in fire safety measures and in the event of a fire.

Industrial safety is aimed at compliance with industrial safety requirements established in technical regulations, industrial safety rules, instructions and other regulatory legal acts of the Republic of Kazakhstan (Chapter 14 of the Law).

According to article 69, industrial safety is ensured by [43]:

1) establishment and implementation of industrial safety requirements;

2) approval for use at hazardous production facilities of technologies, technical devices, materials that meet industrial safety requirements;

3) admission to the use on the territory of the Republic of Kazakhstan of hazardous technical devices that comply with industrial safety requirements;

4) declaration of industrial safety of a hazardous production facility;

5) state supervision, as well as industrial control in the field of industrial safety;

6) industrial safety expertise;

7) certification of legal entities for the right to carry out work in the field of industrial safety;

8) industrial safety monitoring;

9) maintenance of hazardous production facilities by professional emergency services or groups.

Chapter 15 of the Act presents:

- “the order of actions of organizations operating a hazardous production facility in case of an incident, accident,

- the procedure for creating a commission for the investigation of accidents,

- the rights of the commission to investigate the accident,

- tasks of the accident investigation ”,

- materials of the accident investigation,

- accident investigation results [43].

Chapters 16 and 17 of the Law are devoted to the state reserve, its formation and use, legal status, accounting and order of issue.

And another important section of the Law is the chapter on “Status and social protection of employees and other employees of civil protection bodies”.

In this chapter you can learn from the number of citizens who form the civil protection bodies, how wages, pension and other benefits for employees and other employees of civil protection bodies are made, their life and health protection, medical support for employees, social guarantees of rescuers and members of their families [44].

As a conclusion from the review of this Law, it can be said that the newly adopted Law combines all legal aspects related to civil protection. And now there is no need to study a large number of legislative acts in order to find out all the necessary (useful and important) information that affects such an important aspect of life as civil protection [44].

Safety is the most important human need along with his need for food, water, clothing, housing, and information. This is a general scientific category, which is not tangible, material, and acts as an integral form of expressing the vitality and vitality of various objects of a particular world, such as domestic and foreign policy, defense, economics, ecology, social policy, people's health, computer science, technology, etc. [42].

There are two types of safe conditions:

- lack of possibility of danger, cataclysms in reality;
- a complete state of protection from any danger, or the ability to counteract them with a high degree of reliability.

Sanitary and epidemiological well-being of the population - “the state of public health, the human environment, in which there is no harmful effect of environmental factors on the person and favorable living conditions are ensured”.

Human environment - a set of objects, phenomena and environmental factors (natural and artificial), which determines the conditions of human life.

Environmental factors - biological (viral, bacterial, parasitic and others). Chemical and physical (noise, vibration, ultrasound, infrasound, thermal, ionizing, non-ionizing and other radiation). Social (nutrition, water supply, living conditions, work, leisure) and other environmental factors that have or may have an impact on humans and (or) the health status of future generations.

Harmful effects on humans - exposure to environmental factors that pose a threat to human life or health or a threat to the life or health of future generations.

Favorable conditions for human life - the state of the environment in which there is no harmful effect of its factors on humans (harmless conditions) and there are opportunities for the restoration of impaired functions of the human body.

Safe conditions for humans - the state of the environment in which there is no danger of the harmful effects of its factors on humans.

Life Safety (LS) is a comprehensive discipline that studies the possibilities of ensuring human safety in relation to any type of human activity. Life safety is a scientific discipline that studies danger and protection from it [3,42].

Objects are considered hazardous if they represent various phenomena, hazardous substances or a flow of energy.

The object of studying the discipline of life safety is a complex of phenomena and processes in the "human-environment" system that negatively affects the person and the environment.

Danger - phenomena, processes, objects, properties of objects, which under certain conditions can harm human life. The danger itself is due to the heterogeneity of the human-habitat system and arises when their characteristics do not coincide.

Residual risk is the property of systems, objects to be potentially dangerous.

- What are the signs of danger? This is
- a real threat to health and life;
- a probable threat to health and life;
- a threat to the normal functioning of ecological systems.

- **Sources of hazards are:**
- man, his activity, objects of labor;
- natural environment;
- technogenic environment;
- various processes that occur during the interaction of man and the environment.

Life safety solves three main tasks:

- hazard recognition with identification of the possible place of its formation and quantitative characteristics;
- development of protective measures taking into account material costs;
- elimination of dangers before their direct impact.

The purpose of health and safety - the safety of human achievement in the habitat. Human safety is determined by the absence of industrial and non-industrial accidents, natural and other natural disasters, hazardous factors that cause injuries or a sharp deterioration in health, harmful factors that cause human diseases and reduce its performance [3,42].

Life safety - a system of knowledge aimed at ensuring safety in a production and non-production environment, taking into account the human impact on the environment.

Principles of life safety:

- - orienting (general direction of the search);
- - organizer (organization of the working day);
- - management (control over compliance, responsibility);
- - technical (aimed at the implementation of protective equipment devices) [42].

Orienting principles include the consideration of the human factor, the principle of rationing, and a systematic approach.

Management principles include stimulation, the principle of responsibility, feedback and others.

Organizational principles include the principle of the rational organization of labor, zoning of territories, the principle of protection by time (limiting the stay of people in conditions when the level of harmful effects is on the verge of permissible).

Technical principles include principles that require the use of specific technical solutions to improve safety:

- the principle of protection by quantity (for example, maximum reduction of harmful emissions;

- the principle of distance protection (the effect of a harmful factor decreases due to increased distance), protective grounding, insulation, fencing, shielding, sealing;

- the principle of the weak link (its use in systems operating under pressure: bursting discs, pressure cookers, etc.) [33,42].

To ensure the safety of life, personal and collective protective equipment is needed.

The choice of collective protective equipment depends on the category of hazardous factor, for example, on electromagnetic radiation, radiation, increased sources of noise and vibration, etc.

Personal protective equipment is used as additional protective equipment, or when collective protective equipment is not provided or is ineffective.

The main axioms of life safety:

- any activity (inaction) is potentially dangerous;

- for each type of activity there are comfortable conditions conducive to its maximum efficiency;

- all natural processes, anthropogenic activity and objects of activity are prone to spontaneous loss of stability or to long-term negative impact on a person and his environment, i.e. have residual risk;

- residual risk is the root cause of potential negative effects on humans and the biosphere;

- safety is real if the negative impacts on a person do not exceed the maximum permissible values, taking into account their complex effects;

- an environmentally friendly state is real if negative impacts on the biosphere do not exceed the maximum permissible values given their complex effects;

- permissible values of negative technological impacts are ensured by compliance with environmental and safety requirements for the technical system, technologies, as well as the use of environmental protection systems (environmental protection technology);

- environmental protection systems at technical facilities and in technological processes have the priority of commissioning and means of monitoring the operating mode;

- safe and environmentally friendly operation of technical equipment and production is carried out when the qualifications and psychophysical characteristics of the operator comply with the requirements of the developer of the technical system and when the operator complies with safety and environmental standards and requirements [3,42].

5.2 Human and habitat

Lifestyle and habitat directly affect the state of health and the quality of human life. Discussions about the impact of hazardous factors on a person, society, and the environment predetermined the emergence of life safety discipline. It is human activity that is the main condition for maintaining life. This activity includes actions performed in everyday life, industrial, spiritual, scientific, cultural life [42].

The life process includes a person and his environment (Fig. 5.1), which affect each other. It is the habitat that has a direct effect on human well-being. If a person feels comfortable under certain environmental parameters, then such parameters are called *optimal.*

The main goal of life safety is to protect a person from the negative impact of situations of a natural and technogenic nature and to create comfortable living conditions [33].

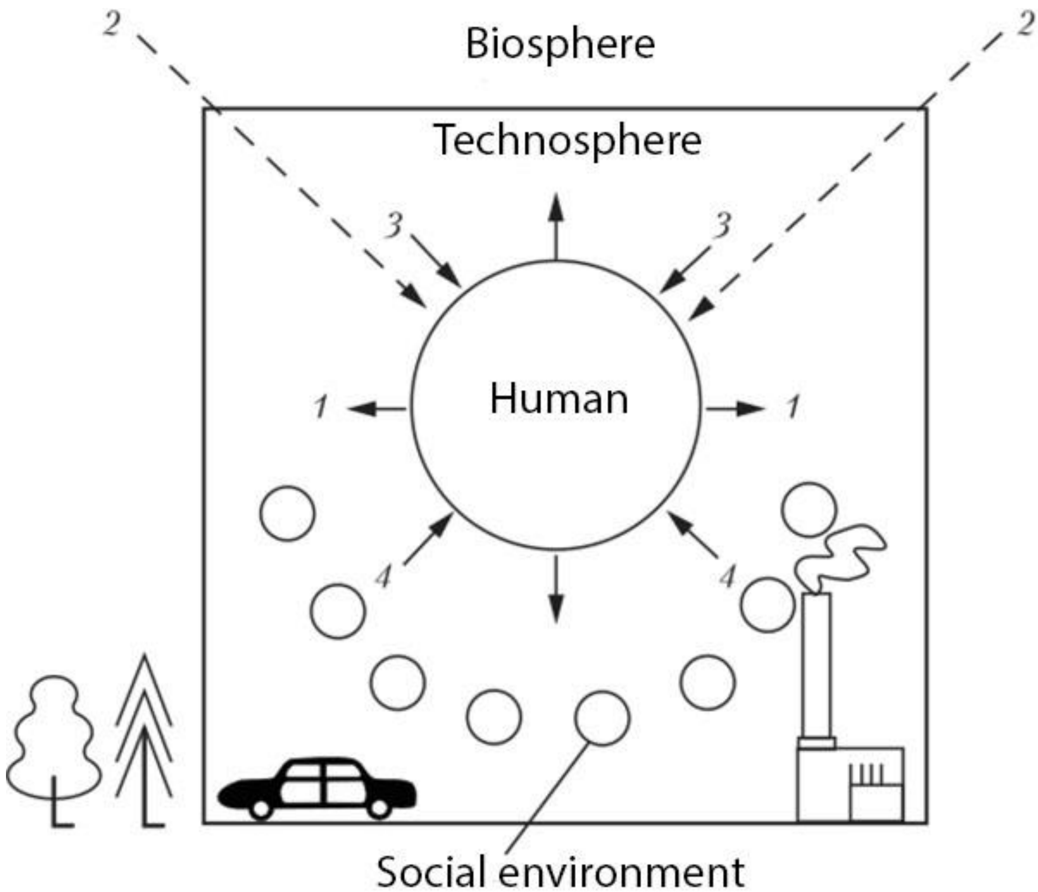


Figure 5.1 - Interaction between humans and the environment

Negative impact can be caused by components of the technosphere (for example, moving equipment, cars, pressure vessels, etc.), as well as actions performed by people.

If we apply a numerical measurement of any negative flow from insignificant to possible values, then we can distinguish the main types of interactions in the "man-environment" system:

- ***comfortable*** (optimal) interaction, when the flows correspond to the optimal conditions of interaction: create optimal conditions for activity and rest, prerequisites for the manifestation of the highest working capacity and, as a result of the productivity of activities, guarantee the preservation of human health and the integrity of the components of the environment;

- ***permissible*** when the flows, affecting the person and the environment, do not have a negative impact on health, but lead to discomfort, reducing the effectiveness of human activity. Compliance with the conditions of permissible interaction guarantees the impossibility of the emergence and development of irreversible processes in humans and in the environment;

- ***dangerous*** when the flows exceed acceptable levels and have a negative effect on human health, causing a prolonged interaction of the disease, and / or lead to degradation of the environment;

- ***extremely dangerous*** interaction, when high-level flows in a short period of time can cause injury, lead to death, cause disturbances in the environment [42].

"Comfortable" and "acceptable" interactions are referred to as "positive conditions of daily activity", and "dangerous" and "extremely dangerous" interactions are not applicable in life safety and negatively affect the environment.

The main components for human life include: air, water, food products, movement and purpose in life.

If in a certain situation there is a threat to health, then this situation is called *dangerous*.

If there is a "real threat to a person's life, his health and property", then such a situation is called *extreme.*

The following types of human behavior are distinguished in the event of an emergency:

- *panic* (a person rushing from side to side, striving to run away, experiencing fear);

- *psychological shock* (a person remains in place, his muscles become numb, sometimes he faints) [42].

Such a situation can happen at any time and anywhere: at the workplace, in domestic conditions, during rest, etc. Therefore, it is very important that a person is ready for unexpected turns in his life, able to quickly assess the situation and the dangers that have arisen, and to carry out further actions without panic, according to the recommendations studied.

On the objects of protection the following types of security are distinguished:

- individual and collective human security in life;
- environmental protection;
- national security;
- global security.

The main types of actions that are threats to human life:

- kidnapping and threats of abduction of employees, members of their families and close relatives;
- killings accompanied by violence, bullying and torture;

- psychological terror, threats, intimidation, blackmail, extortion;
- robberies in order to seize money, valuables and documents.

Criminal attacks against premises (including residential), buildings and personnel are manifested in the form of:

- explosions;
- shelling from firearms;
- mining, including using remote control;
- arson;
- attacks, intrusions, captures, pickets, blocking;
- damage to entrance doors, gratings, fences, display cases.

Types of negative impacts in the “human – environment” system:

a) by origin:

- natural;
- technogenic;
- environmental;
- mixed;

b) by time of manifestation:

- impulse (appear instantly, for example, the danger of electric shock);
- cumulative (accumulating, for example, living in areas of increased radioactive exposure);

c) by localization:

- lithospheric (earthquake, volcanic eruption);
- hydrosphere;
- atmospheric (ozone holes);
- space (solar cycles) [3,42].

5.3 Assessment of the situation in emergencies

The urgency of the problem of protecting the population and territories from emergency situations, ensuring radiation, chemical and biological safety is not reduced. These areas of activity, which are an integral part of national security, directly affect the country's sustainable development and international prestige. Therefore, the existing state system for the prevention and elimination of emergency situations, which is the most important factor in ensuring the stability of the state, is constantly being improved and undergoes significant changes [3].

An acceptable level of safety and quality of life of the population is based on fundamental values: the recognition of the absolute priority of human life at all levels of government and management, the consolidation of citizen's rights in the field of security and the formation of legal mechanisms for regulating the relationship between the individual, government and society. In addition, it is planned to inform the population about potential dangers and its readiness to act in emergency situations of a natural, man-made, environmental and biological-social nature [33].

The principles of sufficient safety and acceptable risk, supplemented by socio-economic factors, should be the basis of life safety programs. Their implementation at the present stage requires the use of adequate economic and mathematical models that reflect the essence of socio-economic, industrial and economic, humanistic phenomena, combined into a single class of systems for protecting the population from emergency situations of a natural, technogenic, environmental and biological-social nature [42].

5.3.1 Evaluation of the chemical environment in emergency situations

Assessment of the chemical environment means determining the extent and nature of air pollution, terrain by chemically hazardous substances (CHS) and analyzing their impact on the activities of economy and population [45].

To characterize the scale of the area of infection with chemicals use:

- radius and area of the accident area;
- the depth and area of contamination of areas with dangerous densities;
- the depth and area of distribution of the primary and secondary clouds of chemically hazardous substances.

The depth of pollution is the maximum length of the corresponding area of pollution outside the accident area, and the depth of distribution is the maximum length of the zone of distribution of the primary or secondary cloud of chemically hazardous substances.

The propagation zone is the area of chemical air pollution outside the accident area, created as a result of the spread of a cloud of a potent toxic substance, an accidentally chemically hazardous substance in the direction of the wind.

The zone of chemical pollution formed by potent toxic substances includes a spill site of toxic substances in damaging concentrations.

Damaging concentration - the content in the air vapors of highly toxic substances that preclude the presence of people without gas masks.

The focus of chemical damage is the territory in which as a result of exposure to potent toxic substances there were massive injuries of people and animals.

To determine the parameters of the zone of chemical pollution, the concepts of depth (D), width (W), area (S) of the distribution of polluted air with damaging concentrations are used [45].

Chemical reconnaissance data, monitoring and forecasting the further spread of the chemical cloud are used to assess the consequences of accidents involving releases of chemically hazardous substances

For the assessment, the following baseline data are required:

- characteristics of the accident object (place and time of the accident, tonnage of containers, name of potent toxic substances);
- meteorological conditions (wind speed and direction, degree of vertical stability of the atmosphere, air temperature and underlying surface);

- topographic features of the terrain (relief, the presence of forests, character building) [45].

Knowing the direction and speed of the wind makes it possible to correctly assess the degree of threat of damage to the population by vapors of potent toxic substances that propagate in the direction of flow of the air mass. The formation of damaging concentrations, the depth of distribution of polluted air also depend on wind speed.

Vertical air currents significantly affect the depth of distribution of potent toxic substances and their concentration in the atmosphere. Their direction is characterized by the degree of vertical stability of the atmosphere. There are three degrees of vertical stability: inversion, isothermy, convection.

Inversion is the increase in air temperature with increasing altitude. It is most often formed on windless clear nights as a result of intense heat radiation from the earth's surface. Inversion prevents air dispersion in height and creates the most favorable conditions for maintaining high concentrations (stagnation) of potent toxic substances.

Isothermy is characterized by a stable equilibrium of air. It is most typical for cloudy weather and, like inversion, contributes to prolonged stagnation of vapors of potent toxic substances in open areas, in forests, and residential areas of settlements.

Convection is the vertical movement of air from one height to another. Warmer air moves up, while colder and denser air moves down. Convection causes a strong dispersion of polluted air, so the concentration of potent toxic substances in the air decreases rapidly. Convection is noted in the spring-summer-autumn period on clear days in the absence of snow cover (Figure 5.2) [45].

Vertical air stability is usually characterized by a thermodynamic criterion. To determine this criterion, it is necessary to measure the air temperature at a height of 50 and 200 cm from the surface of the earth and the wind speed at a height of 100 cm.

The temperature gradient is calculated by the temperature difference at a height of 50 and 200 cm $\Delta T = T_{50} - T_{200}$, which is divided by the square of the wind speed at a height of 100 cm, and a thermodynamic criterion is obtained [45,46]:

$$\text{ТДК} = \frac{T_{50} - T_{200}}{\nu^2} \qquad (5.1)$$

In this case, the sign of the temperature gradient is taken into account:

$\frac{T_{50} - T_{200}}{\nu^2} \geq +0{,}1 -$ vertical air stability that corresponds to convection;

$\frac{T_{50} - T_{200}}{\nu^2} \leq 0{,}1 -$ vertical air stability which corresponds to inversion;

$0{,}1 \geq \frac{T_{50} - T_{200}}{\nu^2} \geq -0{,}1$ - ВУВ vertical air stability that corresponds to isothermy.

Intensive movement of the surface air layer occurs at a wind speed of more than 4 m/s.

In the absence of wind (calm), the vertical stability of air is determined only by the temperature gradient ΔT:

- if $\Delta T > 0$, then the vertical stability of the air corresponds to convection;
- if $\Delta T < 0$, then the vertical stability of the air corresponds to the inversion;
- if $\Delta T = 0$, then the vertical stability of the air corresponds to isothermy [45].

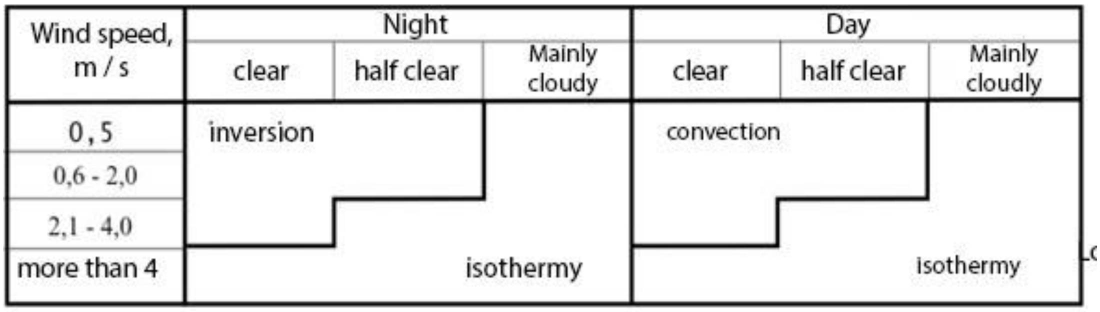


Figure 5.2 - Determining the state of atmospheric stability depending on wind speed and time of day

Prediction of the extent of chemical pollution in case of possible accidents is carried out when determining the meteorological parameters of air, as well as using the calculation formulas (5.1-5.16) and the data given in table. 5.1–5.9. Figure 5.3 graphically shows the spread of a cloud of potent toxic substances depending on the shape of the air sustainability state.

The equivalent amount of matter in the primary cloud is determined by the formula [45]

$$Q_{э1}=K_1K_3K_5K_7Q_0 \qquad (5.2)$$

where K_1 – coefficient depending on storage conditions of potent toxic substances;

K_3 – a coefficient equal to the ratio of the threshold toxic dose of chlorine to the threshold toxic dose of another potent toxic substance (table 5.1);

K_5 – coefficient taking into account the degree of vertical stability of air (for inversion it is assumed equal to 1 for isothermy - 0.23, for convection - 0.08);

K_7 – coefficient taking into account the influence of air temperature (table. 3.1);

Q_0 – the amount of substance ejected during an accident, tons.

For compressed gases, Q_0 is calculated by the formula

$$Q_0 = dV_x, \qquad (5.3)$$

where d is the density of potent toxic substances, t/m^3 (table. 5.2); Vx - storage volume, m^3.

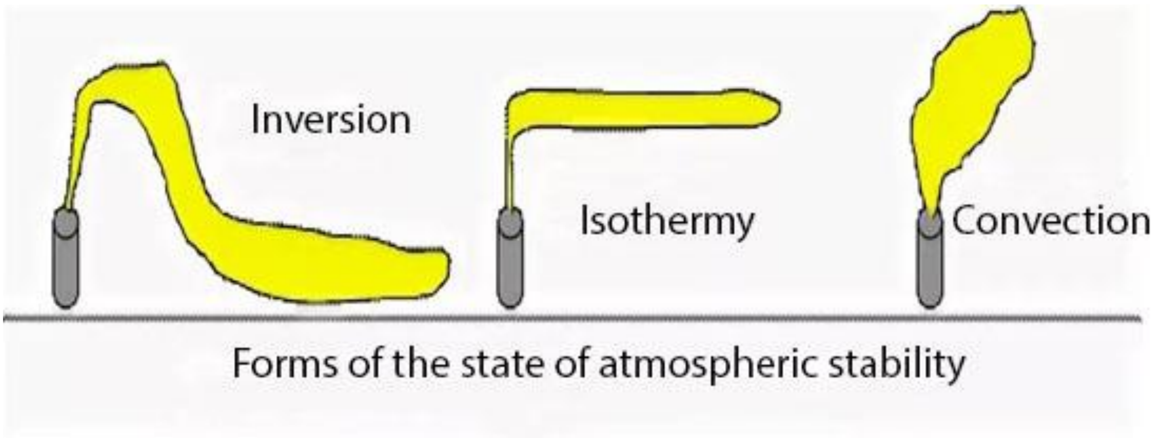


Figure 5.3 - Spread of a cloud of potent toxic substances depending on the state of air stability

In case of accidents on the gas pipeline, Q_0 is calculated based on the ratio:

$$Q_0 = \frac{ndV_x}{100}, \tag{5.4}$$

where n - is the content of potent toxic substances in natural gas, %;
d – density of potent toxic substances, t/m^3;
V_r – gas section volume between automatic shutoff valves, m^3.

The equivalent amount of matter in the secondary cloud is found by the following formula [45]:

$$Q_{э2} = (1\text{-}K_1)K_2K_3K_4K_5K_6K_7\frac{Q_0}{hd}, \tag{5.5}$$

where K1 is the coefficient depending on the storage conditions of potent toxic substances (table. 5.1);

K_2 - coefficient depending on the physicochemical properties of potent toxic substances (table. 5.1);

K_3 - a coefficient equal to the ratio of the threshold toxic dose of chlorine to the threshold toxic dose of another potent toxic substance (table 5.1);

K_4 - coefficient, which takes into account wind speed (table. 5.3);

K_5 – coefficient, which takes into account the degree of vertical stability of the air (for inversion it is taken equal to 1, for isothermy - 0.23, for convection - 0.08);

K_6 - coefficient depending on the time N elapsed after the start of the accident;

K_7 - coefficient taking into account the influence of air temperature (table. 5.1);

Q_0 - the amount of substance ejected during the accident, t;

h - layer thickness of potent toxic substances, m;

d - the density of potent toxic substance, t/m^3.

Table 5.1 - The values of auxiliary coefficients for determining the equivalent amount of potent toxic substances and evaporation time [45]

Name of potent toxic substance	Meaning of auxiliary coefficients							
	K_1	K_2	K_3	K_7 for air temperature, °C				
Ammonia: pressurized storage	0,18	0,025	0,04	0/0,9	0,3/1	0,6/1	1/1	1,4/1
isothermal storage	0,01	0,025	0,04	0/0,9	1/1	1/1	1/1	1/1
Acetone cyanohydrin	0	0,002	0,316	0	0	0,3	1	1,5
Hydrogen: - fluoride	0	0,028	0,15	0,1	0,2	0,5	1	1
– chloride	0,28	0,037	0,3	0,4/1	0,6/1	0,8/1	1/1	1,2/1
– cyanide	0	0,026	3	0	0	0,4	1	1,3
Dimethylamine	0,06	0,041	0,5	0/0,1	0/0,3	0/0,8	1/1	2,5/1
Methyl: - bromide	0,04	0,039	0,5	0/0,2	0/0,4	0/0,9	1/1	2,3/1
– chloride	0,125	0,044	0,056	0/0,5	0,1/1	0,6/1	1/1	1,5/1
– mercaptan	0,06	0,043	0,353	0/0,1	0/0,3	0/0,8	1/1	2,4/1
Acrylic Acid Nitrile	0	0,007	0,8	0,04	0,1	0,4	1	2,4
Nitrogen oxides	0	0,04	0,4	0	0	0,4	1	1
Ethylene oxide	0,05	0,041	0,27	0/0,1	0/0,3	0/0,7	1/1	3,2/1
Sulfur Anhydride	0,11	0,049	0,333	0/0,2	0/0,3	0,3/1	1/1	1,7/1
Hydrogen sulfide	0,27	0,042	0,036	0,3/1	0,5/1	0,8/1	1/1	1,2/1
Carbon disulphide	0	0,021	0,013	0,1	0,2	0,4	1	2,1
Hydrochloric acid	0	0,021	0,3	0	0,1	0,3	1	1,6
Formaldehyde	0,19	0,034	1	0/0,4	0/1	0,5/1	1/1	1,5/1
Phosgene	0,05	0,061	1	0/0,1	0/0,3	0/0,7	1/1	2,7/1
Chlorine	0,18	0,052	1	0/0,9	0,3/1	0,6/1	1/1	1,4/1
Chlorcian	0,04	0,048	0,8	0/0	0/0	0/0,6	1/1	3,9/1

Note. The values of the coefficient K7 are given in the numerator for calculating the *primary*, in the denominator for the *secondary cloud* of potent toxic substances and evaporation time.

Table 5.2 - Physical and toxic properties of potent toxic substances [45]

Name of potent toxic substance	the density of potent toxic substance, t/m^3		Boiling point, °C	Threshold toxic dose mg·min /l
	gas	liquid		
Ammonia: - storage under pressure	0,0008	0,681	–33,42	15
– isothermal storage	–	0,681	–33,42	15
Acetone cyanohydrin	–	0,932	120	1,2
Hydrogen: - fluoride	–	0,989	19,52	4
– chloride	0,0016	1,191	–85,1	2
– cyanide	–	0,687	25,7	0,2
Dimethylamine	0,0020	0,680	6,9	1,2
Methyl: – bromide	–	1,732	3,6	1,2
– chloride	0,0023	0,983	–23,76	10,8
– mercaptan	–	0,867	5,95	1,7
Acrylic Acid Nitrile	–	0,806	77,3	0,75
Nitrogen oxides	–	1,491	21,0	1,5
Ethylene oxide	–	0,882	10,7	2,2
Sulfur Anhydride	0,0029	1,462	–10,1	1,8
sulfuretted hydrogen	0,0015	0,964	–60,35	16,1
carbon bisulfide	–	1,263	46,2	45
Hydrochloric acid	–	1,198	–	2
Formaldehyde	–	0,815	–19,0	0,6
Phosgene	0,0035	1,4332	8,2	0,6
Chlorine	0,0032	1,553	–34,1	0,6
Chloropicrin	–	1,658	112,3	0,02
Chlorcian	–	1,220	12,6	0,75

Table 5.3 - the value of the coefficient K_4 depending on wind speed

Wind speed, m/s	1	2	3	4	5	6	7	8	9	10	15
K_4	1,0	1,33	1,67	2,0	2,34	2,67	3,0	3,34	3,67	4,0	5,68

The value of the coefficient K_6 is after calculating the duration of T, h, evaporation of the substance:

$$K_6 = \begin{cases} T^{0,8} \text{ under } N < T; \\ T^{0,8} \text{under } N \geq T. \end{cases}$$

under $T < 1$ h K_6 taken for 1 hour.

The duration of the damaging effect of potent toxic substances is determined by the time of its evaporation from the spill area. The evaporation time of potent toxic substances from the spill area is calculated by the formula [45]:

$$T = \frac{hd}{K_2 K_4 K_7}, \tag{5.6}$$

where h is the thickness of the layer of potent toxic substances, m;
d - density of potent toxic substances, t/m^3 (table 5.2);
K_2 - coefficient depending on the physicochemical properties of potent toxic substances, t / m3 (table 5.1);
K_4 – coefficient, that takes into account wind speed (table 5.3);
K_7 - coefficient that takes into account the effect of air temperature (table 5.1).

The thickness of the fluid layer h of potent toxic substances spilled freely on the underlying surface is assumed to be 0.05 m over the entire area of the spill. For potent toxic substances spilled into a sump or landslide, the thickness h is determined as follows [45]:

- in case of spills from containers having a sump (landslide):

$$h = H - 0{,}2, \tag{5.7}$$

where H is the height of the sump (landslide), m;

- in case of spills from tanks located in a group having a common the sump (landslide):

$$h = \frac{Q_0}{Fd}, \tag{5.8}$$

where Q_0 is the amount of substance ejected (spilled) during the accident, t;
F - the area of the spill into the sump (landslide), m^2;
d - density of potent toxic substances, t/m^3.

The depth of the contamination zone with the primary (secondary) cloud of potent toxic substances during accidents at process pipelines, tanks, storages and vehicles is estimated according to table 5.4.

If the equivalent amount of potent toxic substances in the primary (secondary) cloud, calculated according to formulas (5.2) and (5.5), does not correspond to the tabular ones (Table 5.4), the depth of the cloud contamination zone of potent toxic substances is determined by interpolation according to the following formulas [45,46] :

$$\Gamma_1 = \Gamma_{min} + \left(\frac{\Gamma_{max} - \Gamma_{min}}{Q_{max} - Q_{min}}\right)(Q_{э1} - Q_{min}); \tag{5.9}$$

$$\Gamma_2 = \Gamma_{min} + \left(\frac{\Gamma_{max} - \Gamma_{min}}{Q_{max} - Q_{min}}\right)(Q_{э2} - Q_{min}), \tag{5.10}$$

Table 5.4 - Depth of the pollution zone, km [45]

Wind speed, m/s	Equivalent amount of potent toxic substances, t										
	0,01	0,05	0,1	0,5	1	3	5	10	20	30	50
1	0,38	0,85	1,25	3,16	4,75	9,18	12,53	19,20	29,56	38,13	52,60
2	0,26	0,59	0,84	1,92	2,84	5,35	7,20	10,83	16,44	21,01	28,73
3	0,22	0,48	0,68	1,53	2,17	3,99	5,34	7,96	11,94	15,18	20,59
4	0,19	0,42	0,59	1,33	1,88	3,28	4,36	6,46	9,62	12,18	16,43
5	0,17	0,38	0,53	1,19	1,68	2,91	3,75	5,53	8,19	10,33	13,88
6	0,15	0,34	0,48	1,09	1,53	2,66	3,43	4,88	7,20	9,06	12,14
7	0,14	0,32	0,45	1,00	1,42	2,46	3,17	4,49	6,48	8,14	10,87
8	0,13	0,32	0,42	0,94	1,33	2,30	2,97	4,20	5,92	7,42	9,90
9	0,12	0,28	0,40	0,88	1,25	2,17	2,80	3,96	5,60	6,86	9,12
10	0,12	0,26	0,38	0,84	1,19	2,06	2,66	3,76	5,31	6,50	8,50
11	0,11	0,25	0,36	0,80	1,13	1,96	2,53	3,58	5,06	6,20	8,01
12	0,11	0,24	0,34	0,76	1,08	1,88	2,42	3,43	4,85	5,94	7,67
13	0,10	0,23	0,33	0,74	1,04	1,80	2,37	3,29	4,66	5,70	7,37
14	0,10	0,22	0,32	0,71	1,00	1,74	2,24	3,17	4,49	5,50	7,10
15	0,10	0,22	0,31	0,69	0,97	1,68	2,17	3,07	4,34	5,31	6,86

where G1 and G2 - the depth of the zone of contamination by the primary (secondary) cloud of potent toxic substances, km;

Γ_{min} - the minimum possible depth of the contamination zone with the primary (secondary) cloud of potent toxic substances, km;

Γ_{max} - the maximum possible depth of the pollution zone with the primary (secondary) cloud of potent toxic substances, km;

Q_{min} - the minimum possible amount of potent toxic substances in the primary (secondary) cloud, t;

Q_{max} - the maximum possible amount of potent toxic substances in the primary (secondary) cloud, t;

$Q_{э1}$ – the equivalent amount of potent toxic substances (t) in the primary cloud, calculated by the formula (3.2);

$Q_{э2}$ – equivalent amount of potent toxic substances (t) in the secondary cloud, calculated by the formula (3.5) [45,46].

The total depth of the contamination zone (Figure 5.4), due to the action of a primary or secondary cloud of potent toxic substances, is determined by the formula:

$$\Gamma = \Gamma' + 0{,}5\Gamma'', \qquad (5.11)$$

where Г ‘, Г“ - respectively, the largest and smallest of the sizes Г1 and Г2.

The maximum possible depth of air mass transfer is found by the following formula:

$$\Gamma_n = N\vartheta, \quad (5.12)$$

where N is the time from the start of the accident, h;
ϑ- transfer rate of the leading edge of infected air at a given wind speed and degree of vertical air stability, km / h (table 5.5).

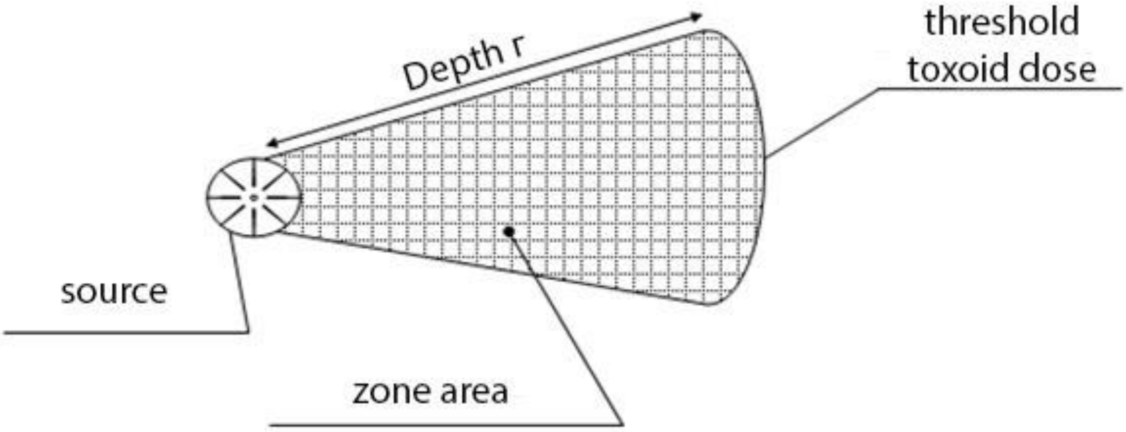


Figure 5.4 - Parameters of the chemical infection zone

Table 5.5 - Transfer rate of the leading edge of a cloud of polluted air depending on wind speed, km/h [45]

State of the atmosphere (degree of vertical stability)	Wind speed, m/s														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Inversion	5	10	16	21	-	-	-	-	-	-	-	-	-	-	-
Isothermy	6	12	18	24	29	35	41	47	53	59	65	71	76	82	88
Convection	7	14	21	28	-	-	-	-	-	-	-	-	-	-	-

The area of the zone of possible contamination for the primary (secondary) cloud of potent toxic substances is calculated by the formula

$$S_v = 8{,}72\cdot10^{-3}\Gamma^2\varphi, \quad (5.13)$$

where S_v - is the area of the zone of possible pollution of potent toxic substances, km^2;
φ – angular dimensions of the zone of possible pollution (table. 5.6).

The area of the actual contamination zone of potent toxic substances is calculated by the formula:

$$S_a = K_8\Gamma^2 N^{0,2}. \quad (5.14)$$

where S_a - is the area of the actual contamination zone by potent pollutants, km^2;

K_8 - a coefficient depending on the vertical stability of the air is assumed to be equal during inversion - 0,081; isothermy - 0.133; convection - 0.235;

Г - depth of the pollution zone, km;

N - time which passed after the start of the accident, h.

Table 5.6 - Angular dimensions of the zone of possible contamination with potent toxic substances depending on wind speed

Wind speed, m/s	Less than 0.5	0,6–1,0	1,1–2,0	More than 2
Angular dimensions, °	360	180	90	45

The time of approach of a cloud of potent toxic substances to a given object depends on the speed of transfer of the leading front of the cloud of polluted air and is determined from the ratio:

$$t = \frac{S_{(R)}}{\upsilon}, \tag{5.15}$$

where $S_{(R)}$ - distance from the source of pollution to a given object of protection, km;

υ – transfer speed of the leading front of polluted air, km/h.

In the event of the destruction of a chemically hazardous object, when predicting the depth of the contaminated zone, it is recommended to take data for the simultaneous release of the total stock of toxic substances at the object [45].

The equivalent amount of potent toxic substances in a cloud of polluted air is found by the formula:

$$Q_э = 20K_4K_5\sum_{i=1}^{n} K_{2i}K_{3i}K_{6i}K_{7i}\frac{Q_i}{d_i}, \tag{5.16}$$

where K4 is a coefficient that takes into account wind speed (table. 5.3);

K_5 - coefficient taking into account the degree of vertical stability of air (for inversion it is taken equal to 1, for isothermy - 0.23, for convection - 0.08);

K_{2i} – a coefficient depending on the physicochemical properties of the i-th potent toxic substance (table 5.1);

K_{3i} – a coefficient equal to the ratio of the threshold toxic dose of chlorine to the threshold toxic dose of the i-th potent toxic substance (table 5.1);

K_{6i} – coefficient depending on the time elapsed after the destruction of the object;

K_{7i} - temperature correction for the i-th potent toxic substance (table 5.1);

Q_i – reserves of the i-th potent toxic substance at the facility, t;

d_i – density of the i-th potent toxic substance at the facility, t/m^3 [45].

When carrying out the calculations, it is necessary to use the values of the degree of vertical air stability (Table 5.7), the values of time elapsed since the beginning of the accident, N to the degree of 0.8 (Table 5.8) and the values of time elapsed from the beginning of the accident, N to the degree of 0.2 (table. 5.9).

Table 5.7 - Determining the degree of vertical stability of air according to weather forecast [45]

Wind speed, m/s	Night		Morning		Day		Evening	
	clear, partly cloudy	overcast	clear, partly cloudy	overcast	clear, partly cloudy	overcast	clear, partly cloudy	overcast
Less than 2	in	is	is (in)	is	c (is)	is	in	is
2,0–3,9	in	is	is (in)	is	is	is	is (in)	is
4 and more	is	is	is	is	is	is	is	is

Note: in - inversion; is - isothermy; c - convection; letters in brackets - with snow cover.

Table 5.8 - the value of N in the degree of 0.8 [45]

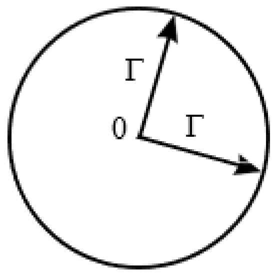
Whole numbers N	$N^{0,8}$ value at tenths									
	0	1	2	3	4	5	6	7	8	9
0	0,000	0,158	0,276	0,382	0,480	0,574	0,664	0,752	0,836	0,919
1	1,000	1,079	1,157	1,233	1,309	1,383	1,456	1,529	1,600	1,671
2	1,741	1,810	1,879	1,947	2,014	2,081	2,148	2,214	2,279	2,344
3	2,408	2,472	2,536	2,599	2,662	2,724	2,786	2,848	2,910	2,971
4	3,031	3,092	3,152	3,212	3,272	3,331	3,390	3,449	3,507	3,566
5	3,624	3,682	3,739	3,797	3,854	3,911	3,968	4,024	4,081	4,137
6	4,193	4,249	4,304	4,360	4,415	4,470	4,522	4,580	4,634	4,689
7	4,743	4,797	4,851	4,905	4,960	5,012	5,066	5,119	5,172	5,225
8	5,278	5,331	5,383	5,436	5,488	5,540	5,592	5,644	5,696	5,748
9	5,800	5,851	5,902	5,954	6,005	6,056	6,107	6,158	6,208	6,259
10	6,310	6,360	6,410	6,460	6,511	6,561	6,611	6,660	6,710	6,760

Table 5.9 - the value of N in the degree of 0.2 [45]

Whole numbers N	$N^{0,2}$ value at tenths									
	0	1	2	3	4	5	6	7	8	9
0	0,000	0,631	0,725	0,786	0,832	8,870	0,903	0,931	0,956	0,979
1	1,000	1,019	1,037	1,054	1,070	1,084	1,098	1,112	1,125	1,137
2	1,149	1,160	1,171	1,181	1,191	1,201	1,211	1,220	1,299	1,237
3	1,246	1,254	1,262	1,270	1,277	1,285	1,292	1,299	1,306	1,130
4	1,319	1,326	1,332	1,339	1,345	1,351	1,357	1,363	1,368	1,374
5	1,380	1,385	1,391	1,396	1,405	1,406	1,411	1,416	1,421	1,426
6	1,431	1,436	1,440	1,445	1,449	1,454	1,458	1,463	1,467	1,471
7	1,476	1,480	1,484	1,488	1,492	1,496	1,500	1,504	1,508	1,512
8	1,516	1,519	1,523	1,527	1,531	1,534	1,538	1,541	1,545	1,548
9	1,552	1,555	1,559	1,562	1,565	1,569	1,572	1,575	1,579	1,582
10	1,585	1,588	1,591	1,594	1,597	1,600	1,603	1,606	1,609	1,612

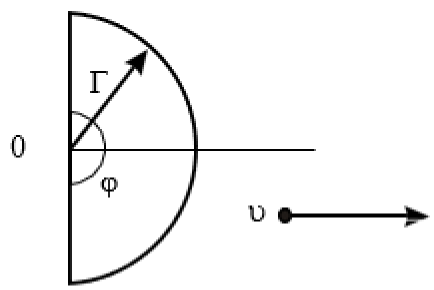
The procedure for applying pollution zones to topographic maps and schemes. The zone of possible cloud contamination of potent toxic substances on maps (schemes) is limited by a circle, a semicircle, or a sector having angular sizes φ and a radius equal to the depth (G) of the pollution zone. Angular dimensions depending on the wind speed according to the forecast are given in table. 5.6. The center of a circle, semicircle, or sector coincides with the source of pollution [45].

1. At a wind speed of less than 0.5 m/s, the pollution zone has a circle shape:



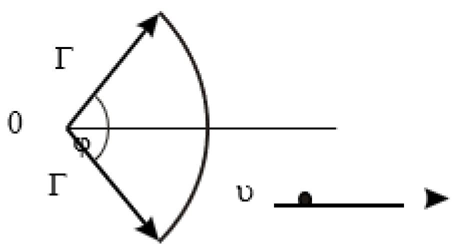
Point "0" corresponds to the source of pollution; angle φ = 360 °; the radius of the circle is equal to G.

2. At a wind speed of 0.6–1.0 m/s, the pollution zone has the form of a semicircle:



Point "0" corresponds to the source of pollution; angle φ = 180 °; the radius of the circle is G.

3. With a wind speed of more than 1 m / s, the pollution zone has the form of a sector:



Point "0" corresponds to the source of pollution; the radius of the sector is equal to G; the sector bisector coincides with the axis of the cloud trail and is oriented in the direction of the wind [45].

5.3.2 Assessment of radiation situation in emergency situations

The radiation situation is a combination of the effects of radioactive contamination of the area, affecting the activities of economic facilities, civil defense forces and the population.

The radiation environment is characterized by the size of the zones, the degree of radioactive contamination - the exposure dose rate (radiation level) and radiation doses until complete decay (Fig. 5.5, Table 5.10) [42,45].

According to the degree of radioactive contamination of the area and the possible consequences of external exposure, it is customary to distinguish four zones on it: moderate (zone A), strong (zone B), dangerous (zone C) and extremely dangerous (zone D) pollution.

Sources of contamination of the local pollution and atmosphere during a nuclear explosion are radioactive products (fragments of fission of nuclear fuel, part of the nuclear fuel and radioactive substances generated in the soil upon exposure to neutrons).

Assessment of radiation exposure includes:

- determination of the extent of radioactive contamination;

- analysis of the effect of radioactive contamination on the activities of facilities and the public;

- selection of the most appropriate options for actions in which radiation injuries are excluded [42,45].

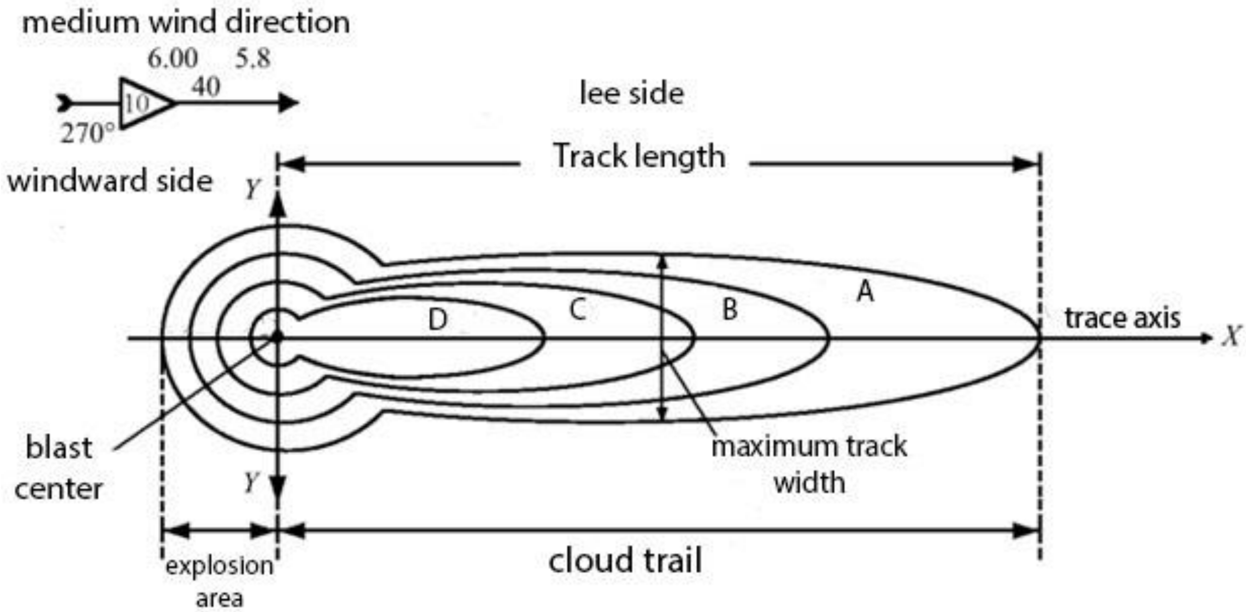


Figure 5.5 - Zones of Radioactive pollution [45]

Table 5.10 - Characterization of infection zones

Zone	$\dot{X}_{1h}$, R/h	$\dot{X}_{10h}$, R/h	$\dot{X}$, R/h
A	8-80	0,5-5	40-400
B	80-240	5-15	400-1200
C	240-800	15-50	1200-4000
D	More than 800	More than 50	More than 4000

Identification of possible radiation doses while on a polluted area. To determine the dose in an area contaminated with radioactive substances, it is necessary to know the time of the explosion, the power of the exposure dose (PED) for a certain time after the explosion, the length of time in the polluted area and the degree of protection of people (Table 5.11) [42,45].

The change in exposure dose rate in a contaminated area is characterized by the dependence

$$\dot{X}_t = \dot{X}_0\left(\frac{t}{t_0}\right)^{-1,2}, \tag{5.17}$$

where $\dot{X}_t$ is the exposure dose rate at the considered time t after the explosion, R/h;

he radiation dose over time from t_1 to t_2 will be

$$X = \frac{5(X_b t_1 - X_e t_2)}{K_a}, \tag{5.18}$$

or

$$X = \frac{5\dot{X}_1(t_b^{-0,2} - t_e^{-0,2})}{K_a}, \tag{5.19}$$

where $\dot{X}_b$ и $\dot{X}_e$ are the exposure dose rate at the beginning of t_b and at the end of t_e stay in the infection zone, R/h, respectively;
$\dot{X}_1$ - exposure dose rate for 1 h after the explosion, R/h;
K_a – shelter attenuation coefficient [45].

From the second day after the explosion or during short stays in the contaminated area (several hours) during the first day of exposure, it is advisable to use a simplified formula [45]:

$$X = \dot{X}_{av} t,$$

$$\dot{X}_{cp} = \frac{\dot{X}_1 + \dot{X}_2 + .. + \dot{X}_n}{n}, \tag{5.20}$$

where $\dot{X}_{av}$ - the average value of the exposure dose, Р/ч; n – number of exposure dose rate measurements; t – the time spent in the polluted area, h.

When overcoming areas of radioactive contamination, the calculation of possible doses is carried out according to the formula

$$X = \frac{\dot{X}_{av} L}{\upsilon K_a}, \tag{5.21}$$

where $\dot{X}_{av}$ - average value of exposure dose rate, R/h; L – route length, km; υ – speed of movement, km/h;K_a – attenuation coefficient by vehicles (tab. 3.12).

Table 5.11 - Dose received in an open area with an exposure dose rate (EDR) of 100 R/h for 1 h after an explosion [45]

The start time of exposure from the moment of the explosion, h	Duration of stay, h														
	0,5	1	2	3	4	6	7	8	10	12	14	16	18	20	24
0,5	74,5	11,3	158,0	186,0	204,0	231,0	240,0	249,0	262,0	273,0	282,0	289,0	295,0	301,0	310,0
1,0	39,9	64,8	98,8	121,0	138,0	161,0	170,0	178,0	190,0	201,0	209,0	216,0	222,0	228,0	237,0
1,5	25,8	44,8	72,8	91,0	106,0	127,0	135,0	142,0	154,0	164,0	172,0	179,0	185,0	190,0	199,0
2,0	19,0	34,0	56,4	72,8	85,8	105,0	113,0	119,0	131,0	140,0	148,0	155,0	161,0	166,0	174,0
2,5	14,9	28,0	46,2	61,6	72,5	90,4	97,6	103,0	115,0	123,0	131,0	137,0	143,0	149,0	156,0
3,0	12,2	22,4	38,8	51,8	62,4	77,8	84,6	91,9	100,0	110,0	117,0	124,0	130,0	134,0	142,0
4,0	8,8	16,4	29,4	40,2	56,6	66,6	69,4	74,7	83,8	91,6	98,3	104,0	109,0	114,0	122,0
5,0	6,8	13,0	23,6	32,4	40,0	52,8	58,0	62,8	71,2	78,5	84,7	90,2	95,3	99,8	108,0
6,0	5,5	10,6	19,4	27,0	33,8	45,0	49,8	54,2	62,0	68,7	74,5	79,8	84,6	88,9	96,6
7,0	4,7	9,0	16,5	23,3	29,3	39,4	43,4	47,8	55,1	61,6	66,7	71,6	76,1	80,2	87,2
8,0	3,9	7,6	14,4	20,4	25,6	34,8	38,8	42,6	49,3	55,1	60,4	65,2	73,5	69,5	80,5
9,0	3,5	6,8	12,8	18,1	22,9	31,3	35,1	38,6	45,3	50,4	55,2	59,6	63,7	67,3	73,4
10,0	3,1	6,0	11,2	16,0	20,4	28,2	31,7	34,9	40,7	46,0	58,8	55,1	59,7	62,8	69,4
12,0	2,5	4,8	9,2	13,2	17,0	23,7	26,7	29,5	34,8	39,6	43,9	47,9	51,4	54,7	60,8
16,0	1,8	3,5	6,7	9,7	12,5	17,8	20,3	22,6	26,9	30,9	34,6	37,9	41,1	44,1	48,8
20,0	1,4	2,7	5,3	7,8	10,1	14,4	16,6	18,4	22,1	25,4	28,5	31,1	33,5	35,9	40,6
24,0	1,1	2,2	4,3	6,3	8,3	12,0	13,7	15,8	18,5	24,1	23,8	26,2	28,6	30,9	35,1

Note. When calculating radiation doses for other values of the exposure dose rate, it is necessary to multiply the dose in the table by the ratio $\dot{X}/100$, where $\dot{X}$ is the actual exposure dose rate for 1 h after the explosion.

The attenuation coefficient can be calculated by the formula

$$K_a = 2^{\frac{h}{d}}, \tag{5.22}$$

where h is the thickness of the layer of protective material, cm; d - layer of half attenuation, cm (see table. 5.19).

Table 5.12 - γ-radiation attenuation coefficient by shelters and vehicles [45]

Name of shelters and vehicles	K_a
Open position on the terrain	1
Open trenches	3
Covered slots	50
Cars, buses	2
Railway platforms	1,5
Covered wagons	2
Passenger corrals	3
One-storey industrial buildings	7
Residential stone houses: one-storey basement	 10 40
two-storey basement	15 100
three-storey basement	20 400
five-storey basement	27 400
Residential wooden houses: one-storey basement	 2 7
two-storey basement	8 12
Shelters: Class 1	 5000
Class 2	3000
Class 3	2000
Class 4	1000
Anti-radiation shelters: of the 1st group	 1000
of the 2nd group	500
3rd group	200
4th group	100

Determination of the duration of people in in polluted areas. To determine the duration of people's stay in the contaminated area, it is necessary to know the time of entry (t_{en}) to the contaminated area (or the time of formation of radioactive contamination), the exposure dose rate (EDR) at the time of entry ($\dot{X}_{en}$) and the radiation dose that the population can receive (personnel of the units during emergency response), attenuation coefficient [47]

$$\frac{XK_a}{\dot{X}_{en}}$$

and according to its indications, depending on the time of entry or the beginning of irradiation, using table. 5.13, find the permissible time spent in the zone of radioactive contamination [45].

Table 5.13 - Permissible time spent in the area contaminated with radioactive substances, h.min [45]

$\frac{XK_a}{\dot{X}_{en}}$	The time elapsed from the moment of the explosion to the start of exposure									
	min	h.min								
	30	1	2	3	4	5	6	8	10	12	24
0,2	0.20	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
0,3	0.30	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20
0,4	0.40	0.30	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
0,5	1.00	0.40	0.35	0.35	0.30	0.30	0.30	0.30	0.30	0.30	0.30
0,6	1.10	1.00	0.45	0.45	0.40	0.40	0.40	0.40	0.40	0.40	0.40
0,7	1.30	1.10	0.50	0.50	0.45	0.45	0.45	0.45	0.45	0.45	0.45
0,8	1.40	1.30	1.00	1.00	0.50	0.50	0.50	0.50	0.50	0.50	0.50
0,9	2.00	1.40	1.10	1.10	1.00	1.00	1.00	1.00	0.55	0.55	0.55
1,0	3.10	2.00	1.20	1.20	1.20	1.10	1.10	1.10	1.00	1.00	1.00
1,2	12.0	3.10	2.00	2.00	1.30	1.30	1.30	1.25	1.20	1.20	1.20
2,0	31.0	12.0	4.00	3.10	2.45	2.35	2.30	2.20	2.10	2.10	2.10
2,5	without restriction	31.0	6.30	4.30	3.50	3.30	3.15	3.00	2.50	2.50	2.40
3,0		without restriction	10.0	6.00	5.00	4.30	4.00	3.50	3.30	3.30	3.15
4,0			24.0	11.0	8.00	7.00	6.00	5.45	5.00	5.00	4.30
6,0			without restriction	36.0	20.0	15.0	12.0	10.0	8.00	8.00	7.00
10,0				without restriction	without restriction	60.0	40.0	25.0	21.0	18.0	13.0

Note. Here X is the permissible dose of radiation; K_a - attenuation coefficient; $\dot{X}_{en}$ - exposure dose rate at the time of entry into a contaminated area or at the time of detection of radioactive substances.

Determination of the degree of radioactive contamination of equipment. The degree of radioactive contamination of equipment when performing tasks in a radioactively contaminated area can tentatively be estimated by the formulas from Table. 5.14 [42,45].

Table 5.14 - Assessment of the degree of pollution of equipment when performing tasks on a radioactively contaminated area

Types of infection	Pollution conditions, soil		
	dry weather	rain, wet soil	snowfall, snow cover
In case of radioactive dust (primary infection)	Q = 100X	Q = 500X	Q = 300X
When overcoming the zone (secondary infection)	$Q = 1{,}01X_{av}$	$Q = 1500X_{av}$	$Q = 500X_{av}$

Note. In these formulas, Q is the degree of contamination of the equipment, mR/h; X - power of the exposure dose at a given point in the terrain at the time of precipitation, R/h; X_{av} - the exposure dose rate on the route of movement, R/h.

Assessment of the radiation situation during an accident (destruction) of a nuclear power plant (NPP). Assessment of the radiation situation during an accident (destruction) of nuclear power plants is carried out using the following relationships [45]:

1) the decline in the level of radiation after an accident with the release into the environment of a mixture of radionuclides can be determined only by the equation

$$\dot{X}_t = \dot{X}_0\left(\frac{t}{t_0}\right)^{-0,4}, \tag{5.23}$$

where $\dot{X}_t$ – exposure dose rate at time t after the accident, R/h;
$\dot{X}_0$ – exposure dose rate at time t_0 after the accident, R/h;

2) calculation of radiation doses for the personnel of the nuclear power plant and the liquidators of the accident is carried out according to the formula

$$X = 1{,}7(\dot{X}_2 t_2 - \dot{X}_1 t_1), \tag{5.24}$$

or taking into account the attenuation coefficient

$$X = \frac{1{,}7(\dot{X}_2 t_2 - \dot{X}_1 t_1)}{K_a}, \tag{5.25}$$

where X is the dose of radiation, R;
$\dot{X}_1$ и $\dot{X}_2$ – are the exposure dose rate at the beginning of t_1 and at the end of t_2 stay in the infection zone, R/h, respectively;
K_a - attenuation coefficient.

Example 1. Civil defense formation will have to work for (T) 6 hours in a radioactively contaminated area (K_a=1). Determine the radiation dose that the formation personnel will receive when entering the zone 4 hours (t_b) after the accident, if the exposure dose rate by this time was $\dot{X}_4$ = 5 R/h.

Decision.

1. Find the end time of exposure:

$$t_e = t_b + T = 4 + 6 = 10 \text{ h.}$$

2. По уравнению (3.23) рассчитываем МЭД на 10 ч после аварии:

$$\dot{X}_t = \dot{X}_0\left(\frac{t}{t_0}\right)^{-0,4} = 5 \cdot \left(\frac{10}{4}\right)^{-0,4} = 3,47 \text{ R/h.}$$

3. According to equation (24), we calculate the radiation dose that the formation personnel will receive during the work:

$$X = 1,7(\dot{X}_{10}t_{10} - \dot{X}_4 t_{10}) = 1,7 \cdot (3,47 \cdot 10 - 5 \cdot 4) = 25 \text{ R.}$$

Example 2. Determine the permissible duration of the work of the group of emergency responders in a contaminated area if the measured exposure dose rate at the entrance to the area after t_b=2 hours after the accident was $\dot{X}_2$ = 3 R/h. Permissible dose of radiation X_p = 10 R, K_a=1.

Decision.

1. Find the coefficient, *a*:

$$a = \frac{\dot{X}_1}{X_p K_a} = \frac{\dot{X}_2}{K_2 X_p K_a} = \frac{3}{0,76 \cdot 10 \cdot 1} = 0,4$$

(at t_b = 2, the coefficient K_2 = 0.76 is determined by the table. 3.15).

2. According to the table 17 with a=0.4 and t_b=2 hours, we obtain the permissible operating time t_p = 4 hours.

Equations (5.23) - (5.25) are used to determine the exposure dose rate and doses for the total exposure to the emergency release radionuclide mixture for approximately 10 years after the accident. During this period, the bulk of short-lived radionuclides decays, and the radiation dose will depend on contamination with long-lived radionuclide cesium-137 (half-life $T_{1/2}$ = 30 years). The coefficient K_t for recalculating the exposure dose rate for different times t after the accident is determined according to table 5.15, and the permissible duration of people in a radioactively contaminated area during an accident (destruction) of nuclear power plants is determined according to table 5.16 [45].

To calculate the exposure dose rate and doses in this case, the following formulas can be used:

$$\dot{X}_t = \frac{\dot{X}_0}{2^{\frac{t}{T_{1/2}}}}, \qquad (5.26)$$

where $\dot{X}_t$ is the exposure dose rate at the considered time t, R/h;
$\dot{X}_0$ - initial exposure dose rate corresponding to the initial surface activity (level of contamination) of the radionuclide, R/h;
t – time counted from the initial activity (initial pollution level), h;
$T_{1/2}$ – half-life of the radionuclide, year [45].

Then the radiation dose for the time from t_1 to t_2 will be

$$X = \frac{1{,}44 T_{1/2} \dot{X}_0 \left(2^{\frac{t_1}{T_{1/2}}} - 2^{\frac{t_2}{T_{1/2}}} \right)}{K_{осл}}, \qquad (5.27)$$

Table 5.15 - Coefficient $K_t = t^{0,4}$ for recalculating the exposure dose for various times t after an accident (destruction) of a nuclear power plant

t, h	K_t	*t*, h	K_t	*t*, h	K_t	*t*, h	K_t	*t*, h	K_t	*t*, h	K_t
0,5	1,32	3,5	0,61	6,5	0,474	9,5	0,408	16	0,33	120	0,146
1,0	1,0	4,0	0,575	7,0	0,465	10,0	0,4	20	0,303	144	0,137
1,5	0,85	4,5	0,545	7,5	0,474	10,5	0,39	24	0,282	168	0,129
2,0	0,76	5,0	0,525	8,0	0,434	11,0	0,385	48	0,213	192	0,122
2,5	0,7	5,5	0,508	8,5	0,427	11,5	0,377	72	0,182	216	0,116
3,0	0,645	6,0	0,49	9,0	0,417	12,0	0,37	98	0,162	240	0,112

Table 5.16 - Permissible length of stay of people in a radioactively contaminated area during an accident (destruction) of a nuclear power plant, hours

$a = \frac{\dot{X}_1}{X_p K_a}$	The time that has passed from the moment of the accident to the start of irradiation, tb, h							
	1	2	3	4	6	8	12	14
0,2	7.30	8.35	10.00	11.30	12.30	14.00	16.00	21.00
0,3	4.50	5.35	6.30	7.10	8.00	9.00	10.30	13.30
0,4	3.30	4.00	4.35	5.10	5.50	6.30	7.30	1.00
0,5	2.45	3.05	3.35	4.05	4.30	5.00	6.00	7.50
0,6	2.15	2.35	3.00	3.20	3.45	4.10	4.50	6.25
0,7	1.50	2.10	2.30	2.40	3.10	3.30	4.00	5.25
0,8	1.35	1.50	2.10	2.25	2.45	3.00	3.30	4.50
0,9	1.25	1.35	1.55	2.05	2.25	2.40	3.05	4.00
1,0	1.15	1.30	1.40	1.55	2.10	2.20	2.45	3.40

Note. $\dot{X}_1 = \frac{\dot{X}_b}{K_t}$, $\dot{X}_b$ - exposure dose rate at the beginning of exposure; K_t – a coefficient that corresponds to the initial exposure time (table. 5.15).

For practical calculations according to formula (5.27), it is necessary to know the value $\dot{X}_0$ corresponding to a given level of contamination with a radionuclide. When solving this problem, use the dependence

$$\dot{X}_0 = 0{,}2\,\mu E A n, \qquad (5.28)$$

where $\dot{X}_0$ –is the exposure dose rate at time t_0 after the accident, R/h;
μ – linear attenuation coefficient (table. 5.17);
E – energy γ-rays MeV;

A – surface activity of initial pollution, Ci/km^2;
n – the number of γ-rays per one decay.

Table 5.17 - Linear attenuation coefficient of γ radiation by air

E, MeV	0,1	0,25	0,5	0,7	1,0	2,0	3,0
$\mu \cdot 10^{-4}$, cm^{-1}	1,98	1,46	1,11	0,95	0,81	0,57	0,46

Example 3. Determine the exposure dose rate in the area contaminated with cesium-137 radionuclide, 10 and 20 years after the accident, if the initial exposure dose rate was $\dot{X}_0$ = 20 mR/h. The half-life of cesium-137 is $T_{1/2}$ = 30 years.

Decision.

The decrease in the exposure dose rate due to contamination of the area with one radionuclide occurs in accordance with equation (5.26):

$$\dot{X}_t = \frac{\dot{X}_0}{2^{\frac{t}{T_{1/2}}}};$$

$$\dot{X}_{10\ \text{лет}} = \frac{20}{2^{10/30}} = 15{,}9 \text{ mR/h};$$

$$\dot{X}_{20\ \text{лет}} = \frac{20}{2^{20/30}} = 12{,}6 \text{ mR/h}.$$

Example 4. Determine the dose of the population when living in areas with surface pollution activity of cesium-137 A = 5 Ci/km^2 for a period of t_1=10 years to t_2 = 70 years after the accident. The half-life of cesium-137 is $T_{1/2}$ = 30 years, the energy of γ-quanta is E = 0.7 MeV, the number of γ-quanta per decay is n = 1. The attenuation coefficient of γ-radiation K_a = 2.5.

Decision.

1. Using equation (3.28), we calculate the exposure dose rate corresponding to the initial activity surface A = 5Ci/km^2.

$$\dot{X}_0 = 0{,}2\mu EAn = 0{,}2 \cdot 0{,}95 \cdot 10^{-4} \cdot 5 \cdot 0{,}7 \cdot 1 = 6{,}6 \cdot 10^{-4} \text{ R/h}.$$

2. The exposure dose rate $\dot{X}_0$ obtained in R/h is converted to R/year and substituted into equation (27):

$$6{,}6 \cdot 10^{-4} \cdot 365 \cdot 24 = 0{,}58 \text{ Р/год}.$$

2. Using equation (3.27), determine the radiation dose:

3. $$X = \frac{1{,}44 T_{1/2} \dot{X}_0 \left(2^{\frac{t_1}{T_{1/2}}} - 2^{\frac{t_2}{T_{1/2}}}\right)}{K_{осл}} = \frac{1{,}44 \cdot 30 \cdot 0{,}58 \cdot \left(2^{-1030} - 2^{-70/30}\right)}{2{,}5} = 6{,}2 \text{ R}.$$

When radioactive particles fall out of the cloud, not only the terrain is infected, but also objects, objects, equipment located on it. This is the primary infection of objects. In dry weather, radioactive dust that has fallen on the ground under the influence of wind can again rise into the air and become a source of secondary infection.

Possible population losses from exposure are determined depending on the size of the dose and the time it was received (table. 5.18) [45].

Table 5.18 - Radiation losses due to external exposure,%

The total dose of radiation, R	Radiation losses during exposure, days				The total dose of radiation, R	Radiation losses during exposure, days			
	4	10	20	30		4	10	20	30
100	–	–	–	–	275	95	80	65	50
125	5	2	–	–	300	100	95	80	65
150	15	7	5	–	325	100	98	90	80
175	30	20	10	5	350	100	100	95	90
200	50	30	20	10	400	100	100	100	95
225	70	50	35	25	500	100	100	100	100
250	85	65	50	35					

Table 5.19 - the Size of the layers of half attenuation of ionizing radiation for some materials

Material	Density, g cm^3	Layer of half attenuation $d_{1/2}$, cm	
		for γ-radiation	for neutrons
Concrete	2,3	5,6	12,0
Water	1,0	13,0	2,7
Soil	1,8	7,2	12,0
Wood	0,7	19,0	9,7
Brick	1,6	8,4	10,0
Polyethylene	0,95	14,0	2,7
Plumbum	11,3	1,3	12,0
Steel	7,8	1,8	11,5
Ice	0,9	14,5	3,0

5.3.3 Dosimetry of ionizing radiation

Ionization is a phenomenon (process) of formation of positive and negative ions and free electrons from electrically neutral atoms and molecules.

Ionizing radiation - flows of particles and electromagnetic quanta, the interaction of which with the medium leads to the ionization of its atoms and molecules. Ionizing radiation is divided into photonic (electromagnetic) and corpuscular (particle fluxes), and by the mechanism of action on a substance they can be directly or indirectly ionizing (Figure 5.6) [42,45].

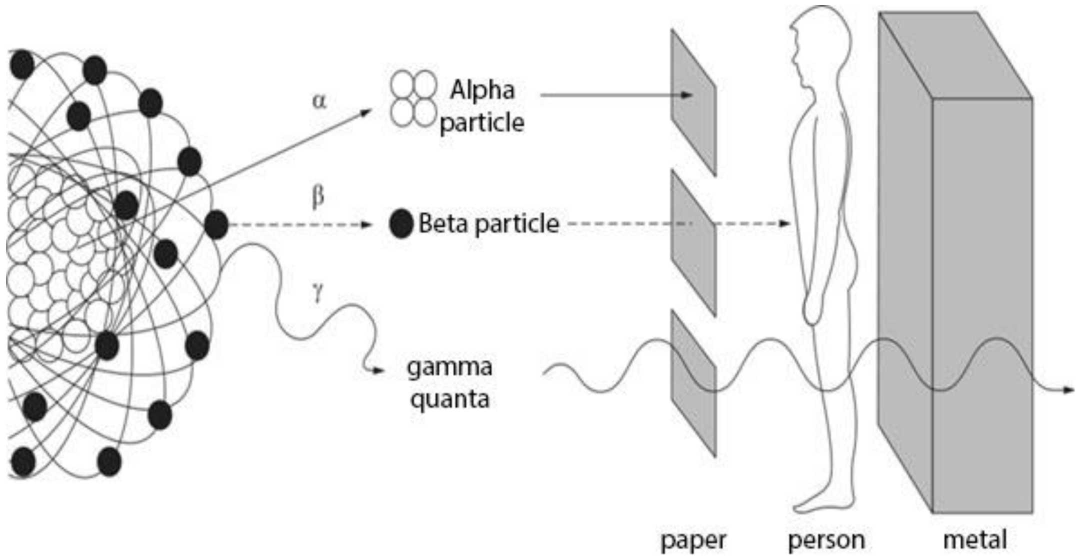


Figure 5.6 - Penetrating ability of various types of ionizing radiation

Photon radiation is electromagnetic radiation (γ-radiation, X-ray and bremsstrahlung). Photon radiation has the same nature of formation as visible light or radio waves, but differs from them only in a shorter wavelength or greater stiffness. With increasing frequency, the energy of the quanta of the electromagnetic field (photons), and, consequently, their destructive effect on the molecules of matter increases. The wavelength λ of X-ray radiation lies in the range from 10–100 nm to 0.01–1 pm, and γ radiation is less than 0.1 pm. The photon energy is related to their wave characteristics by the relations $\varepsilon = h\nu = hc/\lambda$, where h is the Planck constant; ν is the frequency; c is the speed of light. It follows that the energy of X-ray quanta lies in the range from 10–100 eV to 1–100 MeV, and that of γ-quanta exceeds 10 keV [47].

Corpuscular radiation is flows of elementary particles that have a mass other than zero. Most of them are charged particles: β- particles (β^-– are electrons and β^+ are positrons), protons (hydrogen nuclei), deuterons (heavy hydrogen nuclei - deuterium), α particles (helium nuclei) and heavy ions (nuclei of others elements that received high energy in special accelerators). Corpuscular radiation also includes neutrons - nuclear particles that do not have a charge and indirectly cause ionization [45].

The effect of ionizing radiation on a substance is manifested in the ionization and excitation of atoms and molecules of a substance. A quantitative measure of the effect of radiation on a substance is the dose of radiation.

The radiation dose is the amount of energy of ionizing radiation absorbed by a unit mass of the irradiated medium. Distinguished absorbed, exposure and equivalent dose of radiation.

The absorbed dose of radiation is the amount of energy of any kind of ionizing radiation absorbed by the unit mass of any substance

$$D = \frac{dE}{dm}, \qquad (5.29)$$

where *dE* - the absorbed radiation energy; *dm* - mass of substance [47].

The absorbed dose is a quantitative measure of the effect of ionizing radiation on a substance. The unit of measurement of the absorbed dose is gray (Gy) [45].

Gray - absorbed dose of radiation corresponding to an energy of 1 J of ionizing radiation of any kind transferred to an irradiated substance weighing 1 kg

$$1 \text{ Gy} = 1 \text{ J/kg}.$$

In practice, an off-system unit is used - rad (rad - according to the first letters of the English phrase “radiation absorbet dose”). A dose of 1 rad means that in every gram of the substance exposed, 100 erg of energy is absorbed:

$$1 \text{ rad} = 100 \text{ erg/g} = 0.01 \text{ J/kg} = 0.01 \text{ Gy},$$

$$\text{i.e. } 1 \text{ Gy} = 100 \text{ rad } (1 \text{ erg}=10 \text{ J}).$$

Exposure dose of radiation. To characterize the x-ray and γ-radiation by the ionization effect, an exposure dose is used. This dose expresses the energy of photon radiation, converted into kinetic energy of secondary electrons that produce ionization per unit mass of atmospheric air.

An exposure dose of X is used as a characteristic of the effect of photon radiation with energies from 5 keV to 3 MeV on the environment [45].

Exposure dose of photon radiation – this is the ratio of the total charge dQ of all ions of the same sign formed in dry atmospheric air (with complete deceleration of secondary electrons and positrons) in the elementary volume dV to the air mass dm in this volume

$$X = \frac{dQ}{dm}, \tag{5.30}$$

In sitseme units exposure dose measured in coulombs per kilogram (C / kg) and extra-systemic unit is roentgen (R).

Roentgen is a dose of photon radiation at which in 1 cm^3 of dry atmospheric air as a result of ionization under normal conditions (temperature 0 °C, pressure 101.3 kPa or 760 mm Hg), a charge q equal to $3.34 \cdot 10^{-10}$ C of each sign is formed, which corresponds to the formation of $2.08 \cdot 10^9$ ion pairs. 1 cm^3 of air has a mass of $1.29 \cdot 10^{-6}$ kg, then:

$$1 \text{ R} = \frac{3{,}34 \cdot 10^{-10}}{1{,}29 \cdot 10^{-6}} = 2{,}58 \cdot 10^{-4} \text{ C/kg}.$$

Thus,

$$1 \text{ R} = 2{,}58 \cdot 10^{-4} \text{ C/kg};$$

$$1 \text{ C/kg} = 3{,}88 \cdot 10^{3} \text{ R}.$$

Under the conditions of radiation equilibrium of charged particles, an exposure dose of 1 C / kg corresponds to an absorbed dose of 33.8 Gy in air and 36.9 Gy in biological tissue [45,47].

A dose of 1 R corresponds to an absorbed dose of 0.87 rad in air or 0.96 rad in biological tissue. Therefore, in tissues with an error of up to 5%, the exposure dose in x-rays and the absorbed dose in rad can be considered the same.

Equivalent dose of radiation. Due to the different ionizing ability of α-, β- and γ-radiation, even with the same absorbed dose, they have different damaging biological effects.

To assess the degree of radiation hazard from exposure to ionizing radiation, when irradiation is uniform across all body tissues, the concept of an equivalent dose is used.

The difference in the magnitude of the radiation exposure can be taken into account by assigning to each type of radiation its own weighting coefficient of radiation W_R (Table 5.20).

Thus, the weighting coefficient (quality factor) of radiation characterizes the degree of destructive effect on a biological object and shows how many times this type of radiation is more dangerous than photon radiation at the same absorbed dose D [45,47].

Table 5.20 - Weighing coefficients W_R for individual types of ionizing radiation (in accordance with NRB-2000)

Type of radiation	W_R
X-ray and γ-radiation (of any energy)	1
β-radiation (electrons, positrons)	1
Neutrons with energy:: - less than 10 keV	 5
– from 10 to 100 keV	10
– from 100 keV to 2 MeV	20
– from 2 to 20 MeV	10
– more than 20 MeV	5
Protons with an energy of more than 2 MeV	5
α particles, fission fragments, heavy nuclei	20

From the table. 5.20 it is seen that γ-quanta and electrons affect organic tissue equally and for them W_R=1. For α-particles, W_R=20. An equivalent dose is defined as the product of the average absorbed dose of $D_{T,R}$ in an organ or tissue and the corresponding weighting coefficient for a given type of radiation W_R:

$$H_{T,R} = W_R D_{T,R} \tag{5.31}$$

The unit of equivalent dose in the system of units is sievert (Sv). In practice, fractional units are often used:

$$1\ \text{mSv} = 10^{-3}\ \text{Sv};\ 1\ \mu\text{Sv} = 10^{-6}\ \text{Sv}.$$

In accordance with formula (42) for ionizing radiation with a weighting coefficient equal to unity W_R = 1:

$$1\ \text{Sv} = 1\ \text{Gy} = 1\ \text{J/kg}.$$

Rem (biological equivalent of Rad) is used as an off-system unit of equivalent dose:

1 Sv = 100 rem; 1 rem = 0.01 Sv = 1 cSv; 1 mSv = 0.1 rem

The equivalent dose is calculated for some conventional tissue of the human body. The relationship between the units is given in table. 5.21.

Table 5.21 - Connection between units doses [45]

Dose	Units		transfer
	in SI system	off-system	
Expositional	Pendant per kilogram of air (C/kg)	Roentgen (R)	1 C/kg = 3876 R
Absorbed	Gray (Gr)	rad	1 Gr = 100 rad
Equivalent	Sievert (Sv)	rem	1 Sv = 100 rem

Effective radiation dose. When the irradiation of different tissues of the body is heterogeneous, the concept of an effective dose is introduced to evaluate its effect on the whole organism. This is a measure of the risk of the long-term effects of exposure to the human body (organs), taking into account the radiosensitivity from exposure to ionizing radiation.

The effective dose is the sum of the products of the equivalent dose of H_T in organs and tissues by the corresponding weighting coefficients W_T

$$E = \sum_T W_T H_T, \tag{5.32}$$

where W_T – weighting coefficient (radiation risk coefficient) equal to the ratio of the risk of irradiation of a given organ or tissue to the total risk with uniform exposure of the whole body [45,47].

The coefficients W_T make it possible to take into account the effect of irradiation, regardless of whether the whole body is irradiated uniformly or unevenly. Values of weighting coefficients for tissues and organs are given in table. 5.22 The sum of the weighting coefficients for the whole organism is equal to the unit $\sum_i W_T = 1$.

The effective dose, as well as the equivalent, in the SI system is measured in sievert (Sv), the off-system unit is rem.

To assess the effects of public exposure, the annual effective dose is used, which takes into account the total (total) exposure for a calendar year and includes a dose of external and internal exposure to radionuclides received by the human body [45].

In chronic use of food contaminated with cesium-137, the calculation of the individual dose of internal radiation is carried out according to the formula:

$$H = k\sum_i m_i A_{mi}, \tag{5.33}$$

where k is the dose coefficient for cesium, equal to $1.3 \cdot 10^{-8}$ Sv/Bq;

m_i is the annual consumption of the i-th food product, kg;

A_{mi} - specific activity of the i-th product, Bq/kg

Table 5.22 - Weighing coefficients WT for individual organs and tissues [45]

Organ or tissue	W_T
Gonads	0,20
Red bone marrow	0,12
Large intestine	0,12
Lungs	0,12
Stomach	0,12
Bladder	0,05
Breast	0,05
Liver	0,05
Esophagus	0,05
Thyroid gland	0,05
Skin	0,01
The surface of the bone tissue	0,01
The remaining tissue	0,05
Total	1,00

Dose rate and units of measure. Dose rate (radiation level) may vary over time. The radiation dose per unit of time is called the *dose rate, or radiation level*.

Dose rate measurement determines the time during which doses are created that do not cause a dangerous biological effect in the body or cause damage to it [47,48].

Exposure dose rate $\dot{X}$ is the ratio of the exposure dose to time

$$\dot{X} = \frac{dX}{dt}, \tag{5.34}$$

The unit of measurement of the exposure dose rate is the pendant per second per kilogram - *ampere per kilogram*

1 C / (kg·s) = l A/kg, since 1 C/s = 1 A.

In practice, a non-systemic exposure dose unit - roentgen per second (F/s) and milliroentgens per hour (mR/hr)

$1 \text{ R/h} = 2.8 \cdot 10^{-4} \text{ R/s};$

$1 \text{ mR/h} = 2.8 \cdot 10^{-7} \text{ R/s}.$

Absorbed dose rate $\dot{D}$ - ratio of absorbed radiation dose to time

$$\dot{D} = \frac{dD}{dt}, \tag{5.35}$$

The unit of measurement of the absorbed radiation dose rate is joule per second per kilogram (J / (kg · s)), and the non-system unit is rad per second (rad / s).

Equivalent dose rate $\dot{H}_T$ - ratio of increment of the equivalent dose dH_T over the period of time *dt* to this time [45]

$$\dot{H}_T = \frac{dH_T}{dt}, \quad (5.36)$$

The unit of equivalent dose rate in SI is Sv/s or Sv/h. The off-system unit is rem/s or rem/h.

5.4 Assessment of the sustainability of the functioning of object of economy in an emergency

The stability of the object is its physical stability, ability to withstand natural disasters, accidents (catastrophes) and modern means of destruction, that is, the ability to continue working in emergency situations [45].

Initial data for assessing the stability of the facility:

- characteristics of the structures of buildings and structures, their strength and fire resistance;
- characteristics of industrial equipment (machine tools, control equipment, automated systems, etc.);
- characteristics of buildings, premises (category) for fire and explosion resistance;
- characteristic of communal energy networks;
- characteristics of the territory of the facility and the infected area.

Assessment of the stability of the object can be performed in the following sequence:

- assessment of engineering protection of personnel of the economy;
- assessment of the sustainability of the engineering complex.

For the functioning of the economy in emergency situations, it is necessary to ensure the physical stability of the engineering complex and personnel security (provision of personal protective equipment and protective structures at the facility with the largest work shift) [45,48].

Assessment of the stability of the engineering complex to the effects of an air-gas mixture explosion. *The engineering and technical complex* of the facility includes buildings and structures, technological equipment and communications, power networks, heating networks, water supply, sewage and a gas pipeline.

Destruction and damage of buildings, structures, technological installations and pipelines in oil refining, chemical and some other industries with explosive, gas and fire hazardous technologies can lead to the outflow of gaseous or liquefied hydrocarbon products and potent toxic substances. When hydrocarbon products are mixed with air, explosive or fire hazardous mixtures are formed, and along the trail of a toxic cloud - zones of dangerous chemical pollution [45].

Explosive mixture - a mixture with air of gases, flammable liquids, combustible dust or fibers.

An explosion is a rapidly proceeding process of physical or chemical transformation of substances, accompanied by the release of a large amount of energy in a limited volume, as a result of which a shock wave is formed and propagates in the surrounding space, which can pose a threat to human life and health, cause material damage, damage the environment and become a source emergency [47,48].

In most explosions, the source of energy release is chemical transformations of substances associated with oxidation. There are many substances in which a large amount of energy is stored in one form or another in the form of intramolecular and intermolecular bonds. These substances are quite stable and can be in a solid, liquid, gaseous or aerosol state under normal conditions. However, as a result of the initiating action (heat, friction), exothermic processes begin in them, proceeding at a high speed and leading to an explosion.

The most common condensed (solid) explosives are trotyl, hexogen, black powder, pyroxylin, ammonal, etc.

Explosions of condensed explosives proceed in the detonation mode, in which the blast wave in the charge propagates at a constant speed.

Examples of explosions in which the energy release is due to physical processes are the emergency pouring of molten metal into water, in which the evaporation proceeds in an explosive manner due to extremely rapid heat transfer, and the explosions of compressed or liquefied gases. In this case, the energy is determined by the processes associated with the adiabatic expansion of vapor-gas media and overheating of liquids [49].

At industrial enterprises, the most explosive gas-air and dust-air mixtures formed in normal or emergency situations are.

Of the gas-air mixtures, the most dangerous are explosions of mixtures with air of hydrocarbon gases, as well as vapors of flammable liquids (table 5.23) [45].

Explosive combustion is based on fast-flowing chemical reactions of oxidation of combustible materials with atmospheric oxygen. The main parameter characterizing the explosion hazard is the concentration limits of flame propagation (ignition).

The lower (upper) concentration limit of ignition is the minimum (maximum) content of fuel in a mixture of a combustible substance - an oxidizing environment, in which the flame can propagate through the mixture at any distance in the presence of an ignition source (flame, spark, heated body). Within these limits, the mixture is combustible, and outside them - the mixture is not capable of burning [45].

Table 5.23 - Explosive limits of a mixture of some gases and vapor with air [45]

Gas or vapor	Explosive limit, vol%		Gas or vapor	Explosive limit, vol%	
	lower	upper		lower	upper
Ammonia	15,5	27,0	Propylene oxide	2,0	22,0
Acrylonitrile	3,0	17,0	Carbon monoxide	12,5	74,2
Acetylene	2,2	80,0	Ethylene oxide	3,0	80,0
Acetone	2,0	13,0	Propane	2,4	9,5
Gasoline	1,2	7,0	Propylene	2,0	11,0
Benzene	1,4	9,5	Pentane	1,4	7,8
Butane	1,9	8,4	Carbon disulphide	1,0	50,0
Butylene	1,7	9,0	Hydrogen sulfide	4,3	45,5
Hydrogen	4,0	75,2	Hydroc yanic acid	5,6	40,0
Hexane	1,2	7,0			
Heptane	1,0	6,0	Toluene	7,0	49,8
Heptyl	4,7	100,0	Chlorine	3,5	17,0
Dichloroethane	6,2	15,9	Cyclohexane	1,0	9,0
Kerosene	1,0	7,0	Ethane	3,2	12,5
Xylene	3,0	7,6	Ethylene	2,8	28,6
Methane	5,0	15,0	Ethanol	19,0	67,0
Methyl alcohol	5,5	37,0	Ethyl ether	1,85	40,0
			Ethyl bromide	7,0	11,0
Methyl chloride	8,0	20,0	Ethyl chloride	3,5	14,8

The value of the lower and (upper) concentration limit of ignition is used when calculating explosion-proof concentrations of a gas-air mixture and a dust-air mixture inside technological equipment, pipelines, ventilation systems, as well as for a comparative assessment of the explosion hazard of substances.

The concentration limits of ignition in volume percent when calculating the explosion-proof concentrations of the gas-air mixture and the dust-air mixture must be converted to grams per cubic meter using the following equation [45]:

$$\mathrm{K_x} = \frac{\mathrm{XM}}{V_t} \tag{5.37}$$

where K_x – gas concentration in air, g/m^3;

X – gas concentration in air, vol.%;

M – molecular weight of gas, g;

V_t – volume of 1 mole of gas under these conditions, m^3 (at a temperature of 18–20 °C, take the volume of 1 mole equal to $22.4\cdot10^{-3}$ m^3).

Explosion (combustion) of a gas-air mixture. This process occurs when leaks or sudden destruction of sealed containers, pipelines with hydrocarbon gases.

The initiators of combustion or explosion in these conditions are most often accidental.

In the explosion of a gas-air mixture containing 100-200 tons or more of gas, an explosion center is formed, in which it is customary to distinguish three circular zones (Fig. 5.7) [45].

The first zone is the zone of the detonation wave within the explosion cloud (the zone of complete destruction). The damaging effect is characterized by excess pressure in the front of the detonation wave (ΔP_1) within the gas-air mixture, which is about 1700 kPa. The radius of the zone can be determined by the formula [45]

$$r_1 = 17{,}5\sqrt[3]{Q} \tag{5.38}$$

where Q is the amount of liquefied hydrocarbon gases, i.e.

The second zone is the zone of action of explosion products, which covers the entire area of expansion of the products of the gas-air mixture as a result of its detonation. The radius of this zone is calculated by the formula

$$r_2 = 1{,}7r_1 \tag{5.39}$$

Excess pressure (ΔP_2) in the second zone decreases to 300 kPa with distance [45,47].

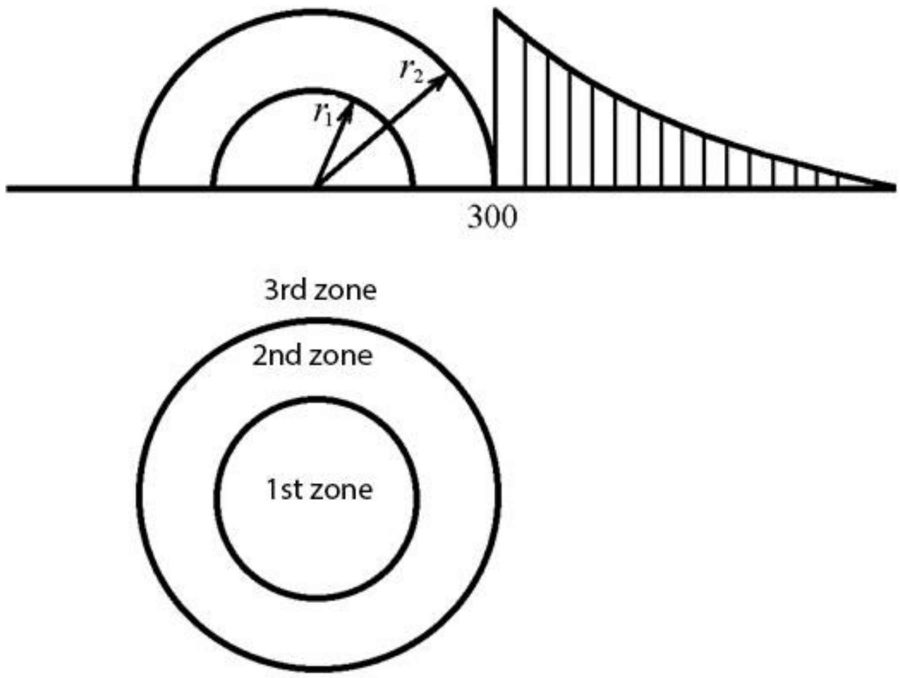


Figure 5.7 - Scheme of explosion of a gas-air mixture

The third zone is the zone of action of the air blast wave. In this zone, a shock wave front is formed, which propagates along the earth's surface. The magnitude of the excess pressure in the shock front (ΔP_3) and the distance at which these pressures act (R_3) are determined according to the graph (Fig.5.8) depending on the amount of hydrocarbon mixture Q [45,47].

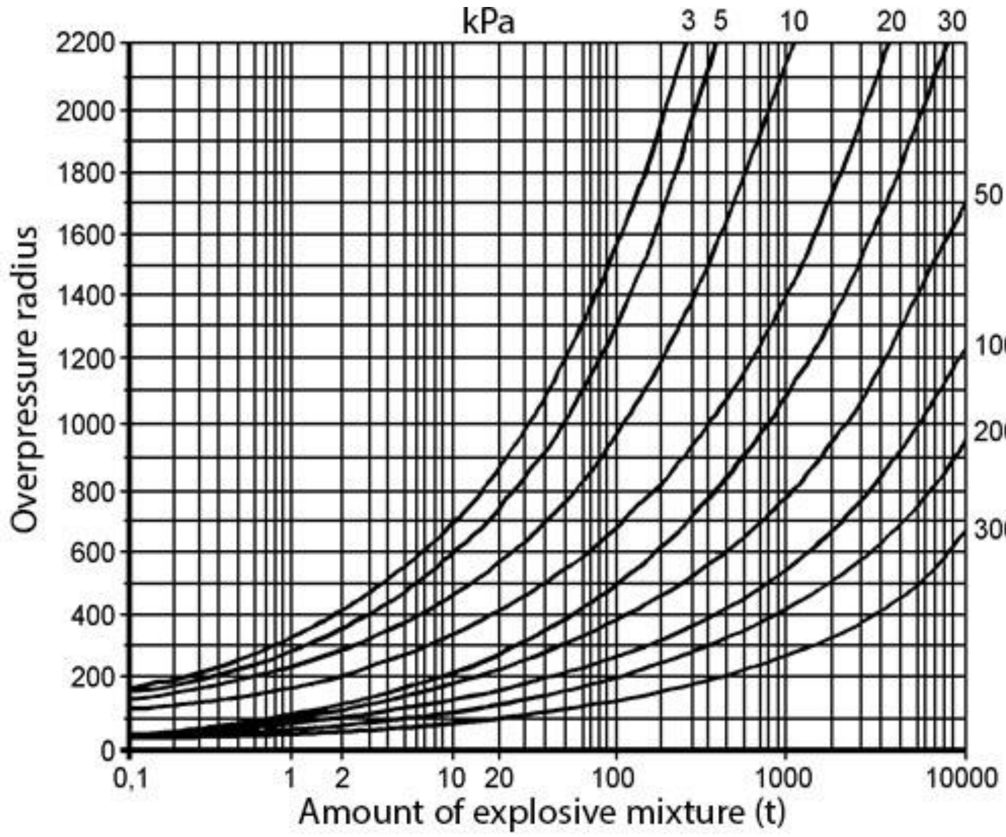


Figure 5.8 - Dependence of the radius of the overpressure zone on the amount of explosive mixture

5.5 Assessment of engineering protection of facility personnel

Engineering protection of personnel is a set of measures aimed at creating a fund of structures that protect the population and workers in production from the damaging factors of emergency situations.

Assessment of protective structures (Figure 5.9) by capacity. We calculate the number of places for the main premises to be sheltered on the available area based on the established norms per person [45]

$$\mathrm{M}_i = \frac{S_m}{S_1}, \quad \mathrm{M}_{\text{общ}} = \sum \mathrm{M}_i \qquad (5.40)$$

where S_m is the area of the main room for those sheltered in protective structures, m^2;

S_1 – the norm of the area of the main room for one sheltered person, m^2.

It is necessary to check the compliance of the volume of the premises in the sealing zone with the established norm for one sheltered one (at least 1.5 m^3/person) [45,48]

$$V_1 = \frac{S_o \cdot h}{\text{M}} \qquad (5.41)$$

where V_1 is the volume of the room per one sheltered person, m^3;
S_0 – the area of all buildings, m^2;
h – room height, m;
M_1- number of places for sheltered people in the shelter.

Check the compliance of the area of the auxiliary premises with the established norms

$$S_a = M \cdot S_1 \qquad (5.42)$$

where S_a – area of auxiliary premises, m2;
M – number of places for sheltered people;
S_1 – the norm of the area of the auxiliary room for one sheltered person, m2 (table 5.24).

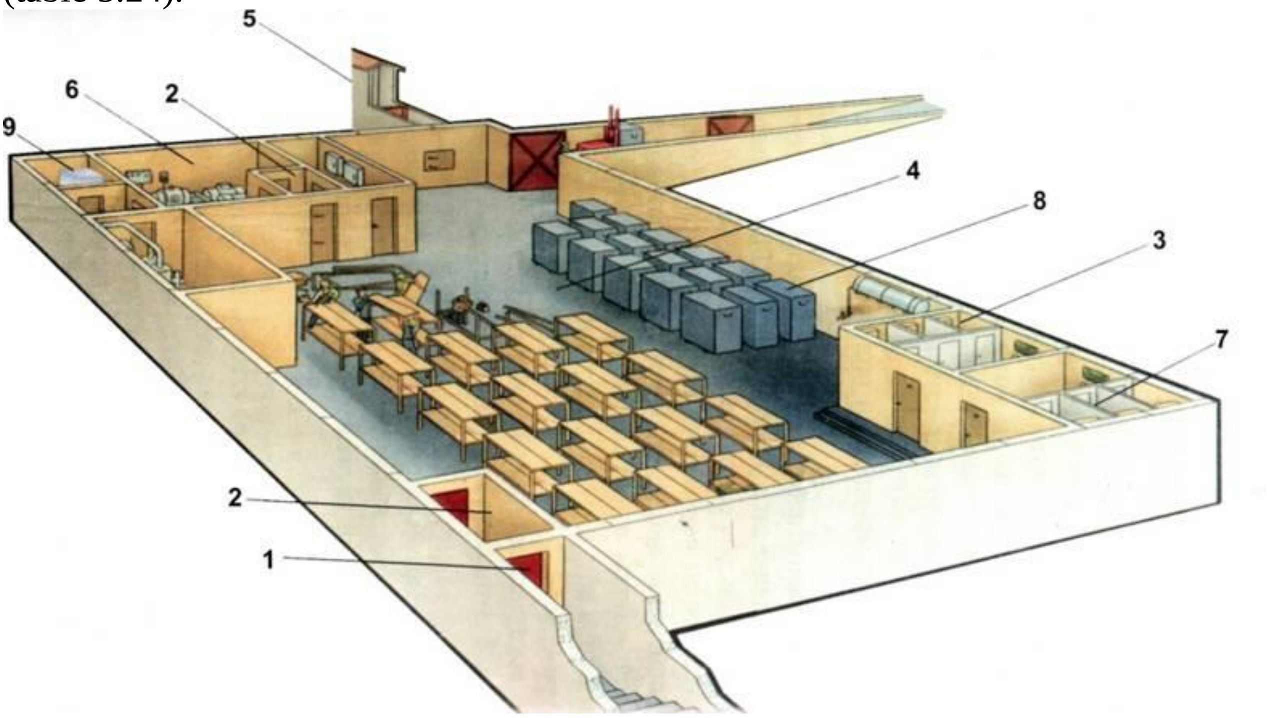


Figure 5.9 - Scheme of the shelter:
1 - protective-hermetic door; 2 - airlock; 3 - sanitary facilities; 4 - room for sheltered people; 5 - emergency exit; 6 - filtering and ventilation chambers (compartments); 7 - medical room; 8 - pantry for food; 9 - diesel power plant

Determine the number of bunks to accommodate the sheltered people

$$H = M \cdot D \qquad (5.43)$$

where M is the number of places for sheltered people in a protective structure;

D – the established norm (0.2 - with a two-tier arrangement of bunks, 0.3 - with a three-tier arrangement of bunks).

We calculate the capacity coefficient $К_с$, which characterizes the capabilities of a protective structure to shelter people

$$К_с = \frac{М_t}{N} \tag{5.44}$$

where $М_t$ – total number of sheltered places,

N - the number of personnel to be sheltered (the largest working shift).

We will assess the air supply system of the shelter. In the course of calculations, we select the type and parameters of filtering and ventilation sets, determine the amount of air supplied by the system in mode I - clean ventilation and in mode II - filtering ventilation.

Table 5.24 - Requirements for civil defense protective structures [45]

Primary requirements	Norm
Floor area of the main room for one person, m^2, at the height of the room: – 2,15 m	0,6
– 2,15–2,9 m	0,5
– 2,9 m and more	0,4
in protective structures dual purpose	1,0
Internal volume of the room for one person, m^3	1,5
Sitting area for one person, m	0,45×0,45
Place for lying for one person, m	1,8×0,55
Area of auxiliary premises for one person, m^2: – without autonomous water and power supply systems	0,12
– in the presence of a diesel power plant, but without autonomous water supply	0,13
– with autonomous water and power supply systems with a capacity: up to 600 people	0,23
600–1200 people	0,22
more than 1200 people	0,2
Medical center area with a capacity of 900-1200 people, m^2	9
Sanitary post for every 500 people, m^2	2
Room area for one set of FVK-1 (FVK-2), m^2	9–12
Room area for diesel power plant, m^2	16–20
Oxygen content, not less,%	16,5
Carbon dioxide concentration, no more,%	4
Carbon monoxide concentration, no more, mg/m^3	100
Methane concentration, no more, mg/m^3	300
Dust concentration, no more, mg/m^3	10
Relative air humidity, not less and not more,%	30 и 90
Air temperature in the shelter, no more, °C	32

Calculate the number of covered, which the system can provide with purified air [45]

$$N_{air}=\frac{W_o}{W_n} \tag{5.45}$$

where W_0 is the total capacity of the air supply system, m^3/h;
W_n – air supply rate per person per hour, m^3/h: in clean ventilation mode - 10, in filter ventilation mode - 2 m^3/h per person.

The assessment of the water supply system is carried out according to the formula

$$N_w = \frac{W_{o\,w}}{W_{1n} \cdot C} \tag{5.46}$$

where $W_{o\,w}$ - total water supply in a protective structure,
$W_{1\,n}$ - the rate of water supply for one sheltered person per day (rate - 3 l / day);
C - the specified period of stay of the sheltered in the protective structure, days.

Assessment of protective structures for the timely shelter of people is carried out depending on their location relative to places of work. Standards for calculations: movement from the place of work to the shelter - 100 m in 2 minutes, the time to fill the shelter - 2 minutes. General conclusions (option) are made based on calculations [45].

5.6 Providing fire safety

A fire is an uncontrolled combustion that causes material damage, harm to health and danger to the life of people and animals.

Fire safety is the state of an object in which the possibility of a fire is excluded, and in case of its occurrence, the necessary measures are taken to eliminate the negative impact of hazardous factors of fire on people, structures and material values.

By the Decree of the Government of the Republic of Kazakhstan dated October 9, 2014, the regulatory legal act "Fire Safety Rules" (FSR) was approved, which establishes fire safety requirements in the territory of the Republic of Kazakhstan. Fire safety rules determine organizational measures to ensure fire safety, the procedure for actions in case of fire, fire safety requirements (during operation) in relation to territories, buildings, structures, premises, electrical installations, heating and ventilation systems, other types of engineering equipment, fire-fighting water supply networks , automatic fire extinguishing installations and fire alarm systems, smoke protection systems, fire warning and evacuation control systems, fire equipment, primary fire extinguishing equipment.

Ensuring fire safety is raising awareness of precautions, prevention and actions during a fire, which will reduce the risks of and the number of fires, the number of human victims, and material damage. The strategy for reducing injury and death from fires is fire prevention and training in safe behavior.

The conditions for fires are fuel, sufficient oxygen and an ignition source. Fire prevention is achieved by controlling one of the three listed elements, which, when present, cause fires. Fire prevention includes the following measures:

- development of a program aimed at preparation, prevention, emergency preparedness and evacuation;
- proper handling of flammable and flammable materials;
- appropriate handling and control of all sources of ignition;
- introducing safe housekeeping practices that reduce the risk of fire;
- installation of a reliable fire protection system and related maintenance;
- dissemination of information on fire safety in educational, training and other information programs.

The main goal of the preparation, prevention and evacuation program is to eliminate the causes of fire, prevent loss of life, and save property from fire. The plan provides educators, staff, and students with information and guidelines to help identify, control, and eliminate causes of fires.

To compile the program requires:

- identification of potential fire hazards;
- rules for handling combustible and flammable materials;
- control and correct use of sources of ignition, mainly electricity, which is the main source of ignition in all rooms. Also, sources of ignition can be smoking, open flames (candles and burning burners), etc.

The main causes of fire are improper storage and use of flammable materials, overloaded electrical outlets and extension cords, improper use of appliances that generate heat, including heaters, unattended electric and gas cooking ranges, discarded cigarettes without extinguishing (Figure 5.10). Implementing fire prevention measures is key in trying to ensure personal safety.

Figure 5.10 - The main causes of fires

Fire prevention measures include the following points:

- "Fire safety rules" should be posted on each floor of the building on a prominent place;
- aware of the risks associated with the activity or process to control sources of ignition and the proper management of combustible and flammable substances;
- regularly inspect emergency evacuation routes, fire extinguishers, emergency and security lighting. In case of equipment malfunction or any other problem, immediately report to an authorized official;
- conduct fire-tactical exercises on a regular basis;
- control the serviceability of the fire alarm.

What everyone should know in case of a fire:

- building evacuation plan and where it is located;
- location of all exits from the building;
- location of fire extinguishers, fire-fighting equipment;
- emergency phones;
- gathering places outside the building.

What to do when you hear a fire alarm or receive an evacuation order:

- before leaving the premises, turn off all electrical appliances, if possible, take valuable things with you;
- close all doors behind you when leaving the premises;
- before opening the door to exit, check them for heat so as not to get into the fire zone;
- do not use the elevator when evacuating from the building;

- call the fire service and report the location and nature of the emergency;

- go to a predetermined collection point and remain there until the emergency personnel in charge allow you to leave the safe area;

- do not obstruct the access of the fire service to the building;

- inform firefighters and rescuers about the location of people who need help and could not leave the premises.

A fire occurs with the simultaneous presence of three components, which is called the "fire triangle" (Figure 5.11):

- a sufficient amount of oxygen to maintain the combustion process;

- sufficient heat to heat the material to its ignition temperature;

- fuel or combustible material.

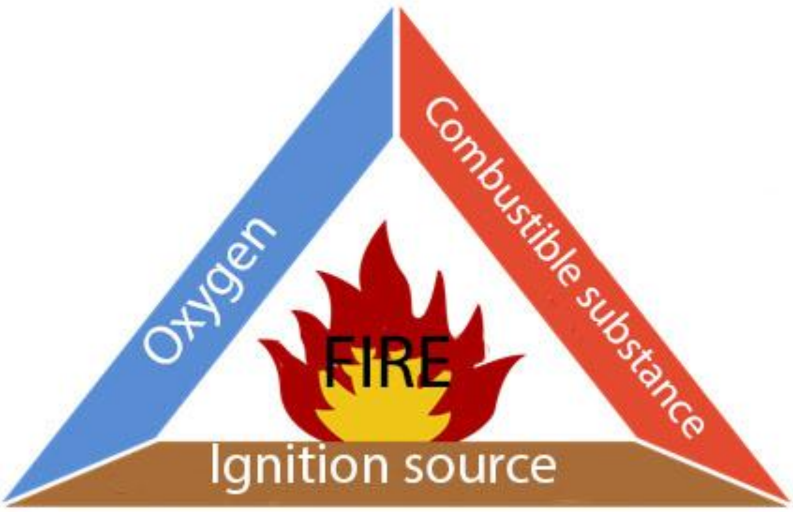


Figure 5.11 - Basic conditions for a fire

In addition, need to indicate the fourth element, which is a chemical reaction, in this case, the "fire triangle" is transformed into a "fire tetrahedron".

The fire will be extinguished if one of the listed elements is eliminated. Basically, fire extinguishers work to eliminate one or more elements of the fire triangle / tetrahedron. Fire safety is based on the principle of separating fuel and ignition sources.

There are five classes of fires, respectively, all fire extinguishers are marked for convenience with symbols for extinguishing a certain class:

1. Class A fires include paper, wood and other common combustible substances.

2. Class B fire - burning of flammable liquids such as gasoline, oil, some paints and solvents.

3. Class C fires - combustion of gaseous fuels (methane, hydrogen, propane).

4. Class D fires are the combustion of combustible metals such as magnesium, potassium and sodium.

5. Class E fires - burning of live electrical equipment (power tools, electrical wiring, fuse boxes, household appliances, televisions, computers, electric motors, etc.).

6. Class F fires - burning of radioactive waste and radioactive substances (Figure 5.12).

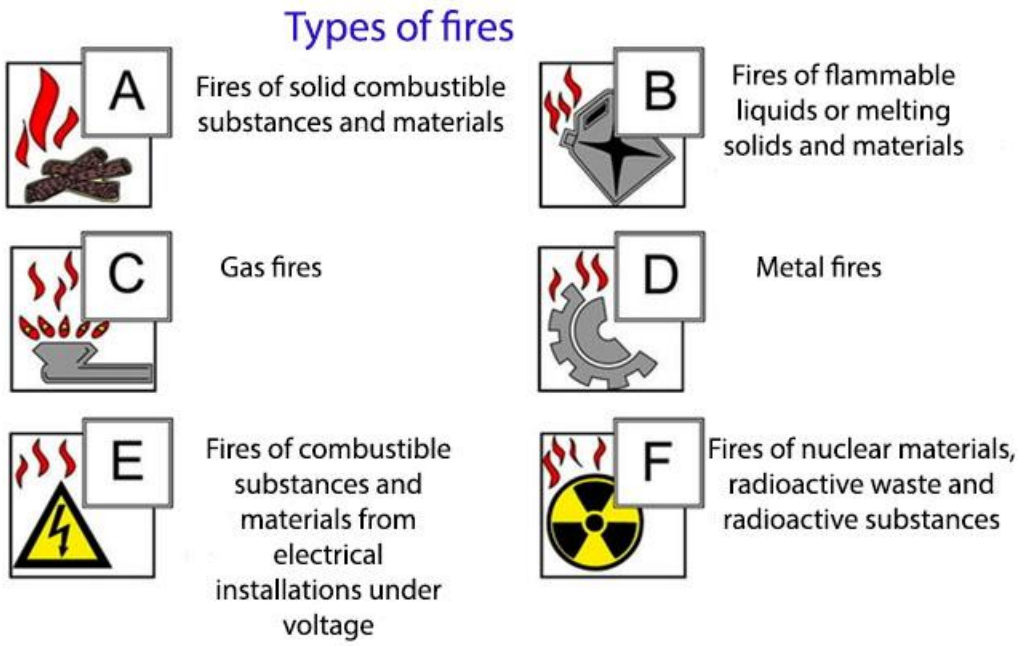


Figure 5.12 - Pictograms of classes of fires to designate devices intended for extinguishing

5.7 Emergencies related to infectious diseases

Throughout history, humanity has been forced to fight the threat of the spread of infectious diseases. It would seem that the progress achieved gives hope: smallpox has been eradicated everywhere and finally, the fight against poliomyelitis is reaching its final stage. However, even today we are faced with both outbreaks of already known diseases and with new, extremely dangerous ailments such as exotic viral hemorrhagic fevers, microplasma infections, tuberculosis, bird flu, etc. Infectious diseases today are the cause of every third death in the world [50].

According to the US Department of Health and Human Services, an influenza pandemic can lead to more deaths and diseases than any other threat.

Infectious diseases differ from all other diseases in that they are caused by live pathogens. Infection is a biological phenomenon based on the introduction and reproduction of microorganisms in a macroorganism (man, animal) with the subsequent development of various forms of their interaction. *Infectious process* - a complex of reactions arising in a macroorganism as a result of the introduction and reproduction of pathogens in it and aimed at maintaining its internal environment and balance with the environment. Microorganisms that can cause an infectious process are called pathogenic. They are classified as bacteria, viruses, rickettsia, fungi, protozoa [50].

An infectious disease is the most striking form of an infectious process that develops in the human or animal body as a result of the penetration and reproduction of a microorganism. An infectious disease is characterized by the following symptoms:

- specificity - each infectious disease causes a certain type of microorganism;
- contagiousness (infectiousness) - the ability of infectious diseases to spread;
- cyclical course - sequential change of incubation (hidden) preclinical, clinical periods with a favorable or fatal outcome;
- formation after infectious immunity [50].

Pathogenic microbes are the smallest living things that are invisible to the naked eye, odorless and of a specific color, persisting for a long time in the external environment, especially in cold weather, capable of causing serious diseases in humans and animals, and infecting plants. The causative agents of infectious diseases in humans and animals are divided into bacteria, viruses, rickettsia, fungi, spirochetes and protozoa, depending on the size, structure and biological properties.

Bacteria are “microscopic organisms of plant origin, predominantly unicellular, of various shapes. Their sizes are from 0.5 to 8-10 microns. They reproduce by simple division every 20-30 minutes, falling into favorable conditions. Bacteria die after a few minutes when exposed to sunlight, disinfectant solutions and boiling, but some of them, for example, anthrax microbes, can turn into special forms - spores. The microbe in the spore form is very resistant to drying, high and low temperatures and disinfectants. Bacteria are the causative agents of such dangerous diseases as anthrax plague, botulism, tetanus, cholera, glanders, etc. [50].

Viruses are the smallest living organisms. Its size is hundreds and thousands of times smaller than bacteria (from 0.2 to 0.4 microns). Unlike bacteria, they develop only in living tissues, that is, they are intracellular parasites. Viruses are highly resistant to low temperatures and desiccation. Sunlight, especially ultraviolet rays, as well as temperatures above 60 C and disinfectants (formalin, chloramine, etc.) have a detrimental effect on them. Viruses are the cause of more than 75 human diseases, including such especially dangerous ones as smallpox, yellow fever [50].

Rickettsiae in size (0.4-1 microns) and shape are close to some bacteria, but live only in the tissues of the organs affected by them. They cause diseases such as typhus, Rocky Mountain spotted fever, and others.

Fungi are single or multicellular microorganisms of plant origin with a size of 3-50 microns or more. They can form spores that are highly resistant to physical and chemical factors: they tolerate freezing, drying, exposure to sunlight and disinfectants well. Fungi cause condidosis diseases.

According to the World Health Organization, more than 1 billion people annually carry infectious diseases around the globe. Large numbers of people can become infected in a short time. (So, cholera El Tor, which began in 1960 in Indonesia, by 1971 covered all countries of the world). The incidence rate of acute dysentery, typhoid fever, diphtheria, viral hepatitis, salmonellosis, and influenza is still high. Their occurrence is especially dangerous in large groups, where everyone can become infected. That is why it is very important to know the signs of infectious diseases, the ways of their spread, methods of prevention and rules of behavior [50].

Infectious diseases of humans are diseases caused by pathogens and transmitted from an infected person or animal to a healthy person. Infectious diseases appear in the form of epidemic outbreaks. An epidemic focus is the place of origin and stay of the sick person, the people and animals around him, as well as the territory within which it is possible for people to become infected with pathogens of infectious diseases [50].

The process of the emergence and spread of infectious diseases among humans is called an epidemic process and is a chain of successively emerging homogeneous infectious diseases of humans.

The epidemic process manifests itself in the form of epidemic and exotic morbidity. To characterize the intensity of the epidemic process, concepts such as sporadic morbidity, epidemic outbreak, epidemic and pandemic are used.

Epidemic morbidity, or endemic, is a constantly recorded incidence in a certain territory, characteristic of a given territory. Exotic morbidity is observed when pathogens are brought into a territory free from this infectious form. Sporadic incidence - the usual incidence of the disease in question in a given locality [50].

An epidemic outbreak is a sharp rise in incidence associated with a single-stage infection of people, limited in time and territory.

Epidemic - a wide spread of an infectious disease, which is significantly higher than the incidence rate usually recorded in a given territory.

A pandemic is an unusual increase in incidence, both in level and in scale of spread, covering a number of countries, entire continents and even the Globe. The concepts of morbidity, mortality and mortality are used to quantify the epidemic process [50].

The incidence is determined by the ratio of the number of cases for a certain period of time (for example, for a year) to the number of residents of a given district, city in the same period. The incidence is expressed in coefficients per 100 thousand, 10 thousand or 1 thousand people.

Mortality - the number of deaths from a given disease, expressed in coefficients per 100 thousand, 10 thousand, 1 thousand people covered by epidemiological surveillance.

Mortality is the percentage of deaths from the number of patients with this infectious disease. In epidemiology, there are different classifications of infectious diseases. One of them is based on the mechanism of transmission of the pathogen, in connection with which all infectious diseases are divided into four groups: 1) intestinal; 2) the respiratory tract; 3) blood (transmissible); 4) outer covers (contact) [50].

Based on mortality, the most dangerous infectious diseases are plague (mortality rate is 80-100%), cholera (mortality rate is 10-80%), yellow fever (mortality rate is up to 70%), AIDS (mortality rate reaches 65-70%).

Mass infectious diseases are typhoid fever and mumps A and B, dysentery, viral hepatitis A and B, influenza, diphtheria, meningococcal infection (meningitis), anthrax, tularemia, etc., although they are not particularly dangerous.

The emergence of an infectious disease and the development of an epidemic is possible if there are 3 factors:

1. The source of infection (infection).
2. The mechanism of transmission of infection.
3. Susceptible organism (human) [50].

1. Sources of infection are infected people and animals - these are natural hosts of pathogens of infectious diseases, from which pathogenic microorganisms are transmitted to healthy people. In cases where the source of the causative agent of the disease is an infected person, then they are classified as anthroposic infectious diseases or anthroponoses. In the case when various animals and birds serve as the source of infection, they are called zoonotic infections or zoonoses.

2. The mechanism of transmission of pathogenic microbes is a set of evolutionarily established methods that ensure the movement of a living pathogen from an infected organism to a healthy one (Figure 5.13). This process has three phases:

I – removing the pathogen from the infected organism;

II – stay of the pathogen for some time in the external environment;

III – introduction of the pathogen into the next organism [50].

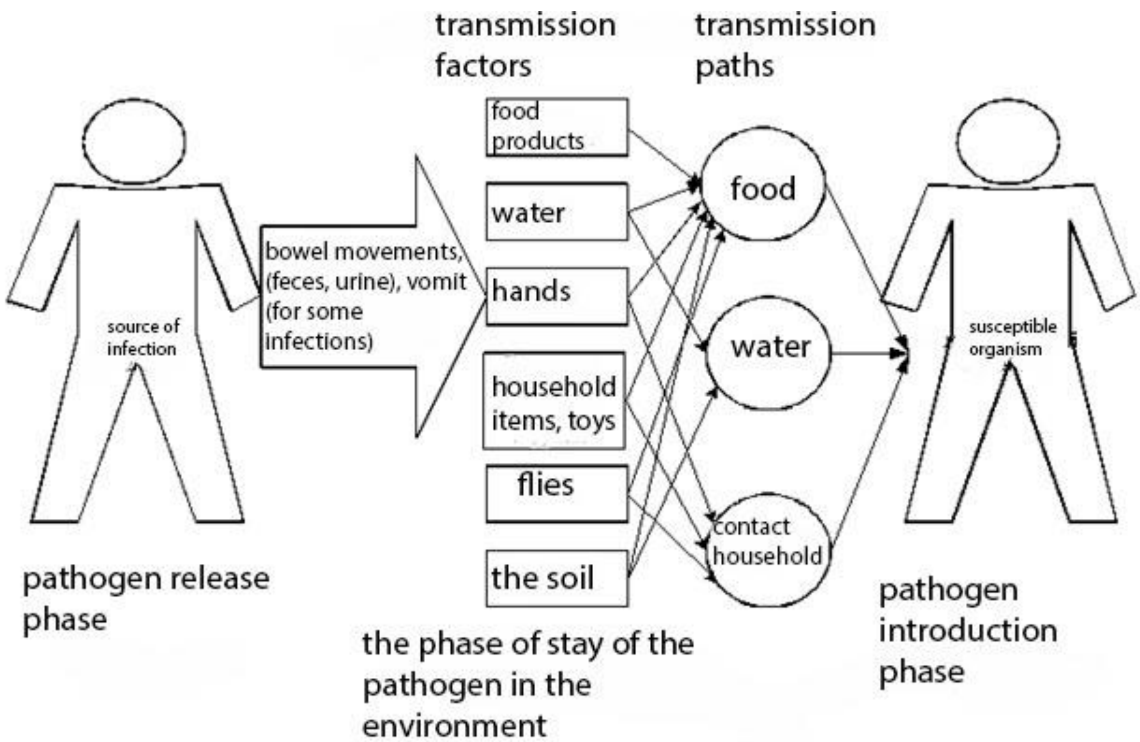


Figure 5.13 - Scheme of transmission of the causative agent of an infectious disease

3. The susceptibility of the organism is a biological property of the tissues of the human or animal organism to be the optimal environment for the reproduction of the causative agent of the disease and to respond to the introduction of the pathogen by an infectious process in various forms of its manifestation.

The activity of the epidemic process changes under the influence of natural and social conditions. The influence of social conditions on the course of the epidemic process is more significant than the influence of natural conditions.

Social conditions are understood as: population density, housing conditions, sanitary and communal improvement of settlements, material well-being, working conditions, cultural level of people, migration processes, health care, etc.

Social conditions are population density, housing conditions, sanitary and communal improvement of settlements, material well-being, working conditions, the cultural level of people, migration processes, the state of health care, etc. [50].

Certain difficulties arise not only in the provision of medical care to the affected population, but also in the elimination of the focus in the focus of infectious diseases. The tasks of localizing epidemics, epizootics, epiphytotics in the event of a difficult situation may turn out to be overwhelming for the medical, veterinary and plant protection services. It will require all the available forces and means, as well as the purposeful use of forces and means of preventing and eliminating emergency situations, including bodies and units for emergency situations, precisely in order to localize the focus of an epidemic, epizootic, epiphytotic [50].

Measures to eliminate the epidemic (epizootic, epiphytotic) focus depend on the type of pathogen and the way the focus occurs. The time of year and day, meteorological conditions, the degree of preparedness of formations and institutions, the availability of forces and means have a great influence on the conduct of work. The work of all services is based on data from the general reconnaissance of the focus of infection, in which medical (including epidemic) reconnaissance is also carried out (the scale of the lesion, the approximate number of those affected, the boundaries of the focus, etc.) [50].

Based on the reconnaissance of the emergency area, the sanitary and epidemiological state can be assessed as:

- successful - infectious diseases are absent or there are isolated cases of them that are not related to each other;

- unstable - some previously unrecorded infectious diseases appear among the population, as well as group diseases that do not spread further (there are no signs of an epidemic);

- unfavorable - group infectious diseases appear with a tendency to further spread, or isolated cases of diseases with especially dangerous infections (plague, cholera, etc.) are noted;

- emergency - an epidemic (epizootic) develops or group lesions of especially dangerous infectious diseases are noted.

Bacteriological reconnaissance - sampling and analysis of samples of air, water, food, etc. is carried out in order to determine the boundary of the focus of bacterial infection. A complex of sanitary and hygienic and anti-epidemic (anti-epizootic) measures is carried out within the outbreak.

Special regime - restrictive measures - quarantine or observation are taken when a focus of an infectious disease occurs in order to prevent the spread of the disease [50].

Quarantine is a system of strict anti-epidemic and anti-epizootic measures to isolate the entire focus of infection and eliminate an infectious disease in it. The following activities are carried out when quarantine is introduced:

- strict control over the entrance (entry) to and exit (exit) from it (cordon, organization of checkpoints and barrage posts);
- control over the observance of a strict anti-epidemic regime in the quarantine territory; protection of infectious diseases hospitals, water sources, food warehouses and enterprises;
- prohibition of the export of any property, food, industrial and agricultural products from the outbreak;
- prohibition of transit passage through the lesion focus of motor transport, restriction of the passage of railway and river transport;
- dissociation of people in the lesion focus;
- prohibition of movement and grazing of farm animals [50].

Observation is a set of restrictive measures aimed at preventing the spread of infection. Observation includes the following activities:

- strengthening of medical and veterinary supervision in the focus of infection;
- restriction of entry and exit, as well as the export of property, animals, fodder from the hearth;
- isolation and treatment of sick and suspicious people or animals; vaccination and disinfection.

Full sanitary treatment of the population, as well as veterinary treatment of animals are carried out in the centers of mass infectious diseases. Full sanitization involves washing the population with warm water with soap and a washcloth, and changing linen. It is carried out at points of special treatment and at specially deployed washing areas. Disinfection and shower installations can be used for treatment. All washing stations and platforms, as a rule, have three compartments: dressing room, washing room and dressing room. Before entering the dressing room, clothes are irrigated with a 0.5% solution of chloramine, and hands and neck are treated with a 2% solution. If there are no well-equipped sanitary and washing points, then full sanitization is carried out in baths, shower pavilions, retrofitted in such a way that the flow of people moves in only one direction and there are no intersections [50].

In the complex of antiepidemic and antiepizootic measures, emergency prevention is of great importance - a complex of medical measures carried out in relation to people who have been infected with pathogens of dangerous infectious diseases in order to prevent the development of an infectious process in them. Emergency prevention is divided into two types [50]:

- nonspecific (until the type of pathogen is established) - with the help of broad-spectrum antibiotics, carried out by sanitary squads in time for yard (apartment) rounds;

- specific (after identification of the pathogen) - with the help of serums, vaccines, toxoids, carried out by vaccination teams.

Disinfection of the area, transport, industrial and residential premises, water, food and fodder, patient care items and their secretions takes a leading place in the complex of measures in the focus of an infectious disease

Disinfection involves the destruction of pathogens of infectious diseases and is carried out by the centers of hygiene and epidemiology and local medical institutions using mechanical (cleaning, washing, washing), physical (burning, boiling, steaming), chemical (treatment with disinfectants and detergents) and combined methods [50].

Disinsection (destruction of harmful insects) and deratization (destruction of harmful rodents) are carried out, if necessary, in the outbreak. Sanitary and educational work among the population of the contaminated region is aimed at ensuring that all residents strictly follow the general rules of behavior in the existing conditions, sanitary and hygienic rules and other personal protection measures. For this purpose, with the help of radio, television and other media, explanatory work is carried out about the presence of foci of infectious diseases, about a specific infection, and about preventing its spread [50].

Monitoring and forecasting of epidemics is carried out by specialized services of ministries and specially authorized organizations, which functionally, according to their purpose, are information subsystems within the state service for emergency situations.

The main task of monitoring and forecasting epidemics is to timely identify and predict the development of epidemics that affect the safe state of the social environment in order to develop and implement measures to prevent and eliminate emergencies [50].

The sources of epidemics and, accordingly, the objects of monitoring and forecasting dangerous social phenomena are the facts of the presence of various viruses, as well as other sources of mass diseases of people.

The objects of monitoring are people susceptible to diseases. The type of disease, the incubation period of the disease, the density of cases (persons / km2), the period of cure of the disease are taken into account. Monitoring and forecasting is carried out by specialized services of ministries and specially authorized organizations, which functionally, according to their purpose, are information subsystems.

5.8 Biological weapons and protection against their use

Biological weapons can be used not only against humans, but also against animals and crops. This type of weapon can be deadly and contagious. Diseases caused by biological weapons can spread rapidly around the world. In addition to disease and tragic loss of life, biological weapons also have devastating economic consequences.

The twenty-first century is the age of biotechnology. Advances in biotechnology are developing at a rapid pace, exacerbated by the impact of globalization and the ever-improving capabilities of information and communication technologies.

In August 2016, the UN Secretary General told the Security Council that "non-state actors are actively engaged in the search for new types of chemical, biological and nuclear weapons". In 2017, the World Economic Forum's Global Risk Report stated that technological innovation could create devastating biological weapons that could fall into the hands of both government and non-government actors, further exacerbating geopolitical risks.

In recent years, various well-known organizations such as the World Health Organization (WHO), the North Atlantic Treaty Organization (NATO) and the United States (USA) Blue Ribbon Group have published a large number of reports on the emerging biological weapons risk, emphasizing that this the topic is the focus of political debate.

Throughout history, during conflicts, infectious diseases have been used as weapons, for example, in the Middle Ages, people with the plague or cattle infected with anthrax were catapulted into a besieged city to infect its inhabitants. The Geneva Protocol, adopted in 1925, prohibits the use of chemical and bacteriological weapons in international armed conflicts. Then, in 1975, the Biological and Toxin Weapons Convention (BTWC) was adopted, becoming the first multilateral disarmament treaty to prohibit the development, production and stockpiling of biological weapons.

The combination of a number of infectious disease criteria is an advantage for their use as a means of biological warfare or terrorism for the following reasons:

- a high degree of morbidity and a potentially high probability of death;
- high infection rate or high toxicity;
- the possibility of mass production and storage without loss of pathogenic potential;
- possibility of delivery all over the world;
- sufficient stability of pathogenic microorganisms in the environment to infect humans after spread.

The main signs of biological weapons impact are considered to be the appearance of symptoms and signs of disease in humans and animals, which can then be confirmed in laboratories (Figure 5.14).

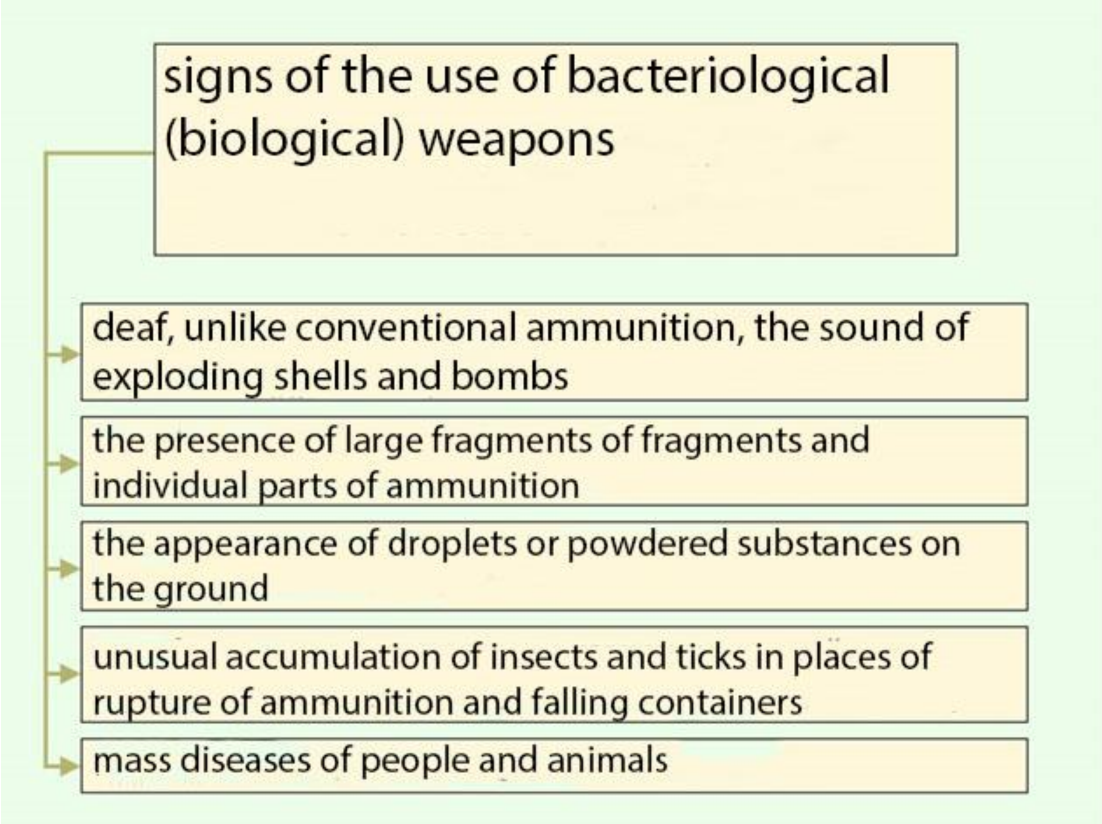


Figure 5.14 - The main signs of the use of biological weapons

People and animals become infected as a result of:

- ingress of toxins on the mucous membrane of the eyes, nose, mouth, as well as on damaged skin;
- eating contaminated food and water, bites of infected insects and ticks, contact with contaminated objects, wounds from shrapnel of ammunition equipped with biological agents, as well as as a result of direct contact with sick people (animals).

A number of diseases are quickly transmitted from sick people to healthy people and cause epidemics (plague, cholera, typhoid, influenza, etc.).

The main means of protecting the population from biological weapons include: vaccine-serum preparations, antibiotics, sulfa and other medicinal substances used for special and emergency prevention of infectious diseases, individual and collective protective equipment used to neutralize pathogens, chemicals.

Cities, settlements and objects of the national economy that have been directly exposed to bacterial (biological) agents that create a source of spread of infectious diseases are considered to be the focus of biological damage. Its boundaries are determined on the basis of biological intelligence data, laboratory studies of samples from objects of the external environment, as well as identifying patients and ways of spreading infectious diseases that have arisen. Armed guards are set up around the focus of infection, entry and exit, as well as the removal of property, are prohibited. A complex of anti-epidemic and sanitary-hygienic measures is carried out in the lesion focus: emergency prevention; sanitary treatment of the population; disinfection of various contaminated objects (Figure 5.15) to prevent the spread of infectious diseases among the population. Insects, ticks and rodents are destroyed if necessary (pest control and vermin control).

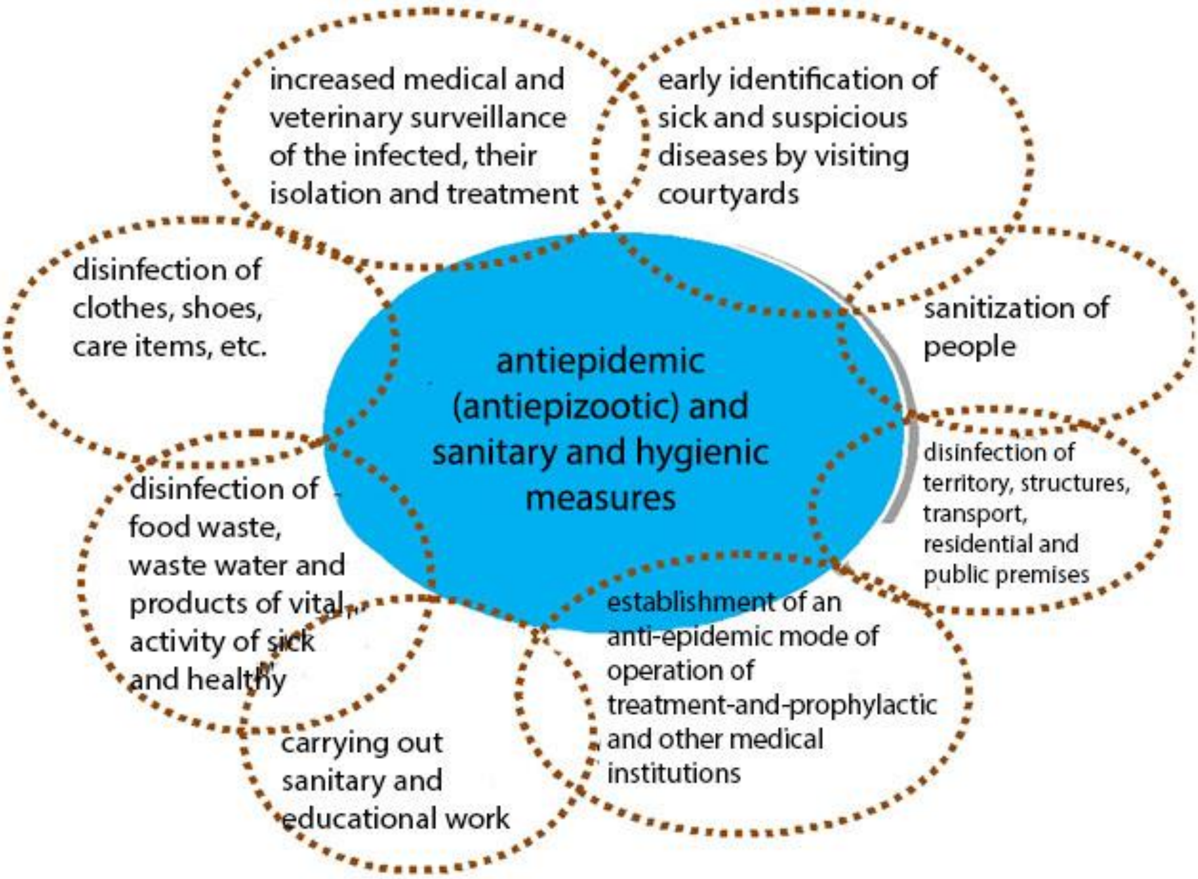


Figure 5.15 - Complex of anti-epidemic and sanitary-hygienic measures

Various technologies and strategies can be used to protect individuals from biological contamination.

To combat chemical or biological agents, various risk reduction mechanisms can be introduced:

1. Administrative control;
2. Engineering control;
3. Physical protection.

Administrative control. In relation to biological agents, administrative control means risk communication (including a warning system), evacuation and cordon off of potentially contaminated areas.

Engineering control means include the use of technologies such as an air flow control, the use of filters, and various forms of protection that are used to restrain or limit the risk of proliferation.

Physical protection. The purpose of this protection is to limit the number of people exposed to biological contamination and to reduce the concentration of the pollutant within a short time. Physical protection includes individual and collective protection.

Personal protective equipment includes masks, respirators, gas masks, protective suits to reduce the likelihood of inhalation and skin exposure to hazardous biological substances. Collective protection is a special form of engineering control that reduces the risk of exposure to a group of people (for example, ventilated filters in buildings, shelters or vehicles).

Questions for self-control:

1. What is regulated by the Law of the Republic of Kazakhstan "On Civil Protection"?
2. By what principle are territorial and sectoral civil protection subsystems created?
3. What civil protection measures are carried out to protect the population and facilities of the Republic of Kazakhstan?
4. What is the essence of the sanitary and epidemiological well-being of the population and favorable conditions for human life?
5. What are the main sources of hazards?
6. Describe the principles of life safety.
7. What are the main types of interactions in the “human-environment” system?
8. What is meant by the assessment of the chemical situation?
9. What is meant by the assessment of the radiation situation?
10. Describe the types of ionizing radiation.
11. What is the difference between exposure, equivalent and effective radiation doses?
12. What does “object stability” mean?
13. What is the procedure for assessing the stability of an engineering and technical complex to the effects of an explosion of a gas-air mixture?
14. How is the capacity assessment of protective structures carried out?
15. What measures are taken to prevent a fire?
16. How does the process of transmission of pathogenic microbes take place?
17. What are the main measures to localize epidemics, epizootics, epiphytotics should be carried out?
18. What are the signs of the use of biological weapons?
19. What are the methods to reduce the risk of contamination from the use of bacteriological weapons?

Conclusion

The training manual collected and analyzed a large amount of information and documents related to the concept of sustainable development, the activities of states moving to a "green" economy. International experience in the field of environmental regulation took place under the influence of public requests to government authorities, which were required to solve the difficult task of ensuring stable economic growth and competitiveness of national economies in the context of globalization and at the same time reducing the negative impact of economic activity on the environment.

In the section "Environmental Protection", the main methods of protecting atmospheric air and water resources from pollution are considered, the principles of operation of purification devices are presented and considered.

The importance of the manuscript is given to the impact of negative factors on humans and the environment. To form an idea among students about social relations arising in the process of carrying out civil protection measures and measures to prevent and eliminate natural and man-made emergencies and their consequences, at the beginning of the section "Life Safety" a review of the Law of the Republic of Kazakhstan "On Civil Protection" was carried out. Safety is the most important human need along with his need for food, water, clothing, housing, information. This is a general scientific category, which is not something tangible, material and acts as an integrated form of expression of the vitality and viability of various objects of a particular world, the internal and foreign policy, defense, the economy, environment, social policy, public health, and science, technology and so on.

On the other hand, this is a very specific, clear and precise scientific category, with its essence and content aimed at protecting the vital interests of a person, society, and the state.

The main tasks of scientific research in the field of civil protection are to reduce the negative impact of natural and man-made emergencies, to develop recommendations for regulatory and methodological support for the assessment and management of risks in the field of civil protection in order to ensure the protection of the population and territories from emergency sieves of a natural and man-made nature. According to the tasks set, the manual contains methods:

- assessment of the chemical and radiation situation in emergency situations;
- assessment of the stability of the functioning of an economic object in an emergency;
- assessment of the engineering protection of the facility personnel;
- protection of the population in case of fires.

Terminological dictionary by discipline «Environmental sustainability and life safety»

Abiotic environmental factors - components and phenomena of inanimate, inorganic nature, directly or indirectly affecting living organisms: climatic, soil (edaphic), orographic, hydrographic.

An accident - an emergency technogenic event, that occurred for structural, production, technological or operational reasons or because of accidental external influences and consisting in damage, failure, destruction of technical devices or structures.

An environmental accident - the release of harmful substances into the environment by industrial facilities in the amount that leads to a general danger to the environment, people and material values.

Adaptation - adaptation of an organism to certain environmental conditions, developed in organisms in the process of evolution due to a whole complex of features - morphological, physiological and behavioral. As a result of adaptation, ecological groups of organisms are formed, adapted to various environmental conditions: moisture lovers - hydrophytes and "dry beetles" - xerophytes; plants that are resistant to shade and require full sunlight for normal development; animals that live in forests or swamps, are nocturnal or daytime. The adaptation explains the different composition of the biota of ecosystems in different ecological conditions.

Anthropogenic pressure - a comprehensive indicator of the intensity of the human impact on ecosystems. Anthropogenic load includes the use of the resources of populations of species included in ecosystems (hunting, fishing, harvesting medicinal plants, felling trees), grazing, recreational impact, pollution (discharge of industrial, household and agricultural wastewater into water bodies, precipitation of suspended solids from the atmosphere or acid rain), etc. If the anthropogenic load changes from year to year, then it can be the cause of fluctuations of ecosystems, if it acts on ecosystems constantly, then it can cause ecological succession. Under rational nature management, anthropogenic load is regulated by means of ecological regulation to a level that is safe for ecosystems.

The atmosphere is the gaseous shell of the Earth, consisting of a mixture of different gases. The main constituents of the atmosphere are nitrogen and oxygen. Mixed in small quantities with these gases, carbon dioxide and methane play an important role, increasing the concentration of which causes the greenhouse effect.

Autecology is a branch of ecology that studies the relationship of individuals (an organism) with the environment, including biotic factors.

Security is the state of protection of the vital interests of the individual and the state from internal and external threats or dangers.

Safety in emergencies - a set of standards, representing the main scientific and technical documents on emergency situations.

Life safety is a discipline which studies the dangers that threaten humans in the environment and the patterns of their manifestation in order to develop a comprehensive system of measures to protect humans and the environment from natural hazards and hazards formed in the process of human activity.

Biogeochemical cycles (biogeochemical circulation of substances) - the exchange of matter and energy between various components of the biosphere, due to the vital activity of organisms and is of a cyclic nature. All biogeochemical cycles are interconnected and form the dynamic basis for the existence of life. In other words, biogeochemical cycles are the transition of nutrients from inanimate nature (from the reserves of the atmosphere, hydrosphere and earth's crust) to living organisms and back to the inanimate environment. The energy flows of the Sun and the activity of living matter serve as the driving forces of biogeochemical cycles, which leads to the movement of chemical elements: C, N, P, S, H_2O, etc.

Biogeocenosis is an evolutionarily developed, spatially limited, internally homogeneous, natural system of functionally related living organisms and their surrounding abiotic environment, characterized by a certain energy state, type and rate of exchange of matter and information.

Biological indicators are biological objects on the basis of which environmental conditions are assessed.

Biological pollution is the entry into the environment (water, atmosphere, soil) or food products of microorganisms that cause diseases of humans, crops and animals.

Biological pollution of the environment is the introduction into the environment (water, atmosphere, soil, as well as food) and the multiplication in it of microorganisms that cause diseases of humans, animals and agricultural plants.

Biological diversity is a set of species, communities and biocenoses (biota of ecosystems).

Biome - a set of different groups of organisms and their habitat in a particular landscape-geographical zone.

The biosphere is the shell of the Earth, the composition, structure and properties of which, to one degree or another, are determined by the present or past activity of living organisms. The biosphere includes organisms (about 3 million species), their remains, zones of the atmosphere, hydrospheres and lithospheres inhabited and modified by these organisms.

Biotope - a set of abiotic and biotic factors of the habitat of an organism, population, ecosystem.

Biocenosis - a set of populations of different species living in a certain area.

Suspended dust - particulate matter in the atmosphere, a variant of atmospheric pollution. Suspended dust is 90% composed of a finely dispersed fraction, which is difficult to collect with dust collectors.

Demographic explosion - a sharp increase in population, as a result of a decrease in mortality against the backdrop of high fertility.

Water use - the procedure, conditions and forms of use of water resources: 1) use of water bodies to meet the needs of the population and the national economy; 2) the use of water for economic or domestic purposes without removing them from water bodies, by "passing it through themselves" (hydroelectric power plants or a water mill).

Water consumption - consumption of water from a water body or from water supply systems. They are distinguished by return water consumption - with the return of taken water to the source and irrevocable water consumption - with its consumption for filtration, evaporation, etc.

The World Meteorological Organization is an intergovernmental UN agency that has existed since 1947 to coordinate meteorological observations carried out in different countries.

The World Health Organization is an intergovernmental organization created in 1946, whose efforts are aimed at combating especially dangerous diseases. The area of expertise is also the impact of various pollution on human health.

World Food Organization (FAO) - formed in 1945 and deals with food security issues of individual countries and the whole world.

The World Charter for Nature is an international environmental document adopted by the United Nations in 1982. The World Charter for Nature places responsibility for the state of the biosphere on all UN member states.

The World Wildlife Fund is one of the most active intergovernmental organizations at UNESCO, founded in 1961. For the period up to 1988, about 3,000 projects worth $ 60 million were implemented. The headquarters is in Geneva (Switzerland).

Emission - entering the environment (water, atmosphere) of pollutants from enterprises.

Maximum permissible emission (MPE) is a scientific and technical standard established from the condition that the content of pollutants in the surface air layer from a source or their combination does not exceed the air quality standards for the population, fauna and flora.

Homeostasis is the ability of an organism or a system of organisms to maintain a stable (dynamic) balance in changing environmental conditions.

Environmental degradation - deterioration or destruction of the surrounding natural or built environment.

Radiation dose - the amount of radiation measured by air ionization. The unit of measurement is roentgen.

Living substance - the totality of all living organisms, numerically expressed in elementary chemical composition, weight, energy; associated with the environment by the biogenic current of atoms, respiration, nutrition and reproduction.

Pollution is the introduction into the environment or the appearance in it of new harmful chemical, physical, biological, information agents that are not typical for it.

"Greens" are social movements that set the task of preserving the environment.

Sanitary protection zone - a strip separating an industrial enterprise from a residential area (settlement).

An ecological disaster zone is a territory where, as a result of economic or other activities, irreversible changes in the environment have occurred, resulting in a significant deterioration in the health of the population, disruption of natural balance, destruction of natural ecosystems, degradation of flora and fauna.

Environmental risk zone - places on the land surface and in the waters of the world's oceans where human activity can create hazardous environmental situations, for example, areas of underwater oil production on the sea shelf, areas of the sea dangerous for passing tankers, where an accident with an oil spill can occur, etc.

IPA (atmospheric air pollution index) is a complex indicator of atmospheric pollution, which is calculated by the sum of the five main pollutants when converting the absolute values of each MPC number.

Environmental quality indices are quantitative indicators that assess the suitability of the environment for human life or other organisms. It is expressed differently depending on the purpose of the assessment: in points or in absolute units (for example, in MPCs and other characteristics of the degree of pollution by a single substance or a group of substances).

Sustainable development indicators are relevant indicators and criteria that perform a kind of control over the achievement of sustainable development goals, management of this process, assessing the effectiveness of the means used and the level of achievement of the set goals.

Incident - failure or damage to technical devices used at a hazardous production facility, deviation from the technological process, violation of the provisions of laws and other regulatory legal acts of the Republic of Kazakhstan, as well as regulatory technical documents establishing the rules for conducting work at a hazardous production facility.

Quarantine is a system of measures to prevent the spread of infectious diseases and the penetration of unwanted species of organisms into places where they do not yet live.

Environmental quality - a set of indicators characterizing the state of the environment; the degree to which a person's living environment corresponds to his needs.

The magnitude of an earthquake is a conditional value that characterizes the amount of energy released at the source of an earthquake.

International cooperation in the field of nature conservation is carried out under intergovernmental agreements or non-governmental programs organized by social movements and scientists. International cooperation is an essential element in creating a sustainable development society, since effective mechanisms for improving the environmental management system operate only in individual countries.

Environmental monitoring (environmental monitoring) is a system of observation, assessment and forecasting of the state of the natural environment surrounding a person.

Normalization of the quality of the environment - the establishment of a system of quantitative and qualitative indicators (standards) of the state of the environment (for air, water, soil, etc.), which provide favorable conditions for human life and the sustainable functioning of natural ecosystems.

The noosphere is the state of the biosphere, transformed by the human mind. Noosphere - the sphere of reason, the highest stage of the evolution of the biosphere, associated with the emergence and development of humanity in it; the sphere of reason, the highest stage of the development of the biosphere, when intelligent human activity becomes the main determining factor of its development.

Environmental standard - the degree of maximum permissible human intervention in ecosystems, ensuring the preservation of ecosystems of the desired structure and dynamic qualities.

Environment (habitat) - collection of natural and slightly modified activity abiotic people biotic natural factors and social environment together affect man and his household.

Dangers - processes, phenomena, objects that have a negative impact on human life and health.

Desertification is the emergence of landscapes under the influence of human economic activity, close to deserts with a rare vegetation cover.

Waste - types of raw materials unsuitable for further production, their unused residues or substances arising in the course of technological processes (solid, liquid and gaseous) and energy that is not subject to utilization in the considered production.

Environmental impact assessment is a type of activity for the identification, analysis and accounting of direct, indirect and other consequences of the environmental impact of a planned economic and other activity in order to make a decision on the possibility or impossibility of its implementation.

Environmental protection is an area of knowledge that develops a set of measures aimed at maintaining rational interaction between human activities and the environment, ensuring the preservation and restoration of natural resources, rational use of natural resources, preventing the harmful effects of the results of economic activities of society on nature and human health.

Treatment facilities - systems of devices (tanks, pools, etc.), which purify polluted water (industrial or domestic wastewater) and gaseous emissions from industrial enterprises.

MPC (maximum permissible concentration) - the maximum concentration of harmful substances in water, soil, atmosphere, food, which does not harm human health.

Habitat - the human environment, which at the moment has a combination of factors capable of exerting a direct or indirect, immediate or remote impact on human activities, his health and generation.

Sustainable development is development that ensures that the needs of the present are met without compromising the ability of future generations to meet their own needs.

An emergency situation is a situation in a certain territory that has developed as a result of an accident, hazardous natural phenomenon, catastrophe, natural or other disaster that may or has resulted in loss of life, damage to human health or the environment, significant material losses or violation of living conditions.

Environmental sustainability is the ability of an ecological system to maintain its structure and functions in the process of exposure to internal and external factors.

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