MINISTRY OF EDUCATION AND SCIENCE OF UKRAINE
VASYL STEFANYK PRECARPATHIAN NATIONAL UNIVERSITY

Co-funded by the
European Union

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Course of lectures

Ivano-Frankivsk, 2024

INTRODUCTION

The lecture series “Monitoring of Chemical Parameters of Environmental Objects in the Context of European Integration” was developed for students pursuing a master's degree in Chemistry (specialization 102) at the Department of Chemistry of Vasyl Stefanyk Precarpathian National University. The course was created as part of the Jean Monnet Module project “Monitoring of Environmental Objects in the Context of European Integration” (MEOUE), supported by international technical assistance from the European Union's Erasmus+ program.

In preparing these lectures, the authors analyzed the original EU regulatory documents in the field of environment and climate change, relevant EU analytical databases, as well as analytical reports by experts from Ukrainian non-governmental organizations, including the "Resource and Analytical Center 'Society and Environment'," "Green World – Friends of the Earth," "SaveDnipro", "EcoCity."

The main goal of the course is popularization of European ecological principles and the right to safe living, drawing public attention to environmental safety issues. Teaching the course within the educational process, holding open lectures and having free access to its materials will form an active environmental position with sustainable European values among the students, will be important for the future sustainable growth and cohesion of Europe.

An important goal of the course, taking into account the rapprochement of the legislation of Ukraine and the European Union, is the training of specialists who could be engaged in environmental monitoring of environmental objects in accordance with European legal acts, which is facilitated by the approximation of students' training to real conditions and modern challenges of society, taking into account European integration. The course materials will acquaint you with the approaches of the European Union to the monitoring of environmental objects and the processes of harmonization of the Ukrainian environmental monitoring system with European systems, and will provide practical skills necessary for the work of institutions that monitor the state of the environment.

An absolutely necessary task is the education of environmentally responsible citizens who are able to protect their environmental rights, understand national environmental policy and practice of environmental management from a European point of view, and become an active participant in the discussion and study of international environmental policy.

It is important to remember that environmental legislation and practices in the EU and Ukraine are highly dynamic, and it is essential to regularly refer to updated regulatory documents from official EU and Ukrainian resources to stay informed about the latest developments.

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Lecture 2. Environmental regulatory framework for EU membership. A brief description of the process of Ukraine's accession to the EU. Definition of elements of the acquis, basic principles and international agreements in the field of environment. General characteristics of the main EU legal environmental regulations and the implementation of relevant legislation in Ukraine.

Lecture 3. Comparative analysis of Ukrainian and European environmental legislation, policy and practice. Peculiarities of legal support for environmental monitoring in EU legislation. Legal principles of functioning of the State Environmental Monitoring System in Ukraine. Analysis of institutional support for state environmental monitoring. Functioning of the state environmental monitoring system. National priorities in the field of monitoring of environmental objects. Practical approaches of the EU and Ukraine to the monitoring of environmental objects.

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Lecture 9. Climatic and environmental consequences of Russia's war against Ukraine. The impact of the Russian war in Ukraine on the climate.Environmental and economic damage from Russia's military aggression for the world and Ukraine. Assessment of damage from military impact on the environment. The main sources of pollutants entering the environment during hostilities. The impact of hostilities on certain components of Ukraine's environment.

Lecture 10. Cooperation with institutions of civil society in the system of state European monitoring. The role of public monitoring. Involvement of public organizations in environmental management. Strengthening environmental governance by building the capacity of non-governmental organizations. The role of civil society organizations in facilitating monitoring at the community level. Air quality monitoring and management – public participation in decision-making. The main problems of practical application of citizens' rights.

Lecture 11. European and Ukrainian experience in calculating air quality indices and access to environmental information. Use of air quality indices for the purpose of promptly informing the population about air pollution and health risks. The procedure for alerting and informing the population about the deterioration of air quality through WEB services or social networks. Ukrainian state information resources designed to display information on monitoring of environmental objects.

Lecture 12. Water monitoring in the light of the EU. Introduction: water management and water protection policy of the EU.Framework water directive, EU legislation. State water monitoring in Ukraine, its approach to European standards.Water strategy of Ukraine for the period until 2050.

Lecture 13. Quality of underground and surface water and assessment of suitability for use (experience of EU countries). Effectiveness of the implementation of the requirements of the Water Framework Directive. Basin water resources management system. Improvement of monitoring of the quality of land surface waters. Management of water resources in certain European countries.

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Lecture 15. European soil monitoring in Ukraine: legislative framework, methodical and technical support for practical implementation. Peculiarities of soil monitoring organization. Soil monitoring in Ukraine. Technical and economic justification of soil monitoring. Sources and types of soil degradation. Principles of organizing observations on the level of chemical contamination of soils.

Lecture 1. Monitoring of environmental objects in the context of European integration.

Plan.

1. The role of monitoring environmental objects in solving the problems of pollution of environmental objects and the global increase in the temperature of the planet.
2. Global cooperation in the fight against climate and environmental changes.
3. The concept of "environmental monitoring".
4. Global environmental monitoring.

1. The role of monitoring of environmental objects in solving the problems of pollution of environmental objects and the global increase in the temperature of the planet

Human existence is directly related to the environment and the processes taking place in it. Changes in the environment occur under the influence of natural and anthropogenic (caused by human economic activity) biosphere factors.

Two of the biggest problems of the modern world are the global increase in temperature and the pollution of environmental objects.

In many international documents related to environmental protection, the problem of air pollution and the problem of climate change are usually links of the same chain. After all, during the development of strategies to reduce the harmful impact of humans on atmospheric air and climate, we have to deal with the same sources of danger.

Environmental monitoring – observing the environment, assessing its actual state, forecasting its development – plays a key role in overcoming these painful problems of humanity. Being aware of the danger and having up-to-date reliable information, we will be able to help solve them in the ways available to us.

The global climate crisis has clearly shown how interconnected we all are: human health depends on the health of the environment. And for every person, the most valuable thing is life and health. What ensures the health of the environment – optimal climatic factors, clean and safe atmospheric air, water, soil – is a public value and the last free natural resource that for the majority of the planet's population has no alternative to consumption.

What causes climate change? **Climate changes** are global changes, when abnormal deviations from the weather norms of natural zones are reproduced every year for at least three decades in a row.

Due to the burning of fossil fuels – coal, oil, natural gas –, industrial production, deforestation and livestock breeding, the average temperature of the Earth is rising. This activity results in the release of huge amounts of so-called greenhouse gases into

our atmosphere, which increases **the greenhouse effect** and causes global temperature rise.

The greenhouse effect is the heating of the earth's surface, oceans, and lower layers of the atmosphere caused by certain gases in the air. They let the sun's rays into the lower layers of the atmosphere, but prevent them from returning back into space, as if covering the Earth with a blanket. But these gases capture heat from the Sun so well that if their level rises slightly, the Earth's temperature also rises, which has significant negative consequences for life on Earth.

Various natural processes control the natural amount of these greenhouse gases in the atmosphere. However, human activity has rapidly increased the amount of some greenhouse gases in the atmosphere, causing the Earth to heat up at a rapid rate.

In the World Meteorological Organization (WMO), the main greenhouse gases, the concentration of which is increasing, are called:

- carbon dioxide or carbon(IV) oxide CO_2,
- CH_4 methane,
- nitrogen oxides,
- water vapor,
- fluorine-containing gases (F-gases): hydrochlorofluorocarbons (HCFC), hydrofluorocarbons (HFC), hydrofluorocarbons and perfluorocarbons, for example, CHF_3 and CF_4, respectively, sulfur hexafluoride SF_6, nitrogen trifluoride NF_3,
- ozone in the lower atmosphere.

These anthropogenic greenhouse gases can remain in the atmosphere for years, decades, or even longer (depending on the gas). For the convenience of calculations, they are all converted into the so-called "CO_2 equivalent". That is why all greenhouse gases are often simply called "carbon".

Climate change affects the amount of precipitation and average temperature, seasonality. If we talk about Europe as a continent, it is expected that it will become warmer in Europe, drier in some regions, and wetter in others.

These changes will affect not only our health, but also the ecosystems we depend on and the economy.

The weather in Europe is becoming more and more extreme:

- more, stronger and longer heat waves. Heat waves are the deadliest extreme weather events in Europe, during which conditions are dangerous to human health, meaning more additional deaths and hospitalizations, especially among the elderly and sick, if adaptation measures are not taken.
- more frequent, extreme floods,
- more frequent severe droughts. To understand their impact on the economy, the following forecasts are used: in Europe, the total economic losses in all sectors of the economy due to droughts are expected to increase by the end of this century from

the current 9 billion euros per year to 25 billion euros per year with a global warming by 1.5 degrees Celsius (°C), 31 billion euros per year for 2°C warming and €45 billion for 3°C warming based on science-based scenarios,

- larger forest fires,
- the rise of climate-sensitive diseases,
- climate change also affects the ability of many plants and animals to survive in new climatic conditions.

Tackling climate change requires two interrelated actions that work together:

- mitigating the consequences of climate change: reducing emissions of greenhouse gases into the atmosphere and increasing their absorption to slow down climate change,
- climate change adaptation: actions to adapt to the effects of climate change, such as preventing floods, preparing for heat waves and reducing other climate risks.

2. Global cooperation in the fight against climate and environmental changes

What were the first important steps taken by the world community to reduce greenhouse gas emissions? 197 countries signed **the Paris Agreement** in 2015, committing to keep the rise in global average temperatures well below 2° C above pre-industrial levels and to continue efforts to limit temperature increases to 1.5° C above pre-industrial levels.

Reducing emissions requires a rethinking of society, economy, science and politics. The sooner we act to reduce these emissions, the better off we will be in the future. Solving this problem requires us to change everything we do, from how we grow our economy and grow our food, to how we travel and live. This is a problem that is felt both globally and locally.

Global cooperation is essential to mitigating the effects of climate change.

United Nations Framework Convention on Climate Change (UNFCCC)and the Paris Agreement provide cross-border cooperation to fight climate change and ensure a sustainable future.

Ukraine aspires to become part of the EU, so we need to know and apply its experience in the fight against climate change. **The European Union's Green Deal** or **Green Deal (EGD)**, launched in December 2019, pledged to make Europe the first climate-neutral continent by 2050, meaning a place where all human-caused greenhouse gas emissions are absorbed by ecosystems and capture technologies and carbon storage.

The Green Course is a roadmap that includes strategies for the development of a sustainable, clean, safe and healthy Europe.

It consists of an action plan to make the EU economy sustainable by turning climate and environmental challenges into opportunities across the board.

EGD covers all sectors of the economy, including transport, energy, agriculture, construction and industry. Action Plans were developed for various sectors. Each part of the Plan envisages approved EU goals until 2030, which are important to implement in order to achieve the overall goal. Over the past decades, the EU has taken strong action against climate change, leading to a reduction in emissions of more than 30% in 2020 compared to 1990 levels.

This is mainly the result of the increase in the use of renewable energy and the decrease in the use of carbon-containing fossil fuels. Improvements in energy efficiency and structural changes in the economy have also contributed to these goals. Now, more ambitious goals have been set – a net reduction of greenhouse gas emissions by 55% by 2030 and the achievement of climate neutrality by 2050.

"Green Course" should become a signpost for Ukraine during its recovery as well. Currently, Ukraine is waging a war for the right to exist, and protection of our state, safety of our people, and preservation of our values is a top priority. But at the same time, de-occupied and damaged territories are being restored and rebuilt, Ukraine receives support from international partners, including the EU. This is a chance to rebuild Ukraine after the war in a sustainable and green way, which will be important for the development of a competitive economy and a comfortable life for the population. Implementation of EGD in Ukraine should be cross-cutting: environmental and climate issues should be considered in the fields of energy, industrial policy, agriculture, transport, finance, etc.

What are the policies and measures in the field of reduction of anthropogenic greenhouse gas emissions and adaptation to climate change in Ukraine? The Decree of the Cabinet of Ministers of Ukraine dated October 20, 2021 No. 1363 approved **the Strategy for Environmental Security and Adaptation to Climate Change** for the period until 2030 and the operational plan for the implementation of the Strategy for 2028-2030. The strategy was developed with the aim of increasing the level of environmental safety, reducing the effects and consequences of climate change in Ukraine.

The strategic goals are, in particular:

- reducing the level of industrial pollution,
- achieving a "good" ecological state of waters,
- increasing the effectiveness of the state system of environmental impact assessment and state supervision (control) in the field of environmental protection,
- raising the awareness of representatives of central and local state authorities and local self-government bodies, which are authorized to make decisions in the field

of the environment, the public on issues of mitigation and adaptation to climate change.

3. The concept of "environmental monitoring"

For decades, the European Union has been fighting to improve the quality of air, water and soil through the control of emissions of harmful substances and the integration of environmental protection requirements into the industrial and energy sectors. But all types of environmental pollution have no borders and are actually **transboundary.** This worries many countries, in particular, Ukraine's environmental problems, which have arisen as a result of the exploitation of mineral deposits, are mainly related to the development of oil and gas deposits, potassium salt, and the conduct of mining operations by the open-pit method are potentially dangerous.

At the unique man-made object of the Ivano-Frankivsk region – **the Dombrovsky quarry (**figure 1) – where in the 60s of the 20th centuryfor the first time in the world, potash raw materials began to be mined in an open-pit way (as a rule, mined by mines), a drainage trench functioned during active exploitation, pumping stations that pumped out surface water worked (until 2008). However, when the operation was stopped, the pit began to fill with water.

Figure 1. The Dombrovsky quarry, Kalush city, Ivano-Frankivsk region.

White salt is thenardite (sodium sulfate), which, together with potassium and magnesium salts, is lost from polymineral deposits, brines, creating environmental problems in our region and not only... The deposit can become either an ecological threat of a transboundary scale, or a real salvation for restoration of potash industry of Ukraine (the composition of brines allows to obtain potassium-magnesium sulfate fertilizers, which are in short supply both in Ukraine and in the world).

Through the Dombrovskyi quarry, fresh underground waters in the Carpathian region are salted. Due to inactivity, the brine of the quarry pollutes the Sivka River, which flows into the Dniester, and it, in turn, is predicted to carry the polluted water even to other countries in the most unfavorable situation, that is, cross-border pollution will occur.

The given example of the possibilities of cross-border pollution shows that the world needs and is very important a transparent system of monitoring and reporting on emissions.

According to the international standard (ST ISO 4225-80), **monitoring** is a repeated measurement to observe changes in any parameter in a certain time interval; a system of long-term observations, evaluation, control and forecasting of the state and changes of objects. The term was proposed on the eve of the UN Stockholm Conference on the Environment (Stockholm, June 5-16, 1972) as an addition to the term "control".

Without careful **monitoring** of emissions over a long period of time, it is impossible to understand the impact of the various measures that countries take to reduce emissions of pollutants.

The concept of **"environmental monitoring"** was first introduced by Professor R. Mann at the Stockholm UN Conference on the Environment, and currently has received international distribution and recognition.

Environmental monitoring (EM) (from the Latin monand tor – the one who controls, warns) is a system of observation and control of natural, natural-anthropogenic complexes, the processes occurring in them, the environment in general with the aim of rational use of natural resources and environmental protection, forecasting the scale of inevitable changes.

Monitoring differs from ordinary control in that it is not carried out once, but involves constant systematic observations according to established regulations or over a certain, rather long period of time. In addition to observations and obtaining information, monitoring also includes elements of active actions, such as assessment, forecasting, development of recommendations, in this case environmental protection.

Environmental monitoring plays an important role for the environmental protection policy of all countries of the world, which is carried out in accordance with environmental forecasts. It is **a source of information** for society about the state of the environment and trends in its development.

From the point of view of state administration, **EM** is a tool for assessing the state of the natural environment, as well as preparing data for making adequate management decisions and further informing governmental, public, and international organizations.

EM provides performingfollowing **general tasks:**

- ❑ observation of changes in the environment;
- ❑ forecasting the consequences of human intervention;
- ❑ assessment of the state of the environment and forecasting its changes;
- ❑ modeling of processes of changes in the environment.

The need to perform these tasks determines **the monitoring structure**, which is formed from the following blocks (figure 2):

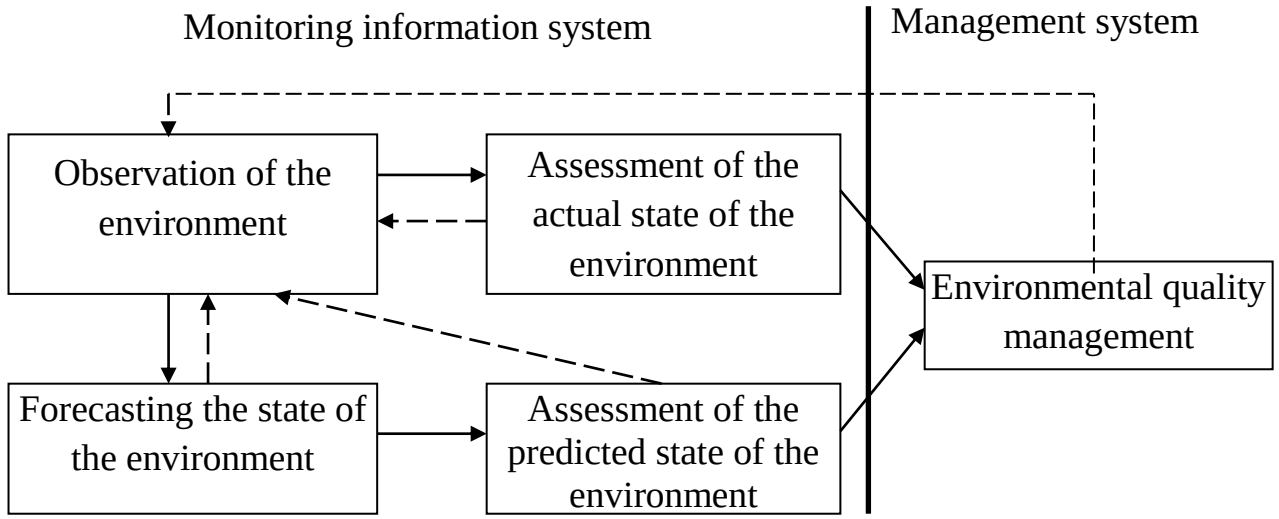

Figure 2. Block diagram of the monitoring system.

Environmental monitoring is hierarchically organized by **levels:**

- ❑ **global** – covering the Earth as a whole, carried out on the basis of international cooperation,
- ❑ **national** – covers individual states, is carried out within the state by specially created bodies,
- ❑ **regional** – carried out within large areas that are intensively developed by humans,
- ❑ **local** – carried out within settlements, industrial centers, directly at enterprises.

When performing its functions, environmental monitoring uses various **methods of obtaining primary and secondary information.**

To obtain **primary information,** direct observations are used at appropriate stations, observation points (stationary, mobile): meteorological, hydrological, oceanic, geophysical, biological, background observations. Data on the state of the environment is also obtained using remote means of observation, in particular as a result of direct observations from Earth satellites, vertical soundings, photographic and geophysical surveys, as well as geostationary observations.

Secondary information is accumulated during the processing of data received as primary information. The results are fixed in the form of maps, tables, graphs. Computer databases combined with certain analytical tools for working with spatial information –**geographic information systems (GIS) are used to accumulate and generalize information**.

It is necessary to study the environment **in dynamics,** that is, to assess its past and present conditions, as well as predict changes in its parameters in the future.

Information about the state of the environment and trends of change is the basis for the development of nature protection measures, it is also taken into account when planning the development of the economy.

Studying and evaluating the negative consequences of anthropogenic actions in order to prevent or reduce losses is one of the most important conditions for organizing the economy and guaranteeing environmental safety.

Observations within the framework of the monitoring system based on the action of **the main anthropogenic factors and the processes** they cause are grouped according to the following directions:

- ❑ observation of local sources of pollution and polluting factors,
- ❑ observation of the state of the natural environment,
- ❑ observation of the state of the biotic (living) component of the biosphere,
- ❑ observation of the reaction of large systems (climate, world ocean, biosphere as a whole),
- ❑ observation of the state of health and well-being of the population.

To establish the dynamics of changes in the state of the biosphere, measurements are repeated at certain time intervals, and important indicators are monitored continuously.

The observation system can consist in the organization of measurements at specific points (at stations) or in a large area and obtaining integral indicators.

For observations, it is important to know the initial (**background**) state of the environment, that is, the state that was maintained before significant human intervention.

Assessment of changes in the state of the natural environment makes it possible to determine possible damages caused by natural and anthropogenic actions, to find out the optimal conditions for human activity, as well as additional natural opportunities that can be used by a person.

As a result of anthropogenic influences, the environment may suffer losses:

- ❑ environmental,
- ❑ economic,
- ❑ aesthetic.

When **assessing the state** of the environment, the following criteria are used:

- maximum allowable concentrations of pollutants – the maximum concentration of a substance in the environment (NS), which does not affect the human body and does not cause remote mutagenic and carcinogenic consequences,
- maximum permissible doses (the amount of a harmful substance, the action of which does not cause a harmful effect on the body, ecosystem),
- maximum permissible emissions of substances into the atmosphere, maximum permissible discharges of harmful substances into water bodies,
- the maximum permissible anthropogenic load (the load on the natural environment caused by human activity, the long-term impact of which will not lead to changes in ecosystems).

The most common criterion for assessing the quality of the components of the natural environment (atmospheric air, fresh and sea waters, soils) is **the maximum permissible concentration (MPC)** of harmful substances.

At the current stage of human development, protection and rational use of the environment is a global problem, for the solution of which it is necessary to combine the efforts of many countries, as well as various scientific disciplines with the formation of a single conceptual basis, a spectrum of scientific-methodical and practical approaches.

Subject environmental monitoring as **a science** is the organization and functioning of the monitoring system, assessment and forecasting of the state of ecological systems, their elements, the biosphere, the nature of the influence of natural and anthropogenic factors on them.

This field of natural activity cannot develop without specially trained specialists, it needs a systematic approach in substantiating networks and types of observations, the systematicity of their conduct and constant improvement of methodical and technical support.

Environmental monitoring as a complex branch of knowledge uses general scientific methods of research, but also develops its own methods of analysis and forecasting of the state of ecological systems and processes occurring in them.

Organization of monitoring is an extremely complex multifaceted task. The complexity of environmental monitoring is that it has **a dual nature:** it consists of natural and man-made systems.

The main task is to organize monitoring on different parts of the earth's surface, taking into account the alternation of these areas, which differ in the nature of anthropogenic load.

The methods of monitoring environmental objects should be as close as possible to the recommendations **of the International Program of Cooperation on Integrated Environmental Monitoring** , supported by most European countries: determination and forecasting of the state of ecosystems taking into account local

landscape and geochemical conditions, climate changes and the influence of man-made sources of pollutants.

The monitoring system is based on **the following principles**:

- ❑ systematicity of observations on the condition of the object,
- ❑ timeliness of receiving and processing observation data at the object and generalizing (local, regional and state) levels,
- ❑ the complexity of using monitoring information,
- ❑ objectivity of primary, secondary, analytical and predictive information,
- ❑ consistency of normative, organizational and methodological support at different levels,
- ❑ efficiency of delivery of monitoring information to interested organizations.

Objects of environmental monitoring, depending on the level and purpose of research, can be:

- ❑ the environment in territorial groups of different sizes (local, regional, national, global level),
- ❑ its elements (atmospheric air, surface and underground waters, soil and plant cover, ecosystems, their abiotic and biotic components),
- ❑ sources of impact on the environment.

For these objects, the following are distinguished:

- ❑ **monitoring of the chemical parameters of the environment** (pH, oxygen content, oxidizability (the amount of oxygen equivalent to the consumption of an oxidant for the oxidation of all organic and mineral substances), coarsely dispersed impurities, the total amount of water-soluble substances, dry residue, alkalinity (the total content of bases: strong, aniline, carbonate-, hydrocarbonate-, dihydrophosphate-, hydrogenphosphate-sulfite-, sulfide-, hydrosulfide-ion), acidity, chemical pollutants – solid, gaseous and liquid substances, chemical elements and compounds of artificial origin that enter the biosphere and disrupt natural processes circulation of substances and energy),
- ❑ monitoring of physical parameters of the environment (temperature, pressure, hygrometric indicators, air movement speed, solar radiation, ionizing radiation, acoustic and electromagnetic radiation),
- ❑ microbiological monitoring of the environment (bacteria, viruses, fungi, etc.).

Environmental monitoring in all developed countries is carried out differently, taking into account **national characteristics,** but based on UN recommendations.

Metrological support of state environmental monitoring systems is carried out in individual countries in accordance with the current legislation of these countries on ensuring the unity of measurements and according to intergovernmental agreements.

Material and technical support of environmental monitoring systems is carried out by state executive authorities, enterprises, institutions and organizations conducting state monitoring of the natural environment.

The financing of works on the implementation of environmental monitoring is carried out in accordance with the procedure for financing environmental protection measures at the expense of funds provided for in the state and local budgets of the countries in accordance with the legislation.

The entities of the environmental monitoring system in various countries are ministries and agencies, which are entrusted with the implementation of functions for monitoring environmental objects by state regulatory legal acts.

The relationship between the subjects is based on:

- on the coordination of actions during the planning, organization and conduct of observations and joint monitoring activities,
- mutual informational support of decisions in the field of environmental protection, environmental safety and rational use of natural resources,
- effective use of existing organizational structures, means of observation and modern information technologies,
- contribution to the effective resolution of joint tasks of monitoring and environmental safety,
- responsibility for the completeness, timeliness and reliability of the observations and information provided,
- collective use of information resources,
- free information exchange.

4. Global environmental monitoring

The main decision of the Stockholm Conference of the UN on the environment (June 1972): ecological problems of the environment are global in nature.

For their assessment and analysis, it is necessary to create **a Global Environmental Monitoring System (GEMS)** by combining existing national systems (primarily European, Soviet and American). At the first intergovernmental meeting of **GEMS**, held in 1974 in Nairobi, the foundations **of GEMS were adopted.**

The purpose of GEMS is to provide interested national and international organizations with information about the state, natural and anthropogenic changes of the environment, necessary for managing the quality of this environment.

Tasks of the GEMS program:

1. Organization of an extended system of warnings about threats to health.
2. Assessment of global atmospheric pollution and its impact on climate change.

3. Assessment of the amount and distribution of contamination of biological systems and food chains.

4. Assessment of critical problems arising as a result of agricultural activity and land use.

5. Evaluation of the response of terrestrial ecosystems to the influence of the environment.

6. Assessment of ocean pollution and the impact of pollution on marine ecosystems.

7. Creation of an improved system of warnings about natural disasters on an international scale.

GEMS consists of five subsystems:

I. Monitoring of the state of the atmosphere.
II. Monitoring of long-distance transport of pollutants.
III. Human health.
IV. Research of the World Ocean.
V. Monitoring of renewable resources.

The global monitoring system is organically intertwined with national systems – it largely unites **the background stations** of national systems. Biosphere reserves are considered as an integral part of **GEMS**.

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Lecture 2. Environmental regulatory framework for EU membership.

Plan.

1. Introduction. A brief description of the process of Ukraine's accession to the EU.
2. Definition of elements of the acquis, basic principles and international agreements in the field of environment.
3. General characteristics of the main EU legal environmental regulations and the implementation of relevant legislation in Ukraine.

1. Introduction. A brief description of the process of Ukraine's accession to the EU

The process of accession to the EU generally consists of three stages:

1. Acquisition of candidate status. When a country is ready, it becomes an official candidate for membership, but this does not necessarily mean that formal negotiations have begun.

2. Formal membership negotiations, including membership criteria. The candidate moves on to formal membership negotiations, a process that involves adopting national legislation in line with defined EU legislation, preparing to be able to properly apply and enforce it, and implementing judicial, administrative, economic and other reforms that the country needs in order to meet the joining conditions known as joining criteria.

3. Accession to the EU by concluding a relevant agreement.

On June 25, 2024, an Intergovernmental Conference was held in Luxembourg, which gave an official start to the negotiations on Ukraine's accession to the European Union. Accession negotiations are a process during which Ukraine and the European Commission harmonize our national legislation with European legislation.

The EU procedure defines 35 negotiating sections, each of which is responsible for a certain area. Ukraine needs to fully or partially implement about 3,000 acts of EU law, as well as to carry out a number of structural reforms. It is difficult to predict the duration of this process. Most countries went through this path from 4 to 7 years.

It should also be noted that despite the official start of negotiations on June 25, their substantive part will begin a little later. The elections to the European Parliament have only recently ended, and now the new composition of the European Commission is being formed , which should create negotiation groups. And it takes time. The active phase of negotiations with the EU on the regional cluster will begin in January-February 2025.

The opening of negotiations on accession to the EU by sections of the so-called "green cluster" is important in connection with the priority of green issues on the agenda of the European Commission, in particular due to the implementation of the

European Green Course. The green cluster includes, among other things, environmental issues and climate change (chapter 27). Chapter 27 “Environment and Climate Change” is one of the largest changes to be implemented.

Acquis communautaire in the field of environment and climate change includes about 80 main EU directives and regulations, as well as hundreds of additional legal acts, various decisions, recommendations, policies, court practice. Under the acquis communautaire we understand the totality of legislative acts, political documents and the practice of their application that exist in the European Union at any given moment.

Thus, necessary for the implementation of the acquis by Ukraine are not only directives and regulations, as the implementation of the Association Agreement in the area of the environment and climate change was traditionally perceived in Ukraine, but also policies, principles, and other documents that not only regulate this or that issue, but also establish a political framework for implementation.

The list of regulatory legal acts of the EU, which Ukraine needs to implement in order to obtain EU membership, goes far beyond the existing obligations within the framework of the Association Agreement between Ukraine and the EU. It includes not only new acts, but also whole areas that were not mandatory for implementation before. For example, the field of waste management has 15 main EU directives and regulations, while the Association Agreement includes only 5 of such acts, and areas such as the fight against noise pollution or the regulation of zoos are completely excluded from the scope of the Association Agreement. However, on a number of issues that are not in the Association Agreement, Ukraine has already carried out legislative and other work. In particular, this concerns the issue of chemicals or certain types of waste. The implementation of acts and policies in the field of environment and climate change goes beyond the environmental chapter of the negotiations (Chapter 27). In particular, in connection with the implementation of the EEC, environmental and climate issues will be considered in the context of energy, industrial policy, agriculture, transport, the single market, etc. Work within the framework of the negotiation process will include not only approximation of legislation, but also its implementation and performing . The actual implementation of the acquis will require a great deal of administrative capacity, both with regard to the acts themselves and with regard to interaction with the EU (for example, in the context of reporting).

The challenge in the process of meeting the conditions for admission is the dynamism of European law in the field of environment and climate change. The EU is currently making changes and adopting new documents in areas closely related to the implementation of the European Green Deal. This creates a so-called "moving target" in the implementation of necessary tasks in the field of environment and

climate change and requires constant monitoring of updates and implementation of the latest versions of regulatory and legal documents.

It should also be noted that the approach to the European acquis in the field of environment and climate change must be done correctly: taking into account the latest revisions of documents, implementing all elements of the directive or regulation, using the tools and mechanisms defined in the regulatory documents.

At the moment of accession to the EU, all European approaches, standards and principles should work in Ukraine. Cooperation in the government-EU-society triangle is needed to strengthen the potential for approximation of legislation and especially its implementation in Ukraine.

European legislation on environmental protection is the most progressive in the world. For Ukraine, which "inherited" the Soviet attitude to the environment as a resource base, this will be an unconditional breakthrough. But it is already obvious that not everything will be smooth on the way to the implementation of European norms. Unlike the EU, in Ukraine there is a gap between the adoption of legislation and its compliance. Therefore, without the reform of environmental control, which will create an independent law enforcement structure with powers and means of influence, all the efforts of legislators in the field of environmental protection may remain "on paper".

But despite all these warnings, the most meaningful stage of Ukraine's European integration is now beginning.

2. Definition of acquis elements, basic principles and international agreements in the field of environmental protection

2.1. Content of negotiations and compliance with the EU acquis

The start of negotiations automatically means that the candidate state accepts the acquis – the rights and obligations associated with the Union and its institutional framework. Acceptance and implementation of the acquis by the candidate country is the basis of negotiations on its accession to the EU. A candidate country for EU membership must implement all legislation and all other decisions, even advisory ones, adopted in the EU.

Characteristics of the elements of the acquis , which Ukraine will be obliged to implement:

EU **treaties are** mandatory agreements between EU member states. They establish the objectives of the EU, the rules for the EU institutions, the way decisions are made and the relationship between the EU and its member states. Contracts, among other things, contain principles that are also mandatory to observe.

The main agreements that are in force now are:

- Treaty on the European Union,
- Treaty on the Functioning of the European Union,
- Treaty on the establishment of the European Atomic Energy Community.

A directive is a type of act of secondary EU legislation. The Directive is obligayory on the result to be achieved for each Member State to which it is addressed, but leaves the choice of forms and means of implementation to the national authorities. As a rule, directives are the main instrument for harmonizing the legislation of member states. Directives are the main, by volume, source in which the norms of European environmental and climate law are established.

The regulation is a type of act of secondary legislation of the EU. The regulations establish general rules that apply equally in all EU member states. The Regulations are mandatory in their entirety and directly applicable in all Member States. They have legal force without further implementation into the national law of the Member States, and individuals can refer to them in national courts. Regulations are adopted in cases where there is a need to uniformly regulate this or that issue in all member states, therefore they are considered the main instrument of law unification.

Decisions (of the EU Council or the European Commission) are individual acts that are mandatory on the parties to which they are addressed. As a rule, decisions relate to special, narrow, mostly technical issues and are obligatory only for those subjects of European law to whom they are addressed. Used to clarify detailed administrative requirements or update technical aspects of a regulation or directive. The addressee is not necessarily the state – it can be individual categories or specific legal entities.

EU international treaties are a special group of sources of EU law that establish the obligations of the EU and its member states in the international arena. International agreements concluded by the EU are binding for EU institutions and EU member states.

Along with legally binding legal acts (regulations, directives, decisions), EU institutions can adopt acts of **a recommendatory** nature – recommendations and conclusions – which are not binding and can be taken into account by states when solving individual issues.

Recommendations are acts by means of which the EU institutions propose to voluntarily take certain actions or refrain from taking them. Recommendations can be both individual (relating to a specific member state) and general in nature (contain general rules of conduct - recommended norms).

Conclusions are acts expressing the official position of the EU institutions on some issue.

It should be noted that negotiations always include not only the "acceptance" of the acquis as a condition for accession, but also the provision of its implementation and monitoring of compliance (implementation and enforcement) by the candidate state.

2.2. Principles of EU environmental policy

The Treaty on the Functioning of the European Union (TFEU) establishes several principles of EU environmental policy:

- ❑ precautionary principle;
- ❑ principle of prevention;
- ❑ the principle of correcting environmental damage at its source;
- ❑ "polluter pays" principle.

Although these principles concern the environmental policy of the EU itself (and not the member states), their practical implementation by the EU bodies in the relevant acts requires the states to observe (recognize) such principles.

All these principles are part of Ukraine's obligations under the Association Agreement, Article 292(4) of which reproduces the text of Article 191(2) of the TFEU verbatim.

These principles were included in the Basic principles (strategy) of the state environmental policy of Ukraine for the period until 2030. At the same time, they were not enshrined in the Basic Law of Ukraine "On Environmental Protection".

2.3. International agreements in the field of environmental protection

Today, the EU is a party or signatory to about 54 international agreements in the field of environmental protection. In the process of joining the EU, Ukraine must also join them (ratify, sign or join).

Currently, Ukraine is a party to 24 such agreements in their latest editions (that is, it has also ratified the relevant amendments). In addition, although Ukraine is a party to the Montreal Protocol on Substances that Deplete the Ozone Layer, it will be necessary to ratify the Kigali Amendment to it.

Some EU international treaties in this area will not require Ukraine to join, as they are limited by the geographical scope of application (for example, the Alpine Convention).

3. General characteristics of the main legal regulationsEU environmental acts and implementation of environmental policy and legislation in Ukraine

3.1. Ambient air quality. General characteristics

The policy and legislation of the EU in the field of atmospheric air are systemic and have a long history. This area remains relevant and undergoes significant changes

within the framework of the implementation of the European Green Course. Thus, on October 26, 2022, the European Commission published its proposal to improve the main framework document in this area (Directive 2008/50/EC on ambient air quality and cleaner air for Europe) with the aim of introducing new air quality standards, the right to compensation for damages, caused to health due to atmospheric air pollution, etc.

Some of the EU acts in this area are systemic and can be considered as separate mechanisms.

Most of the acts related to fuel quality (apart from fuel sulfur content) are currently under the responsibility of DG CLIMA (the EU's climate directorate) and are therefore not included in this part (although some of these acts are included in the "Ambient air quality" section Appendix XXX to the Association Agreement). In addition, a significant part of the acts concerns greenhouse gas emissions of the transport sector (about 20), which, accordingly, are usually also attributed to the climate change sector (in particular, the new Regulation No. 2019/631 on setting CO_2 emission standards for passenger and light commercial vehicles).

In general, the field of atmospheric air quality is very closely related to regulation in the field of climate change.

This area includes 6 main EU acts, a number of additional ones, and is also closely related to separate international agreements in this area, to which the EU is a party (Convention on long-range transboundary air pollution and a number of protocols to it).

3.1.1. Atmospheric air quality management

This unit combines several acts, the scope of which concerns the protection of atmospheric air in general.

Main acts:

- Directive 2008/50/EC of the European Parliament and of the Council of May 21, 2008 on ambient air quality and cleaner air for Europe (consolidated text);
- Directive 2004/107/EC of the European Parliament and the Council of December 15, 2004 on arsenic , cadmium, mercury, nickel and polycyclic aromatic hydrocarbons in atmospheric air (consolidated text);
- Directive (EU) 2016/2284 of the European Parliament and of the Council of December 14, 2016 on the reduction of national emissions of certain air pollutants, amending Directive 2003/35/EC and repealing Directive 2001/81/EC.

The key regulatory act in this block (and for the field of atmospheric air protection) is Directive 2008/50/EC on ambient air quality and cleaner air for Europe. Directive 2008/50/EC sets air quality standards for 12 pollutants, including limits and targets. The main obligations of the member states are monitoring and assessment of the state of the atmospheric air, zoning of the territory (definition of zones and

agglomerations), exchange of information on the state of the air, provision of such information to the public and other interested persons (informing), air quality management (to eliminate problems) and reporting . For these mechanisms, the directive establishes detailed implementation requirements (for example, requirements for the content of air quality management plans, references to relevant technical regulations/measurement methods, etc.).

Directive 2004/107/EC regulates pollution by certain heavy metals (arsenic, cadmium, mercury, nickel) and polycyclic aromatic hydrocarbons. Joint Implementing Decision 2011/850/EC on mutual exchange of information and reporting on atmospheric air quality was adopted in compliance with Directives 2008/50/EC and 2004/107/EC. Both directives are closely related to EU-ratified international agreements (the Convention on Long-Range Transboundary Air Pollution and a number of protocols to it).

This block also includes Directive (EU) 2016/2284 on the reduction of national emissions of certain air pollutants (NEC Directive). This directive was adopted as part of the Clean Air for Europe package (2013), in part to fulfill the obligations under the Gothenburg Protocol to Combat Acidification, Eutrophication and Ground-Level Ozone (1999) to the Convention on Long-Range Transboundary Air Pollution (Ukraine is not a party to the protocol). The directive establishes obligations to reduce national emissions of five main air pollutants: sulfur dioxide, nitrogen oxides, non-methane volatile organic compounds and fine particulate matter (PM2.5). For each such polluter (group), the directive establishes specific target obligations (for each country separately) to reduce their emissions until 2029 and from 2030 (as a percentage of 2005 emissions). In addition, the directive requires the monitoring of these substances, the compilation of inventories and the implementation of so-called national programs for monitoring the state of atmospheric air.

The practical tasks arising from the implementation of acts in this area are complex, require considerable time, human and material resources, and the capacity of authorities.

The situation in Ukraine. This sphere is the object of legal regulation in Ukraine. Two acts included in the obligations under the Association Agreement and were, accordingly, the subject of active efforts of the Government in recent years. In recent years, the Government and the Verkhovna Rada have made certain efforts to implement certain EU acts in this area, which are part of the obligations under the Association Agreement. At the same time, the full implementation of EU law in this area still requires a long time due to the lack of human, institutional and financial resources (in particular, for the development of a system for monitoring the state of atmospheric air in accordance with the requirements of the directives). It will also require accession to (ratification) of all international agreements in this area to which

the EU is a party, in particular within the framework of the Convention on Long-Range Transboundary Air Pollution.

The implementation of Directive 2016/2284 will require a completely new effort.

3.1.2. Emissions of volatile organic compounds

This block contains two main acts: directives concerning emissions of volatile organic compounds from gasoline.

Directive 94/63/EC on the control of emissions of volatile organic compounds (VOCs) arising from gasoline storage and during its transportation from terminals to service stations (it is also called the "Stage I directive") is aimed at preventing VOC emissions from operations, installations, vehicles or vessels used to store, load and transport gasoline from one storage (terminal) to another or from storage to filling stations.

Directive 2009/126/EC on the recovery of gasoline vapors at Stage II during refueling of vehicles at gas stations regulates requirements for the prevention of air pollution by VOC emissions during refueling of vehicles at service stations (gas stations).

Emissions of volatile organic compounds are also regulated by Directive 2004/42/EC, which establishes requirements for the content of volatile organic compounds in paints and varnishes and materials for polishing vehicles, as well as requirements for the labeling of the corresponding products. However, this directive is traditionally included in the sphere of regulation of industrial pollution.

Main acts:

- ❑ Directive 94/63/EC of the European Parliament and of the Council of December 20, 1994 on the control of emissions of volatile organic compounds (VOCs) arising from oil storage facilities and during its transportation from terminals to service stations (consolidated text);
- ❑ Directive 2009/126/EU of the European Parliament and of the Council on the recovery of gasoline vapors at Stage II during refueling of vehicles at gas stations (consolidated text).

The situation in Ukraine. This area is partly the subject of legal regulation in Ukraine: only two directives are included in Annex XXX of the Association Agreement. In the field of emissions from gasoline operations, additional measures are needed, one of the directives is not covered by the Association Agreement (on the recovery of gasoline vapors in Stage II during refueling of vehicles at gas stations).

3.1.3. Sulfur content in some types of fuel

This block contains only one directive: Directive 2016/802/EU on the reduction of sulfur content in certain types of liquid fuels.

This directive establishes requirements for the sulfur content of diesel, boiler and marine fuels and, accordingly, prohibits the placing of such fuels on the market. In addition, the directive requires regular monitoring of fuel quality on the market.

Main acts: Directive 2016/802/EU of the European Parliament and the Council of May 11, 2016 on reducing the sulfur content in certain types of liquid fuel (codification).

The situation in Ukraine. The previous Directive 1999/32/EC is included in the Association Agreement, so implementation work has already been carried out in Ukraine. Currently, additional efforts are needed to ensure market control of fuel quality.

3.2. Water quality and water resources management. General characteristics

The water policy and legislation of the EU are very developed, and the first acts were adopted already in the 70-80s. Within the framework of the European Green Course, further improvement of this area is taking place, in particular in the areas of wastewater treatment and the quality of surface and underground water. Most of the EU acts in this area are systemic and can be considered as separate mechanisms.

The main normative legal act in this area is the Water Framework Directive 2000/60/EU, which establishes the principles of water resources management (in particular, the basin principle) and goals (including the achievement of "good status" of water resources).

In this area, the EU also separately regulates relations regarding water resource quality standards, use and protection of groundwater, flood risk management, and bathing water quality.

Separately, it is possible to highlight the prevention of water pollution from specific types of activities (urban wastewater, use of nitrates in agriculture), drinking water quality, and protection of the marine environment. Regulation in this area is closely related to other sectoral legislation on waste management, nature conservation, fisheries, industrial pollution, chemical safety, plant protection products, environmental impact assessment, public participation and others.

This thematic block includes more than 10 EU acts, as well as many guiding and recommendatory documents of EU bodies.

3.2.1. Management and quality of water resources

The management and quality of water resources conditionally unites those directives and regulations that mainly regulate relations in the field of fresh water resources (surface and underground). At the same time, it should be taken into account that the acts included here also regulate other issues, in particular marine

resources. This is particularly the case for the Water Framework Directive, the scope of which extends to all water resources.

Main acts:

- Directive 2000/60/EC of the European Parliament and of the Council of October 23, 2000 establishing a framework for Community action in the field of water policy (consolidated text);
- Directive 2008/105/EC of the European Parliament and the Council of December 16, 2008 on the establishment of environmental quality standards in the field of water policy, on the amendment and subsequent repeal of Council Directives 82/176/EEC, 83/513/EEC, 84/156/ EEC, 86/280/EEC and amending Directive 2000/60/EC of the European Parliament and of the Council (consolidated text);
- Directive 2006/118/EC of the European Parliament and the Council of December 12, 2006 on the protection of groundwater against pollution and depletion (consolidated text);
- Directive 2007/60/EC of the European Parliament and the Council of October 23, 2007 on the assessment and management of flooding risks;
- Directive 2006/7/EC of the European Parliament and of the Council of February 15, 2006 on the management of bathing water quality and repealing Directive 76/160/EEC.

The key acts in this block are the Water Framework Directive 2000/60/EC, as well as its two "daughter" directives: Directive 2008/105/EC on the establishment of environmental quality standards in the field of water policy and Directive 2006/118/EC on the protection of groundwater from pollution and exhaustion.

The Water Framework Directive establishes the principles of management of all water resources in order to prevent water deterioration. Thus, it requires approval of river basin management plans and programs of measures aimed at achieving "good state" of waters (which includes good chemical and good ecological state), definition of protection zones. It also contains a list of priority substances, water pollution with which requires special measures (for such substances, the established environmental quality standards must be achieved in order to achieve a good chemical state). In 2022, the European Commission came out with a proposal to add 24 new substances as priority substances. The Water Framework Directive has detailed requirements for monitoring the state of surface, underground and other waters. For such priority substances (as well as some others), environmental quality standards (maximum concentrations) are established in Directive 2008/105/EU.

Directive 2006/118/EC on the protection of groundwater against pollution and depletion establishes requirements for the quality of groundwater.

Directive 2007/60/EC on flood risk assessment and management is a systemic tool that is also based on integrated water resources management. Its main objective

is to reduce and manage flooding risks by assessing, mapping and developing risk management plans.

Directive 2006/7/EC on the management of the quality of bathing waters requires monitoring, assessment of the condition of bathing waters and informing citizens. By a separate implementing decision 2011/321/EC, the European Commission established requirements for information signs that must be posted to inform the public about the state of bathing water, by decision (EC) 2017/1583 – standards of equivalence of microbiological methods.

The practical tasks arising from the implementation of acts in this area are complex and require considerable time, human and material resources, and the capacity of authorities. Among such tasks, it is possible to single out the establishment (definition) of river basins and sea waters, the development of appropriate management plans for water basins, flooding risks, monitoring the state of water resources, establishing water resource quality standards and discharge standards, reporting, etc.

The situation in Ukraine. This sphere is already the object of legal regulation in Ukraine. In recent years, the Government has made significant efforts to implement certain EU acts in this area, mainly those that are part of the obligations under the Association Agreement. With regard to some mechanisms of EU law in this area, Ukraine shows significant progress in convergence (introduction of the basin principle of water resource management, gradual development of river basin management plans, flood risk assessment and approval of such risk management plans for all basins, etc.).

From the perspective of policies in this area, the Marine Environmental Protection Strategy of Ukraine (2021), the Water Strategy of Ukraine for the period up to 2050 (2022) and the operational plan for the implementation of the Water Strategy for 2022-2024 (2022) were recently approved.

At the same time, the full implementation of EU law in this area still needs a long time. In addition, only two acts are included in the obligations under the Association Agreement and, accordingly, have been the subject of active efforts by the Government in recent years.

3.2.2. Prevention of water pollution

EU water legislation also covers the pollution of water resources by urban sewage and nitrates.

This group includes three main EU acts:

- ❑ Directive 91/271/EEC on urban wastewater treatment;
- ❑ Regulation (EU) No. 2020/741 on minimum requirements for water reuse;
- ❑ Directive 91/676/EC on the protection of waters against pollution caused by nitrates from agricultural sources.

Directive 91/271/EEC on the treatment of urban wastewater is aimed at protecting the environment from the negative impact of wastewater (in particular, from eutrophication). It contains requirements for the collection, treatment and discharge of urban wastewater (depending on the size of settlements or so-called "agglomerations", such requirements are different), in particular for certain types of enterprises. A separate implementing decision of the European Commission 2014/431/EU establishes requirements for reporting on national programs for the implementation of this directive.

Regulation (EU) 2020/741 on minimum requirements for water reuse establishes minimum requirements for treated wastewater for the purpose of using it for irrigation of agricultural land (entered into force on June 26, 2023), and also requires the introduction of a permit procedure for the use of treated wastewater city wastewater. This is a single regulation in the field of protection and use of water resources.

Directive 91/676/EC on the protection of waters against pollution caused by nitrates from agricultural sources (the so-called nitrate directive). This directive is closely related to the Water Framework Directive and is the main legal act in the EU aimed at protecting water resources from the negative impact of agriculture. The main tools of this directive are mandatory monitoring of nitrate content in water bodies, identification of so-called vulnerable zones and adoption of the code of good agricultural practices. Agricultural producers must comply with the code, especially within vulnerable zones.

It is clear that the implementation of this block requires significant capital investments (in particular, sewage treatment plants) and will have a significant impact on the implementation of agricultural activities.

The situation in Ukraine. This area is partially regulated in Ukraine, and in recent years certain steps have been taken to transpose two directives (on urban water treatment and the nitrate directive). At the same time, the practical implementation of this block of EU law in Ukraine is at the initial stages.

3.2.3. Drinking water quality

The most important act of the EU in the field of drinking water quality is Directive (EU) 2020/2184 on the quality of water intended for consumption.

Main acts:

- ❑ Directive (EU) 2020/2184 of the European Parliament and of the Council of December 16, 2020 on the quality of water intended for human consumption (revised);
- ❑ Council Directive 2013/51/Euratom of October 22, 2013 on establishing requirements for the protection of public health with regard to radioactive substances in water intended for human consumption.

The main goal is to protect public health from the negative impact of drinking water pollution and improve access to drinking water. The directive establishes quality standards for drinking water and obliges to carry out constant monitoring of such indicators.

Separately, Council Directive 2013/51/Euratom regulates the issue of drinking water quality in the context of radioactive contamination.

The situation in Ukraine. This area is the subject of legal regulation in Ukraine. In recent years, steps have been taken to bring the corresponding requirements in the field of drinking water closer to European ones. Practical implementation requires additional efforts in the direction of eliminating the conflict regarding the definition of terms for drinking water, ensuring the population's access to water of appropriate quality.

3.2.4. Marine environment

Protection of the marine environment is partially covered by other EU legal acts, in particular the Water Framework Directive.

The main act in this area is Directive 2008/56/EC of the European Parliament and the Council of June 17, 2008 on establishing a framework for the Community's activities in the field of environmental policy for the marine environment (Marine Strategy Framework Directive) (consolidated text).

The main requirement of the directive is the approval by the state of the so-called marine strategy for achieving a good ecological state of marine waters. This includes a number of other obligations, including assessment of the state of sea waters, qualification (definition) of a good ecological state, monitoring of the state of marine resources, etc. A separate decision of the Commission (EU) 2017/848 approved the criteria and methodological standards regarding the good ecological status of marine waters and standardized monitoring and assessment methods.

The situation in Ukraine. In recent years, a number of measures have been taken to implement this directive in Ukraine, the Marine Environmental Protection Strategy of Ukraine, the monitoring program of the Black and Azov Seas have been approved. These issues are partly covered by the Water Strategy of Ukraine.

3.3. Pan-European legislation for monitoring and improving soil health

Since the current EU legislation on land (soil) protection is still developing, there are currently no pan- European approaches to defining a mandatory list of pollutants that are a priority for state land protection management.

On April 10, 2024, the European Parliament adopted in the first reading the proposal of the European Commission on the soil monitoring law, the first ever EU soil law.

The aim of the law is to rehabilitate soils by 2050, in line with the EU's zero pollution ambitions, and to create a comprehensive and coherent monitoring system to promote sustainable soil management and remediation of contaminated sites.

The new law will oblige EU countries to first monitor and then assess the health of all soils on their territory. National authorities can apply soil descriptors that best illustrate the characteristics of each soil type at national level. Members of the European Parliament propose a five-level classification for assessing soil health (high, good, moderate ecological status, degraded and critically degraded soils). Soils with good or high ecological status are considered healthy.

There are approximately 2.8 million potentially contaminated sites in the EU. Members of the European Parliament supported the requirement to compile a public list of such sites in all EU countries no later than four years after the entry into force of this directive.

EU countries must also investigate, assess and clean up contaminated sites to eliminate unacceptable risks to human health and the environment from soil contamination. The costs should be paid by polluters according to the "polluter pays" principle.

It is expected that this document will be considered by the new parliament after the elections to the European Parliament on June 6-9, 2024.

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Lecture 3. Comparative analysis of European and Ukrainian environmental legislation, policy and practice.

Plan.

1. Peculiarities of legal support for environmental monitoring in EU legislation.
2. Legal principles of functioning of the State Environmental Monitoring System in Ukraine.
3. Analysis of institutional support for state environmental monitoring.
4. Functioning of the state environmental monitoring system.
5. National priorities in the field of monitoring of environmental objects.
6. Practical approaches of the EU and Ukraine to the monitoring of environmental objects.

1. Peculiarities of legal support for monitoring environmental objects in EU legislation

Among the acts of EU legislation in the field of environmental protection and nature management, we can single out the EU Directives regulating the field of monitoring of environmental objects :

- Directive 2000/60/EC of the European Parliament and of the Council of October 23, 2000, which establishes limits for Community action in the field of water policy (Water Framework Directive);
- Directive 2008/50/EC of the European Parliament and of the Council of May 21, 2008 on air quality and cleaner air for Europe;
- Directive 2004/107/EC of the European Parliament and the Council of December 15, 2004 on arsenic, cadmium, nickel, mercury and polycyclic aromatic hydrocarbons in atmospheric air;
- Directive 2016/2284 of the European Parliament and the Council of October 23, 2001 on establishing national limit volumes of emissions of certain polluting substances into atmospheric air;
- Directive 2010/75/EU of the European Parliament and the Council of November 24, 2010 on industrial emissions (comprehensive pollution prevention and control) (revised);
- Directive of the European Parliament and the Council 2008/98/EU of 19.11.2008 on waste and on the repeal of some Directives;
- Directive of the European Parliament and the Council No. 1999/31/EC dated 26.04.1999 on waste disposal.

On April 10, 2024, the European Parliament adopted in the first reading the proposal of the European Commission on the soil monitoring law, the first ever EU soil

law . There are currently no pan-European approaches to defining a mandatory list of pollutants that are a priority for the state administration for land protection.

The development of soil monitoring networks in Europe has been largely influenced by various directives of the European Union, in particular:

- "Nitrate" Directive 91/676/EEC,
- Directive on the sustainable use of pesticides (Directive 2009/128/EC),
- Directive 86/278/EEC on the protection of the environment and, in particular, the soil in cases of the use of sewage sludge in agriculture,
- Regulation on fertilizers (EU Regulation 2019/1009),
- Mercury Regulation (EU Regulation 2017/852)
- Regulation on plant protection products (EU Regulation 1107/2009), on permissible concentrations of heavy metals, control of enterprise emissions, application of effluents and production waste on agricultural land, etc.

Legislation on environmental impact assessment can also be attributed to important aspects of soil pollution regulation. To determine the amount of compensation for environmental damage, it is important to take into account the provisions of Directive EC and CE dated April 21, 2004 No. 2004/35/EC on environmental liability for the prevention and elimination of the consequences of environmental damage.

In recent years, in many countries of the European Union, the work on soil monitoring has been revived in connection with the adoption by the EU on November 17, 2021 of a new soil strategy until 2030, which announces the creation of a global soil monitoring network.

In the context of EU legislation in the field of environmental protection, it is worth noting the European Green Course **EGD**. The roadmap for its implementation is defined by ambitious goals, in particular, regarding the reduction of air, water and soil pollution, restoration of biodiversity, conservation and restoration of forests. For Ukraine, which seeks to cooperate with the EU within the framework of the Green Course, this means not only new challenges for achieving ambitious climate policy goals, but also greater needs for reliable information about the state of the environment for making informed management decisions.

On May 21, 2021, the European Commission adopted the EU Action Plan "Towards zero air, water and soil pollution" – a key result of **the EGD**. It sets out an integrated vision for 2050: a world in which pollution is reduced to levels that are no longer harmful to human health and natural ecosystems, and the steps to achieve it. To steer the EU towards the goal of a healthy planet for healthy people by 2050, the Action Plan sets key targets for 2030 to reduce pollution at source compared to the current situation.

The plan brings together all relevant EU pollution control and prevention policies, with a particular focus on how to use digital solutions to tackle pollution. A review of relevant EU legislation is planned to identify remaining gaps in EU legislation and those where better implementation is needed to fulfill these legal obligations.

2. Legal principles of the functioning of the State Environmental Monitoring System in Ukraine

Ukraine is a party to more than 70 international bilateral and multilateral agreements, the implementation of which requires the use of information on the state of the environment and forecasting of its changes. In this regard, the development of the state environmental monitoring system (SEMS) should be carried out taking into account the requirements of EU legislation and the requirements of bilateral and multilateral agreements.

The Association Agreement between Ukraine, on the one hand, and the European Union, the European Atomic Energy Community and their member states, on the other hand, became the basis for reforming in many areas of environmental protection, since, in addition to the main provisions of Chapter 6 "Environment" of Section V of the Agreement, Annex XXX to Chapter V contains a significant list of EU legislation, the provisions of which Ukraine must transpose.

The basis for the creation and existence of the state environmental monitoring system is Article 50 of the Constitution of Ukraine, which guarantees everyone the right to free access to information about the state of the environment, as well as the right to its dissemination.

The development and implementation of the own state monitoring system was based on the basic principles of the national monitoring system of the SSR Union - it is based on the experience of hydrometeorological services, taking into account the shortcomings of this system - the inconsistency of monitoring systems and methods, as well as on the results of the analysis of existing information on pollution of natural environments.

The scientific concept of the State Environmental Monitoring System of Ukraine was developed by Ukrainian scientists in the late 80s and early 90s of the 20th century (Primak, 1992; Adamenko, 1993).

The Law of Ukraine "On Protection of the Natural Environment" provides for the creation of a state environmental monitoring system (hereinafter referred to as the Environmental Monitoring System) and monitoring of the state of the natural environment and the level of its pollution.

The performance of these functions is entrusted to **the Ministry of Environmental Protection and Natural Resources of Ukraine** and other central

executive bodies, which are subjects of the state environmental monitoring system, as well as enterprises, institutions and organizations whose activities lead or may lead to the deterioration of the environment.

The main principles of the operation of the SEMS are defined in the resolution of the Cabinet of Ministers of Ukraine dated 30.03.1998 No. 391 "On approval of the Regulation on the state environmental monitoring system".

According to it, SEMSis a system of observing, collecting, processing, transmitting, saving and analyzing information about the state of the environment, forecasting its changes and developing scientifically based recommendations for making decisions on preventing negative changes in the state of the environment and complying with environmental safety requirements. The specified Regulation determines the procedure for the creation and functioning of the SEMS in Ukraine, establishes environmental objects for each of the monitoring subjects at the level of the SEMS subsystems.

Today, SEMS includes the following subsystems:

- Monitoring in the field of atmospheric air protection;
- State water monitoring;
- Land monitoring (land and soil monitoring);
- Forest monitoring;
- Monitoring of plant life;
- Monitoring of the animal world;
- Background environmental monitoring (on the territories of the nature reserve fund);
- Monitoring of places of generation, storage and disposal of waste
- Monitoring the impact of genetically modified organisms on the environment.

According to the current legal structure, for each of the above subsystems of the DSMD, it is necessary to create its own legislative and regulatory instruments for the organization and implementation of monitoring of the state of environmental objects.

In particular:

- The Law of Ukraine "On Atmospheric Air Protection" and Resolution of the Cabinet of Ministers of Ukraine dated August 14, 2019 No. 827 "Some issues of state monitoring in the field of atmospheric air protection" determine the order and procedure for monitoring in the field of atmospheric air protection ;
- The Water Code of Ukraine and the Resolution of the Cabinet of Ministers of Ukraine dated September 19, 2018 No. 758 "On Approval of the Procedure for State Water Monitoring";
- The Land Code of Ukraine and the Law of Ukraine "On Land Protection" together with the Resolution of the Cabinet of Ministers of Ukraine dated August 20,

1993 No. 661 "On Approval of the Regulations on Land Monitoring" determine the procedure for land monitoring.

Unlike these three subsystems, others have not received proper development, because such legislative acts as:

- Forest Code of Ukraine;
- Law of Ukraine "On Plant Life";
- Law of Ukraine "On Animal World";
- Law of Ukraine "On the Ecological Network of Ukraine",
- the Law of Ukraine "On the state system of biosecurity upon creation,testing, transportation and use geneticallymodified organisms";
- Law of Ukraine "On the Nature Reserve Fund of Ukraine";
- Law of Ukraine "On Waste"

define the relevant monitoring subsystems as an integral part of the SEMS and indicate the need to establish the procedures for the implementation of the relevant monitoring areas, however, they did not receive adequate regulatory and legal support in the form of Procedures (regulations) for the implementation of such monitoring.

Thus, the basic principles of the organization and functioning of the state environmental monitoring system have been established in Ukraine, as well as the monitoring procedure for individual subsystems has been regulated.

SEMSis based on the use of existing organizational structures of monitoring subjects and functions on the basis of a single regulatory, organizational, methodological and metrological support, unification of constituent parts and unified components of this system.

The Resolution of the Cabinet of Ministers of Ukraine dated 30.03.1998 No. 391 "On the approval of the Regulation on the state environmental monitoring system" imposes the organizational integration of the monitoring system subjects to the Ministry of Environment, regional, Kyiv and Sevastopol city state administrations, the executive body of the Autonomous Republic of Crimea for environmental protection environment on the basis of national and regional (local) environmental monitoring programs consisting of programs of the corresponding levels submitted by the subjects of the monitoring system. In turn, environmental monitoring programs of the respective levels are formed on the basis of concluded agreements on joint activities during the implementation of environmental monitoring at the appropriate level.

According to the legislation of Ukraine, the main tasks of the subjects of the monitoring system are:

- long-term systematic monitoring of the state of the environment;

- analysis of the ecological state of the environment and forecasting its changes;
- information and analytical support for decision-making in the field of environmental protection, rational use of natural resources and environmental safety;
- information service of state authorities, local self-government bodies, as well as provision of environmental information for the country's population and international organizations.

3. Analysis of institutional support for state environmental monitoring

The Regulation on the State System of Environmental Monitoring, approved by the Resolution of the Cabinet of Ministers of Ukraine dated 30.03.1998 No. 391 as amended (hereinafter referred to as the Regulation on Environmental Monitoring), defines the subjects of the Environmental Monitoring System:

- Ministry of Environmental Protection and Natural Resources of Ukraine,
- Ministry of Health,
- Ministry of Internal Affairs of Ukraine,
- Ministry of Agrarian Policy and Food of Ukraine (Ministry of Agrarian Policy),
- Ministry of Development of Communities, Territories and Infrastructure of Ukraine (Ministry of Infrastructure),
- Ministry of Economy of Ukraine (Ministry of Economy),

Centralbodies of executive power subordinated to the Ministry of Environment:

- State Forest Resources Agency of Ukraine,
- State Agency of Water Resources of Ukraine,
- State Geology and Subsoil Service of Ukraine,
- State Agency of Ukraine for Exclusion Zone Management,

Central Committee subordinate to the Ministry of Internal Affairs:

- The State Service for Emergency Situations of Ukraine,

Central bodies of executive power subordinated to the Ministry of Agrarian Policy:

- State Service of Ukraine for Geodesy, Cartography and Cadastre of Ukraine,
- The State Agency of Land Reclamation and Fisheries of Ukraine,
- **Other central bodies of executive power, authorities, institutions and organizations:**
- State Space Agency of Ukraine,
- The body of the executive power of the Autonomous Republic of Crimea on issues of ecology and natural resources (on the territory of the Autonomous

Republic of Crimea), as well as environmental protection units of regional and city state administrations,

- Bodies of accreditation, standardization and metrology,
- In addition to the Central Environmental Protection Agency and the institutions indicated above, **scientific institutions**, in particular the structures of the National Academy of Sciences of Ukraine, and their territorial bodies, enterprises, institutions and organizations belonging to the sphere of their management, regional, Kyiv and Sevastopol city state administrations participate in environmental monitoring activities, as well as executive authorities of the Autonomous Republic of Crimea on issues of environmental protection.

4. Functioning of the state environmental monitoring system

The monitoring system is based on the use of the existing organizational structures of the monitoring subjects and functions on the basis of a single regulatory, organizational, methodological and metrological support, unification of constituent parts and unified components of this system.

SEMS functions according to the state monitoring program, which defines priority tasks and measures for the implementation of monitoring goals on a national scale for the next 5 years. It takes into account the requirements of Ukraine's international and interstate obligations, as well as the provisions of state and special programs that came into force in accordance with the resolutions of the Verkhovna Rada and the CMU. All SEMS subjects, as well as scientific institutions, nature users and public organizations are involved in the implementation.

The existing environmental monitoring system is based on the performance of distributed functions by its subjects and consists of subordinate subsystems. Each subsystem at the level of individual subjects of the monitoring system has its own structural-organizational, scientific-methodical and technical foundation.

The functioning of the SEMS is carried out at the levels distributed according to **the territorial principle**:

– national level, covering priority areas and tasks of monitoring throughout the country;

– regional level, covering priority directions and tasks on the scale of the territorial region;

– local level, covering priority areas and tasks of monitoring on the scale of individual territories with increased anthropogenic load.

Onat the local level, there are observation points, from where information is transmitted to local collection and processing centers. In the case of an automated system, it is a local system that serves a separate district (city) and consists of 2 parts

– control and measurement stations and an information and analytical center, where the received data is processed, sorted and transmitted to the second level.

The regional level is the level of departmental and regional information and analytical centers. From such centers, information on environmental pollution levels is transmitted to relevant interested organizations of various departments and ministries.

The state level of the system includes the state information and analytical center for environmental monitoring and the main information and analytical centers of relevant ministries and agencies, where information on environmental pollution is collected and processed throughout the country.

Based on the received monthly and quarterly information, the Ministry of Natural Resources **publishes an informational and analytical review** "The State of the Environment in Ukraine", which is distributed among interested users.

In addition to the national, regional, and local levels, environmental monitoring is also organized within administrative divisions (regions, districts, cities, villages), recreational zones, or within the oil and gas, agricultural, forestry, and other industries.

Scientific and methodological developments in the field of monitoring and their support are carried out by the scientific organizations of the monitoring subjects, as well as the National Academy of Sciences of Ukraine, the Ukrainian Agrarian Academy of Sciences, and the National Space Agency of Ukraine.

The financing of works on the creation and maintenance of the continuous functioning of the monitoring system and its constituent parts is carried out in accordance with the procedure for financing environmental protection measures at the expense of the funds provided for in the state and local budgets in accordance with the legislation.

5. National priorities in the field of monitoring of environmental objects

The sphere of legislation on environmental protection of Ukraine is very broad and comprehensive (more than 300 normative legal acts). But it is outdated and has a low level of adaptation to the requirements of EU Directives.

All environmental monitoring data from different sources are not collected on one resource. Today, the functioning of the environmental monitoring system is regulated by outdated documents from 20 years ago. And most of the equipment, which, for example, is used by the Ukrhydrometeorological center, was purchased back in the 80s and 90s. Working on such equipment does not allow comparing the monitoring data of the Ukrainian system with the data of other countries. Some indicators cannot be measured at all due to equipment failure or its absence. Such a monitoring system provides only a statement of the fact of exceeding the pollution

index without analyzing the causes and consequences. Such a system cannot be the basis for making effective management decisions.

The Law of Ukraine "On the Basic Principles (Strategy) of the State Environmental Policy of Ukraine for the Period Until 2030" defines the unsatisfactory state of the system of state monitoring of the natural environment as one of the root causes of environmental problems in Ukraine, and the National Security Strategy of Ukraine, put into effect by the Resolution of the President of Ukraine dated 26 of May 2015 No. 287/2015, the unsatisfactory state of the environmental monitoring system is attributed to the main threats to the ecological and national security of Ukraine.

The decision of the National Security and Defense Council of Ukraine dated March 23, 2021 "On challenges and threats to the national security of Ukraine in the ecological sphere and priority measures for their neutralization" foresees the task of creating an effective system of state monitoring of the natural environment using technologies of remote sensing of the Earth, control of outer space, geophysical, geo-informational technologies by developing and approving draft legal acts, strategies and concepts regulating the functioning of the state environmental monitoring system, the national register of emissions and transfer of pollutants, development of hydrometeorological activities, radiation monitoring.

In recent years, the regulatory framework in the field of protection and monitoring of the condition of environmental objects has been actively developing and being updated. The active impetus was due to Ukraine's ratification of the Association Agreement with the European Union, the European Atomic Energy Community and their member states in 2014. In accordance with Article 361 of this Agreement, cooperation is aimed at preserving, protecting, improving and reproducing the quality of the environment, protecting public health, prudent and rational use of natural resources, and encouraging measures at the international level aimed at solving regional and global environmental problems , including in the areas of solving climate change problems and air quality management.

The Association Agreement between Ukraine and the EU requires Ukraine to reform the national system of environmental supervision and control and ensure compliance with the requirements of environmental legislation. Legislative and regulatory changes must comply with international legal documents that are mandatory for implementation in Ukraine (including relevant EU legislation) and national legislation. The Association Agreement between Ukraine and the EU contains an exhaustive list of EU legislation that Ukraine must comply with.

According to the Association Agreement, Ukraine is obliged to implement a number of EU directives in the field of environmental protection, including Directive

2010/75/EU on industrial emissions (comprehensive pollution prevention and control). This process involves and requires a number of changes:

- legislative (in particular, preparation and implementation of the best available technologies – BAT);
- technical (for example, identification of objects requiring an integrated permit and creation of a register of emissions and transfer of pollutants (PRPZ));
- organizational (in particular, ensuring public access to information and participation in environmental decision-making).

On March 20, 2023, the Verkhovna Rada of Ukraine adopted in its entirety the government draft law No. 7327 "On the state system of environmental monitoring, information on the state of the environment (ecological information) and information support for management in the field of the environment." The document is designed to reform the system of environmental monitoring, this draft law can be attributed to European integration. The document should create an effective state environmental monitoring system that provides information management needs in the field of environmental protection.

The law thoroughly permeates 18 legislative acts of Ukraine with the principles of environmental monitoring, sets a certain framework, and will start an important reform in the field of monitoring all environmental components: water, air, soils, forests, plants, animals, waste management and geological processes, etc.

The new observation system will meet international environmental management standards, including the requirements and directives of the Association Agreement between Ukraine and the European Union. Ukraine's monitoring system will be compatible with similar systems of other countries and will be integrated into the European environmental monitoring system of the European Environment Agency.

How will it help the citizens of Ukraine?

- all up-to-date and reliable environmental information will be available 24/7 on the single ecological platform "Ecosystem" – a national online platform that contains up-to-date information on the state of the environment;
- data on the state of the environment in Ukraine will become available on the resources of EU countries. The Ukrainian monitoring system will be integrated with SEIS – an environmental data network administered by the European Environment Agency.

Therefore, the issue of improving legislation in the field of environmental monitoring at various levels is defined as one of the necessary prerequisites for the ecological and national security of Ukraine, for this, appropriate legislative initiatives are being developed to create the necessary prerequisites for the existence of an effective system of environmental monitoring in Ukraine.

6. Practical approaches of the EU and Ukraine to the monitoring of environmental objects

The EU's practical approaches to air and water monitoring in Ukraine are already taken into account by the Resolution of the Cabinet of Ministers of Ukraine dated August 14, 2019 No. 827 "Some issues of state monitoring in the field of atmospheric air protection" and the Resolution of the Cabinet of Ministers of Ukraine dated September 19, 2018 No. 758 " On the approval of the Procedure for State Water Monitoring".

The new Procedure for State Air Monitoring was developed by the Ministry of Environment as part of Ukraine's fulfillment of its obligations in the environmental part of the Association Agreement with the EU, namely Directive No. 2008/50/EU. The innovations include a number of elements in accordance with EU norms, in particular:

- monitoring and management of air quality is foreseen according to the principle of dividing the territory of Ukraine into zones and agglomerations, corresponding zones and agglomerations have been formed (25 zones and 24 agglomerations will be formed),
- in each of the zones and agglomerations, a responsible air quality management body has been determined, which will coordinate the implementation of monitoring, as well as air quality management measures, in particular, the preparation and implementation of air quality improvement plans, short-term action plans , etc.
- the procedure for determining assessment modes for each zone and agglomeration depending on the level of pollution of the territory has been regulated,
- provides for the creation of an information and analytical system of data on air quality and timely informing the population,
- indicators of atmospheric air pollution levels are defined, exceeding which requires the implementation of measures to improve the air condition or minimize the harmful effects of pollution on the health of the population,
- $PM_{2.5}$, PM_{10} and ozone, which have a significant negative impact on human health, are included in the list of pollutants that must be monitored, and are recommended for measurement by WHO.
- provides for the creation of a new network of observation posts that meet the minimum European requirements for monitoring,
- it is envisaged to develop a monitoring program for zones and agglomerations every 5 years.

The new system of monitoring of surface, underground and sea waters according to the new Procedure for State Water Monitoring , which entered into force on January 1, 2019, provides for:

- clear division of responsibilities between organizations that measure indicators, without duplication of powers,
- an extended list of biological, hydromorphological, chemical and physicochemical indicators for monitoring,
- a six-year monitoring cycle has been introduced,
- the classification of water status was introduced: 5 classes of ecological status and 2 classes of chemical status,
- increasing the number of water monitoring points from hundreds to several thousand.

Regarding the requirements of the EU legislation for the land (soil) monitoring system, there are still no pan-European approaches to defining a mandatory list of pollutants that are a priority for the state land protection administration. In April of this year, the European Parliament adopted in the first reading the proposal of the European Commission on the soil monitoring law, the first ever EU soil law, but the organizational and methodological foundations of soil monitoring in the EU are generally well developed.

In Ukraine, the object of monitoring is all land, regardless of the form of ownership, on which monitoring is carried out, in particular, in accordance with the Regulation on land monitoring, approved by the Resolution of the Cabinet of Ministers of Ukraine dated August 20, 1993 No. 661, and the Regulation on soil monitoring on lands of agricultural purpose, approved by order of the Ministry of Agrarian Policy No.51 dated 26.02.2004.

In the process of implementing the land market in Ukraine, the Regulation on land monitoring will undergo drastic changes, because the purpose of this document, in addition to issues of assessing the state of agricultural land, will acquire a broader context in the direction of introducing approaches to assessing the market value of all lands.

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Lecture 4. Main sources of pollution and pollutants atmosphere in Europe.

Plan.

1. Introduction. The impact of air pollution on the quality of life in EU countries.
2. EU actions to improve atmospheric air quality.
3. Sources and emissions of air pollutants in Europe.
4. Status of fulfillment of obligations and required efforts of EU members to reduce emissions for 2020-2029 under the NEC Directive.
5. Impact of air pollution on health in Europe.

1. Introduction. The impact of air pollution on the quality of life in EU countries

Air pollution in Europe continues to cause significant damage to the environment, climate and human health. Most residents of European cities are exposed to dangerous levels of air pollution. The financial costs of solving air pollution problems caused by Europe's largest industrial enterprises are significant and amount to an average of 268 to 428 billion euros per year, according to an analysis by the EEA (European Environment Agency). However, European industry spending on the environment and health fell by a third (-33%) from 2012 to 2021. The EU energy sector accounts for the vast majority – around 80% – of the total reduction, mainly due to the use of best available technologies (BAT) and the shift to renewable energy sources and less polluting fuels. In 2021, these costs corresponded to approximately 2% of EU GDP.

For several decades, the European Union (EU) has air quality standards for the main air pollutants in the Ambient Air Quality Directives . If levels exceed these mandatory standards, Member States must prepare plans to improve air quality and ensure compliance. Although these values were based on the 2005 WHO air quality recommendations, they also reflected the technical and economic feasibility of achieving them in EU Member States. Therefore, EU air quality standards are less demanding than the 2005 WHO air quality guidelines.

In 2021, the World Health Organization (WHO) updated its air quality guidelines for the first time since 2005. This update is based on a systematic review of the latest scientific evidence on how air pollution affects human health. Improving air quality to levels recommended by the World Health Organization (WHO) could prevent more than half of premature deaths caused by exposure to fine particulate matter.

The European Green Deal has helped Europe's industry become greener and more digital. The recent revision of the Industrial Emissions Directive and the new Industrial Emissions Portal Regulation (IEPR) aim to push large European industry

towards decarbonisation, zero pollution, circular economy and innovation. It is expected that the strengthening of the EU Air Quality Directive will contribute to this development by bringing pollution limits closer to the World Health Organization's health recommendations.

In addition to health problems, air pollution can have a significant impact on the European economy through increased health care costs, reduced life expectancy and lost working days in various sectors.

It also damages vegetation and ecosystems, water and soil quality, and local ecosystems.

There is potential to combat air pollution in synergy with efforts to mitigate greenhouse gas emissions under EU climate and energy policies. Measures taken to reduce emissions of air pollutants and greenhouse gases often relate to the same economic sectors but are reported separately under different EU laws - air pollution control as required by the National Emission Reduction Commitments (NEC) Directive and in accordance with the Regulation on the Mechanism for Monitoring and Reporting on Greenhouse Gas Emissions (Regulation on the Monitoring Mechanism). Promoting policy coherence for reporting and action on air pollution, energy and climate change can reduce red tape and promote policy coherence.

2. EU actions to improve atmospheric air quality

Since the 1980s, the EU has adopted a strict air quality policy, enacted legislation to reduce emissions of air pollutants. The relevant directives also define the general methods of monitoring, evaluating and informing the public about atmospheric air quality in the EU. A network of over 4,000 air quality monitoring stations creates reliable, objective, comparable air quality information.

The National Emission Reduction Obligations (NEC) Directive (2016/2284/EU) is one of the legislative instruments under the European Green Deal supporting the ambition of zero pollution to achieve a clean environment. The NEC directive entered into force on 31 December 2016. It is aimed at ensuring a level of air quality that does not harm human health or the environment. The directive establishes national obligations to reduce emissions for 2020-2030 of five main air pollutants: nitrogen oxides (NO_x), non-methane volatile organic compounds (NMVOCs), sulfur (IV) oxide (SO_2), ammonia (NH_3) and small solid particles ($PM_{2,5}$). These pollutants deteriorate the air quality, which leads to a significant negative impact on human health and the environment.

From 2020 to 2029, the emission reduction commitments under the directive mirror those for EU member states under the Gothenburg Protocol of 2012, as amended. From 2030, there will be more ambitious commitments aimed at halving the impact of air pollution on health compared to 2005. It is especially important to

achieve the 2030 air pollution targets under the Zero Pollution Action Plan. To achieve these targets, it is crucial that EU Member States meet their respective emission reduction commitments set for 2020-2029 and 2030 onwards under the NEC Directive.

According to the NEC Directive, Member States are required to develop and implement national air pollution control programs (NAPCPs) which should contribute to the successful implementation of air quality plans developed in accordance with the EU Air Quality Directive, including measures to reduce emissions in the relevant sectors to fulfill national obligations. These programs must work in conjunction with other policies, such as climate change mitigation. Ensuring policy coherence increases the impact of government intervention.

The directive introduces a number of new reporting requirements for member states. They are defined in Annex I of the Directive and include annual information on emissions of a number of pollutants:

- five main air pollutants: NO_x, NMLOS, SO_2 , NH_3 and $PM_{2,5}$;
- other pollutant: carbon(II) oxide CO;
- in addition to $PM_{2,5}$, also particulate matter PM_{10} and, if present, soot (BC) and total suspended particulate matter (TSP);
- heavy metals cadmium (Cd), lead (Pb) and mercury (Hg) and, if available, additional heavy metals arsenic, chromium, copper, nickel, selenium and zinc;
- persistent organic pollutants (POPs), including selected polycyclic aromatic hydrocarbons (PAHs), dioxins and furans, polychlorinated biphenyls (PCBs) and hexachlorobenzene (HCB).

The NEC Directive emphasizes the importance of Member States regularly reporting air pollutant emission inventories to assess progress in reducing air pollution in the EU and to determine whether Member States are complying with their obligations. According to the NEC Directive, Member States must report emissions inventories annually starting in 1990 and, in the case of $PM_{2.5}$, starting in 2000. The EEA holds annual briefings on the status of reporting under the NEC Directive , which assess progress in meeting these legal obligations.

To ensure that emissions information provided by Member States is consistent within the EU and consistent with international requirements, the NEC Directive requires Member States to follow the methodologies agreed by the United Nations Economic Commission for Europe (UNECE) Convention on Transboundary Air Pollution on a Large Scale distance LRTAP (Air Convention). The Directive also requires Member States to use the EMEP/EEA Air Pollutant Inventory Guide when preparing their inventories.

In October 2022, the European Commission proposed an updated Directive on ambient air quality and cleaner air for Europe, the main goal of which is to bring EU

standards closer to WHO recommendations. The revision also aims to strengthen provisions on air quality monitoring and modelling, and on the development of air quality plans to help local authorities achieve cleaner air. The European Commission has published a proposalregarding the revision of the Air Quality Directive , with the following main changes:

- stricter threshold values for contamination, more aligned with the new limits set by the World Health Organization,
- strengthening the right to clean air, improving access to justice,
- the current legislation does not contain provisions that would allow citizens to demand compensation for damage caused to health as a result of air pollution; new rules will bring more effective penalties and compensation opportunities for violations of air quality rules,
- strengthened air quality monitoring rules to support preventive actions and targeted measures,
- requirements to improve air quality modeling, especially if air quality is poor,
- better public information.

The above measures are in line with other legislative proposals, such as the revision of the Industrial Emissions Directive and the recent proposals for Euro 7 emission standards for road vehicles, which will contribute to more stringent air quality standards.

The proposal for a revised Ambient Air Quality Directive was adopted on 26 October 2022.

In parallel, the European Green Deal also provides for stricter requirements to combat air pollution at source, for example through agriculture, industry, transport, buildings and energy. In the European Green Deal, the European Commission committed itself to further improving air quality and to greater alignment of EU air quality standards with WHO recommendations. This commitment was reflected in the Zero Pollution Action Plan , which sets out a vision by 2050 to reduce air, water and soil pollution to levels no longer considered harmful to health and natural ecosystems. In addition, the Zero Pollution Action Plan introduced targets for 2030, two of which focus on air and aim to:

- reduce the impact of air pollution on health (premature death) by more than 55% compared to 2005;
- reduce the proportion of EU ecosystems where air pollution threatens biodiversity by 25% compared to 2005.

Stricter air quality standards will also contribute to the achievement of the goals of the European Plan to Fight Cancer . Air pollution is a known cause of cancer in Europe, particularly lung cancer (EEA, 2022).

At the pan-European level, air emissions are regulated by the Air Convention LRTAP . Parties to the Air Convention must reduce their emissions to the levels set by the Protocols of the Convention to which they are parties (the Gothenburg Protocol, the Heavy Metals Protocol, the Persistent Organic Pollutants Protocol, and previous pollutant-specific protocols) and report on their emissions. The EEA compiles an annual EU emissions inventory report under the Air Convention in cooperation with EU member states and the European Commission.

Emissions reduction policies and measures in EU countries focus on three important air pollutants - fine particulate matter, nitrogen oxides and ammonia – which are reported by Member States under the Directive on National Emission Reduction Obligations. Action is expected in the three sectors that contribute significantly to air pollution, namely transport, energy and agriculture.

3. Sources and emissions of air pollutants in Europe

Air pollutants can be of natural, anthropogenic or mixed origin, depending on their sources or the sources of their precursors. In addition, air pollutants can be classified as primary and secondary. Primary pollutants are released directly into the atmosphere, while secondary pollutants are formed in the atmosphere from pollutant precursors through chemical reactions and microphysical processes.

The main primary air pollutants include: solid particles (PM) with a diameter of 10 μm and 2,5 μm and smaller (PM_{10} and $PM_{2.5}$), soot (BC), sulfur oxides (SO_X), nitrogen oxides (NO_X), ammonia (NH_3), carbon monoxide (CO), methane (CH_4), non-methane volatile organic compounds including benzene (NMVOC) and certain metals and polycyclic aromatic hydrocarbons including benzopyrene (BaP).

The main secondary air pollutants include: PM, ozone (O_3), nitrogen dioxide (NO_2) and several oxidized volatile organic compounds (VOCs). The key precursor gases for secondary PM are: sulfur dioxide (SO_2), NO_X , NH_3 and VOCs.

Particulate matter with a diameter of 10 μm, PM_{10} or less, is emitted mainly from the burning of solid fuels for home heating, although industrial activities, agriculture and road transport are also important sources. Some also come from natural sources, such as sea salt, Saharan dust, or volcanoes, and some (secondary PM) are formed in the atmosphere as a combination of different gases (eg, ammonia and nitrogen dioxide). Concentrations exceeding the EU daily limit value for PM_{10} are observed mainly in Italy and some Eastern European countries. In most countries of Central and Eastern Europe, solid fuels such as coal and firewood are widely used for heating households and in some industrial facilities and power plants.

$PM_{2.5}$ is emitted mainly as a result of burning solid fuels for home heating, industrial activities and road transport. Like PM_{10} , they can also come from natural sources and form in the atmosphere. Agricultural emissions of ammonia significantly

contribute to the formation of small solid particles in the atmosphere. The use of solid fuels is the main cause of PM_{10} emissionsin Central and Eastern Europe, together with emissions from the old car fleet.

Ozone (O_3) is a pollutant that is formed in the atmosphere as a result of chemical reactions in the presence of sunlight between nitrogen oxides, CO, and volatile organic compounds (VOCs), including methane (which is also a potent greenhouse gas). Emissions of these gases occur from anthropogenic sources, and in the case of VOCs, also from biogenic sources. Ozone is also transported to Europe from other parts of the northern hemisphere and the upper atmosphere. The highest concentrations in 2022 were found in some countries of the Mediterranean and Central Europe.

The main source of nitrogen dioxide (NO_2) is road transport, which emits NO_2 near the ground, mainly in densely populated areas, which contributes to the impact on the population. Other important sources are combustion processes in industry and energy supply. Concentrations exceeding the annual limit value were found in many Turkish cities and some large cities with heavy traffic.

Benzo(a)pyrene (BaP) is a carcinogenic pollutant emitted mainly from the burning of coal and wood for heating and, to a lesser extent, from industrial plants and the burning of agricultural waste. The highest concentrations were found in Italy and Eastern Europe, where the use of coal and other solid fuels for heating residential buildings is widespread.

The sectors of the economy responsible for air emissions depend on polluters. Differences between member states also exist due to different economic structures.

Total air pollutant emissions in EU Member States decreased slightly in 2022, maintaining the overall downward trend observed since 2005.

From 2005 to 2022, $PM_{2.5}$ and PM_{10} emissions were reduced by 33% and 32%, respectively. From 2005 to 2022, SO_2 emissions were significantly reduced by 74%. Significant reductions were also observed for nitrogen oxides (44%), carbon black (43%), carbon(II) oxide (41%) and NMVOCs (20%). It is noteworthy that NH_3 emissions decreased by only 16%, which is the smallest indicator among pollutants. Nickel (Ni) and arsenic (As) emissions were reduced by 63% and 60% respectively, while mercury (Hg), lead (Pb) and cadmium (Cd) emissions were reduced by 52%, 43% and 39% respectively. BaP emissions fell by only 20%.

Emissions showed significant absolute separation from economic activity between 2005 and 2022. Absolute decoupling occurs when an environmental impact variable, such as air pollutant emissions, remains constant or decreases while GDP increases. This results in lower emissions of major air pollutants for each unit of GDP produced annually. Pollutant emissions in EU member states fell between 2005 and

2022, even as GDP grew by 61%. The greatest separation is observed for SO_2 , then NO_x, BC, CO and some metals (Ni, As and Hg).

Decoupling of emissions from economic activity can result from a combination of factors such as increased regulation and policy implementation, fuel switching, technological improvements, and improved process energy efficiency.

4. Status of fulfillment of obligations and necessary efforts of EU members to reduce emissions for 2020-2029 in accordance with the NEC Directive

Emissions of major air pollutants continued to decline, maintaining the trend observed since 2005. This is despite an increase in gross domestic product over the same period. This analysis is based on the latest data.

According to the EEA assessment, the latest data (air pollutant inventory data provided by Member States in 2024, covering emissions up to 2022) show that 16 Member States have fulfilled their respective national emission reduction commitments under The EU's NEC Directive sets national emission reduction commitments for 2020-2029 for all five major air pollutants (table 1). Eleven Member States have not done so for at least one of the five main air pollutants.

Reducing ammonia emissions continues to be the most important issue for a third of EU member states. Since 2005, NH_3 emissionshave decreased only slightly or in some cases increased in many EU Member States. Agriculture is the main source responsible for 93% of total ammonia emissions as estimated by the EEA. This highlights the need for more effective policies targeting the agricultural sector to implement good agricultural practices that reduce NH_3 emissions. This includes practices related to the application of fertilizers and manure, as well as the balancing of livestock feed.

NH_3 emissionsaffect biodiversity and contribute to the formation of secondary $PM_{2.5}$, the main air pollutant causing premature death in EU member states. Reducing NH_3 emissionsis crucial to achieving the Zero Pollution Action Plan target of a 25% reduction in the number of ecosystems in the EU where air pollution threatens biodiversity.

Nine Member States have already met their 2030 NH_3 emission reduction commitments in 2022.However, challenges remain as two-thirds of member states still need to reduce their NH_3 emissionsto meet their 2030 targets. The European Commission's third Clean Air Outlook report concluded that current measures, particularly in the agricultural sector, are not sufficient to reduce NH_3 emissionsto the required extentto meet emission reduction commitments. It recommended further action in several Member States. Nine member states will need to further reduce NH_3 emissionsto meet their national emission reduction commitments for 2020-2029.

Table 1.

Percentage emission reductions required by EU Member States to meet their emission reduction commitments for 2020-2029

In 2022, six Member States met their commitments to reduce NO_x emissionsby 2030. However, 21 member states will need to further reduce NOx emissions. According to the 2022 emissions data, Lithuania and Romania have not met their national NOx reduction commitments for 2020-2029. Efforts to reduce NO_x emissionsshould be focused on the road transport sector. It is the main source of registered NO_x emissions, followed by the energy supply sector.

$PM_{2.5}$ causes serious health problems and contributes to premature mortality, so reducing emissions is critical to achieving the goal of reducing premature deaths by 55% by 2030, as outlined in the Zero Pollution Action Plan . Seven member states have already met their commitments to reduce $PM_{2.5}$ emissionsby 2030 by 2022. Romania and Hungary must reduce their $PM_{2.5}$ emissionsto meet their national emission reduction commitments for 2020-2029. Effective abatement measures in the energy sector will be critical to meeting $PM_{2.5}$ reduction commitments: the burning of solid biomass and fossil fuels for residential heating still contributes to this. Measures to reduce emissions include improving insulation and upgrading heating systems, installing low-emission boilers or switching to different fuels. Significant emissions of particulate matter also result from manufacturing and mining and road transport, including from internal combustion engines and vehicle tire and vehicle brakes.

All member states, except one, are fulfilling their national commitments to reduce NMVOC emissions for 2020-2029. Since manufacturing and extractive industries are the main source of emissions, measures to reduce emissions of this pollutant should be focused on industrial sectors. New technologies and improved production processes in the main NMVOC emission sectors can further reduce air pollutant emissions.

The picture regarding SO_2 emissionsis generally more positive. All but one of the member states have fulfilled their national commitments to reduce SO_2 emissionsfor 2020-2029. Five member states are facing challenges in meeting their 2030 emission reduction commitments. Energy supply is the main source of SO_2 emissionsin the EU, with industry and extractive industries the second largest source of emissions. Cyprus still needs to reduce its SO_2 emissions by another 43% to meet its commitments. The main sources of emissions of this pollutant in the country are energy supply and production.

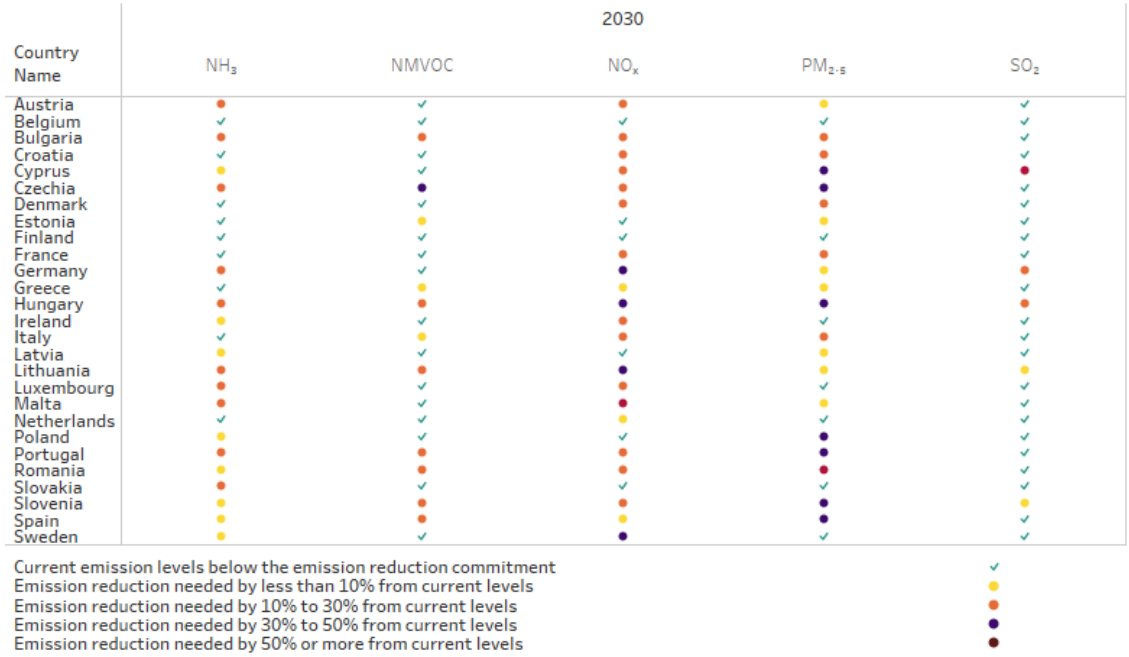
New, stricter obligations will enter into force in 2030. With this milestone in mind, all member states except Belgium and Finland must reduce emissions of at least one pollutant to meet their 2030 commitments. The biggest problem will be the reduction of NH_3, NO_x and $PM_{2.5}$ emissions. Even if a country has already met targets for specific pollutants by 2030, current emission levels and trends suggest that additional measures are needed to avoid growth that would jeopardize these achievements. Member States must do more to meet national emission reduction commitments set for 2030 and beyond. In some cases, the distance to the target is very significant and requires much stronger actions.

Achieving further reductions by 2030 and beyond will be a major challenge for almost all EU countries and for almost all air polluters (table 2). The level of emission reductions for some pollutants is now leveling off. The only exception is sulfur dioxide: 22 member states have already met their reduction commitments by 2030.

Air pollutants ammonia (NH_3), non-methane volatile organic compounds, nitrogen oxides (NO_x), fine particulate matter ($PM_{2.5}$) and sulfur oxides (SO_x) are harmful to human health and the environment, so reducing them of anthropogenic emissions is a priority of both EU and international legislation on air quality. Since 2005, emissions of all five pollutants have decreased: SO_x emissions have decreased significantly by 80%, and NH_3 emissionshave decreased by only 13%. Based on the progress made, it is clear that more efforts are needed to meet the EU's long-term emission reduction commitments, especially in the agriculture, transport and energy sectors.

Table 2.

Percentage emission reductions required by EU Member States to meet their emission reduction commitments for 2030 onwards



5. Impact of air pollution on human health in Europe

Emissions of pollutants into the atmosphere have decreased over the past two decades, resulting in improved air quality. Despite this improvement, air pollution remains the biggest environmental health hazard in Europe, causing cardiovascular and respiratory diseases that adversely affect health, reduce quality of life and cause preventable death. Exposure to fine particulate matter and nitrogen dioxide at levels exceeding World Health Organization guidelines resulted in an estimated 253,000 and 52,000 premature deaths, respectively, in 2021. These pollutants are linked to asthma, heart disease and stroke.

The most vulnerable sections of society are more susceptible to the effects of air pollution. Lower socioeconomic groups tend to be exposed to higher levels of air pollution, while the elderly, children, and people with pre-existing conditions are more susceptible. It is estimated that more than 1,200 deaths among people under the age of 18 are caused by air pollution each year in the EU Member States and cooperating countries .

Despite the current overall improvement in air quality, the air in all EU countries still does not meet the current EU standards. The new EU air quality standards introduced in the revised Ambient Air Quality Directive due to enter into force in 2030 are more ambitious than the current ones.

Under the European Green Deal (EGD) Zero Pollution Action Plan, the European Commission has set an interim target of reducing premature deaths caused

by fine particulate matter ($PM_{2.5}$, a key air pollutant) by at least 55% by 2030 compared to 2005 year. The ultimate goal is that by 2050, air pollution will not have a significant impact on health. Co-legislators agreed to more ambitious EU air quality standards in February 2024. However, they are still less stringent for all pollutants than what the WHO defines in its guidelines for air quality levels .

In 2022, despite continued emission reductions , the majority of the EU's urban population continued to be exposed to key health-damaging air pollutants (Figure 1). In particular, almost the entire urban population (96%) of the EU is exposed to dangerous concentrations of fine particulate matter ($PM_{2.5}$) that exceeded the WHO annual normative level for 2021 of 5 $\mu g/m^3$ and ozone (O_3) concentrations above the short-term normative level of 100 $\mu g/m^3$.

The analysis in the figure highlights the pollutants considered most harmful to human health and those that most often exceed current EU air quality standards and WHO levels.

Concentrations are obtained as a result of measurements at the monitoring station and are officially reported to the EEA by its members and other cooperating countries.

In addition to premature death, air pollution is also a cause of morbidity. People suffering from diseases related to exposure to air pollution are a burden in terms of personal suffering as well as significant costs for the health sector. In 2019, exposure to $PM_{2.5}$ resulted in 175,702 years of life with disability (YLD) due to chronic obstructive pulmonary disease in 30 European countries. At the same time, exposure to NO_2 resulted in 175,070 YLDs due to diabetes (also known as type 2 diabetes) in 31 European countries. That same year, 12,253 people in 23 European countries were hospitalized with lower respiratory tract infections caused by acute ozone exposure. YLD, a measure of healthy life time lost due to disability or disease, was first developed by Harvard University for the World Bank and is now increasingly used in the health sector, including WHO.

Further efforts will be needed to achieve the zero pollution vision by 2050 of reducing air pollution to levels no longer considered harmful to health.

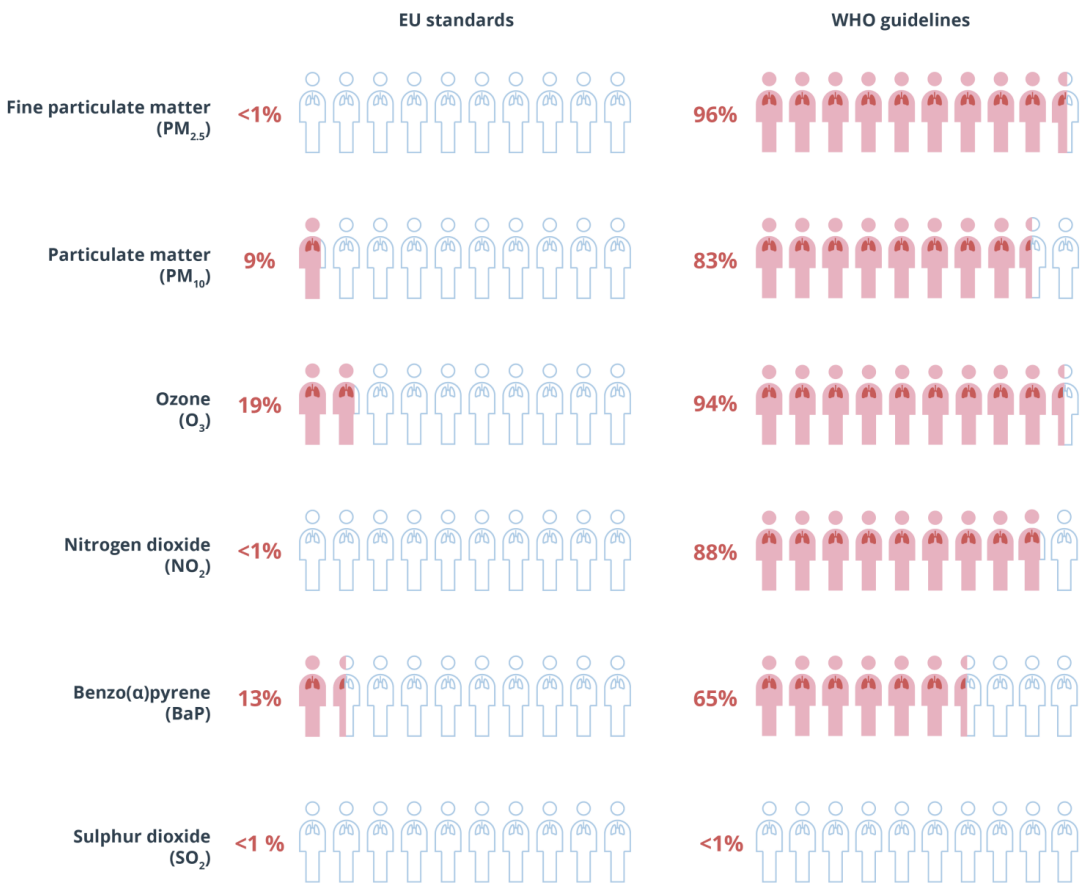


Figure 1. Share of the EU urban population exposed to air pollutant concentrations above certain EU standards and WHO guidelines in 2022

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Lecture 5. Monitoring of industrial pollution of environmental objects. Modern system of environmental permits in the EU.

Plan.

1. Introduction. EU activities in the field of industrial pollution to improve the quality of environmental objects.
2. Directive 2010/75/EU as the main EU tool in regulating pollutant emissions from industrial installationsand its implementation by Ukraine.
3. World systems of access to information about industrial emissions into the environment.
4. The system of environmental permits in the EU and Ukraine.

1. Introduction. EU activities in the field of industrial pollutionto improve the quality of environmental objects

For decades, the European Union has been fighting for the improvement of the quality of environmental objects through the control of emissions of harmful substances into the atmospheric air, the discharge of wastewater and the generation of waste, and the integration of environmental protection requirements into the industrial and energy sectors.

They were developed as legislative acts (from Directive 85/337/EEC on EIA (Environmental Impact Assessment) of 1985 to Directive 2011/92/EC, Directive 96/61/EC on Integrated Pollution Prevention and Control of 1996 (IPPC), Directive 2010/75/EU (IED) on industrial emissions of 2010, as amended), and policy instruments, in particular, such as:

- the Clean Air Program for Europe (CAPE) 2013 – the goal is to ensure full compliance with current legislation by 2020 and further improvement of air quality in Europe so that by 2030 the number of premature deaths is halved compared to 2005 year,
- Environmental Action Programs (EAP) of the European Union are medium-term strategic documents defining the environmental policy of the EU for the next 5-7 years, starting from the first EAP (1973-1976) to the eighth EAP, which entered into force May 2, 2022 as a legally agreed common agenda for EU environmental policy until 2030,
- The European Green Deal (EGD) is a package of systemic political solutions for the transition of the European continent to climate neutrality by 2050 and the development of a fair and prosperous society.

In the report of the European Environment Agency, the EU's "Clean Air" policy, it is determined that the EU's work to improve, in particular, air quality, consists of the following areas:

1. Establishment by EU member states of requirements for atmospheric air

quality, legally approved in two Directives on the quality of atmospheric air (Ambient Air Quality, Directives EU, 2004, 2008).

2. Establishing national goals for reducing emissions pollutants and the development by 2019 of national air pollution control programs, as specified in the National Emission Ceilings (NEC) Directive EU, 2016.

3. Approval of requirements for the volume of emissions and the level of energy efficiency of the main sources of air pollution (from vehicle emissions to industry). The latter are defined in EU legislation regulating industrial emissions (in particular, Directive 2010/75/EU on industrial emissions).

The key act in the field of industrial pollution is, of course, Directive 2010/75/EU on industrial emissions.

As part of the implementation of the European Green Deal, key elements in this area are being reformed, in particular, the Directive on Industrial Emissions and the Regulation on the Register of Emissions and Transfer of PRTR Pollutants.

2. Directive 2010/75/EC asthe main tool of the EU in regulating pollutant emissions from industrial installations and its implementation by Ukraine

Industrial production processes account for a significant share of total pollution in Europe. This is related to the emission of pollutants into the atmosphere, the discharge of wastewater and the generation of waste. Facilities, including power plants, oil refineries and waste processing, cause approximately 40% of greenhouse gas emissions and 20% of air and water pollutants.

Directive 2010/75/EU of the European Parliament and the Council of November 24, 2010 on industrial emissions (integrated prevention and control of pollution) (IED)) refers to the acts of EU legislation in the field of environmental protection and nature management, which regulate the field of monitoring of environmental objects . The IED Directive brought together the Integrated Prevention and Control (IPPC) Directive and six sectoral directives into a single directive in order to streamline the interaction between these legal instruments and provide a clear definition of its provisions.

IED Directive is the basis of the legal regulation of emissions from industrial installations in the EU. As of 2023, about 50,000 industrial installations in the EU are subject to its regulation.

The directive is based on 5 principles of regulation of industrial emissions:

- integrated (complex) approach (integrated environmental permit);
- the best available technologies and management methods (**BATMs)** as the basis of the permit system;
- flexibility (the ability to set less strict requirements for emissions in certain cases);

- control (periodic inspections);
- public participation and access to information.

Each of these principles is subject to detailed regulation by the provisions of the Directive. Let's consider each of its elements separately.

An integrated (complex) approach to issuing environmental permits. About 52 000 installations carrying out industrial activities listed in Annex I to the Directive must operate in accordance with an environmental permit (issued by the authorities of the Member States). This authorization must contain conditions established in accordance with the principles and regulations of the IED.

Directiveprovides an integrated (complex) approach to environmental permits - permits must include comprehensive environmental indicators of the enterprise. At the same time, the following aspects are evaluated, in particular: air emissions, water and soil pollution, waste generation, use of raw materials, energy efficiency, noise, prevention of emergency situations and accidents, restoration of the site after closure, etc.

The EU has been practicing an integrated approach since the early 1980s. With the fragmented approach currently used in Ukraine, emissions to the environment (water, air, soil) and permission to operate the main facility are considered separately at different levels of government and usually by different departments.

The integrated environmental permit must contain conditions established in accordance with the principles and provisions of the Directive.

States are required to issue integrated environmental permits for a certain amount of emissions, developed on the basis of the best available technologies and management methods (**BATM**).

The European Commission facilitates the process of interaction between experts from member states, industry and environmental organizations. The result of this process is the determination of BATM and the development of BATM reference documents (BREFs). The European Commission approves these conclusions from the BATM at the legislative level. In the future, they are a benchmark for the development of environmental permit conditions.

BAT are compiled by special technical bodies of the EU as references (BREFs), and their conclusions (BATM) are approved by the European Commission in the form of implementing decisions and they are mandatory for the relevant permit procedures in the states. Accordingly, 34 additional acts have been adopted for the purposes of this element of the directive alone (including 21 BAT conclusions and General Implementing Decision 2012/119/EU on the collection of data for the preparation of BREFs). In addition to BATMs, to this Directive have been added implemented decisions 2012/115/EU regarding the requirements for the so-called national transitional plans, 2012/249/EU regarding the determination of start-up and

shutdown periods of large combustion plants (according to Article 41 of the directive), as well as several decisions on reporting and information requirements.

The directive contains particularly strict requirements for the operation of so-called large incineration plants (with a thermal capacity of more than 50 MW), as well as special requirements for the operation of waste incineration plants and co-incineration plants, plants and activities that use organic solvents, plants that produce titanium dioxide (since it integrated the relevant provisions of the relevant directives).

Since BATM are a dynamic concept that develops with over time, permit documents must be updated with the main goal - to contribute to the continuous reduction of the impact of industry on the state of the environment. The Industrial Emissions Directive describes detailed rules for permit review and provides for mandatory review of permit conditions within four years after the publication of BAT decisions.

It also describes the roles of all participants in the process of information exchange, in order to achieve a quality result and ensure the use of the principles of BATM for the implementation of the Directive.

The flexibility in regulating industrial emissions is that, in some cases, authorities can set less stringent emission limits if meeting the emission levels stipulated in the BATM would result in costs that are disproportionately greater than the environmental benefits.

Controlof industrial emissions is ensured by the activity of the system of environmental inspections according to the developed work plans. Site visits take place at least once every one to three years (a risk-based approach is applied).

Environmental information has a special status and is protected by the Aarhus Convention on access to information, public participation in the decision-making process, and access to justice on issues related to the environment. Together with the Kyiv Protocol on Pollutant Emission and Transfer Registries, it protects the right of every person to live in an environment that ensures their health and well-being. These are international legally binding instruments of environmental democracy that implement principle 10 of the 1992 Rio Declaration on Environment and Development. The Convention entered into force on October 30, 2001, the Protocol entered into force on October 8, 2009.

IED Directive **the public** has the right to participate in the decision-making process and receive information about its consequences, has access to environmental permits and industrial pollution monitoring reports.

EU member states report the volume of emissions of pollutants to the European Register of Emissions and Transfer of Pollutants (**E-PRTR or PRTR**).

PRTR is an open register that provides environmental information on the main

types of industrial activity. By making pollutant emissions public, PRTRs increase awareness of the main sources of threats to health and the environment and enable the public to play a more effective role in influencing decision-making processes related to such threats. The resulting increase in transparency can put pressure on companies to reduce the pollution burden of their operations.

On April 12, 2024, the EU Council adopted the revised Industrial Emissions Directive (IED) and the Industrial Emissions Portal Regulation 2024/1244 (IEP). These two legislative acts, which complement each other, are aimed at regulating and monitoring the impact of industrial activity on the environment.

The new rules will ensure better protection of human health and the environment by reducing harmful emissions from industrial installations, while promoting energy efficiency, circular economy and decarbonisation. In order to further reduce industrial emissions, more large-scale intensive livestock farms, including pig farms and poultry farms, are included in the scope of the revised Directive. They will also improve environmental data reporting by updating the European Pollutant Release and Transfer Register (E-PRTR) to create a more comprehensive and integrated industrial emissions portal.

The Industrial Emissions Portal is a new portal created by the IEP regulation for more comprehensive and integrated information on industrial emissions, replacing the E-PRTR website. This new portal will increase the EU public's access to information related to industrial emissions and promote public participation in environmental decision-making, including the identification of pollution sources.

At the end of 2019, Ukraine joined the implementation of the goals of the Green Course, and the implementation of the reform of industrial pollution will be perhaps the most important step in this area, as well as a necessary part of the implementation of the Association Agreement with the EU.

The implementation of the EU Directive 2010/75/EU was one of Ukraine's obligations on the way to joining the EU, and the adoption of the relevant law in the third quarter of 2024 is a condition for receiving EU financial assistance under the Ukraine Facility plan. The law was defined by the European Commission as a priority.

On July 16, 2024, the Verkhovna Rada adopted the Law on Integrated Prevention and Control of Industrial Pollution, which implements EU Directive 2010/75/EU into Ukrainian legislation. After a certain transition period, Ukrainian enterprises will work according to the same rules regarding environmental pollution as European manufacturers.

3. World systems of access to information about industrial emissions into the environment

3.1. The Register of Emissions and Transfer of Pollutants as a global system of collecting and disseminating information on emissions into the environment

Everyone has the right to access such information, according to the Kyiv Protocol of the Aarhus Convention. It refers to the obligation of the signatory countries to conduct their environmental policy openly, interact with citizens and involve them in solving environmental issues. And the creation of a national register of emissions and transfer of pollutants (PRPZ) was one of the conditions of this international document.

Prototypes of modern eco-information access systems can be considered:

- a list of 155 chemicals from more than 7,000 industrial facilities, which was created in 1978 in the American state of New Jersey,
- a kind of PRTR database that existed in the Netherlands since 1974.

Following the 1992 UN Conference on Environment and Development, which affirmed the right of communities and workers to know about toxic chemicals and other substances of concern, PRTRs began to be established.

The USA was the first to develop its list of emissions of toxic substances (TRI) in 1985. In Europe, legislative regulation was achieved in 2003-2006. Currently, E-PRTR accumulates information from the registers of EU member states, Iceland, Liechtenstein, Norway, Switzerland, Serbia and Great Britain and contains data on 35,000 industrial enterprises.

Australia, Canada, and Mexico also have their registers, which indicates a truly global scale of system implementation.

All systems of access to eco-information exist in different forms. The scope or details of the implementation of the registers may differ, but the goals of creating a PRTR remain unchanged:

- provide data on pollution and waste to all and free of charge;
- organize transparent reporting to the government;
- facilitate reporting on international commitments such as CLRTAP, UNFCCC;
- facilitate access to data by various government entities;
- agree on international pollution data standards.

A common and very important approach to the formation of all PRTRs is the obligation to provide data on emissions to the register on the polluting enterprises themselves.

The PRTR includes information on:

- a business entity that generates potentially harmful emissions and transports waste to various components of the environment,
- pollutants (PO) emitted and transported,

- the amount of ZR for a specific period of time,
- geographical distribution of RR in the environment.

In addition, according to PRTR functions:

- is conducted separately for specific objects in relation to reporting on point sources and contains data on diffuse sources;
- covers various components of the environment, distinguishing between emissions to air, land and water;
- is based on mandatory reporting that is submitted on a periodic basis;
- contains standardized and timely submitted data, including in electronic form;
- involves public participation in its development and modification;
- is a structured, computerized database or several consolidated databases maintained by a competent authority.

PRTR provides the public with easy access to quality information about emissions of pollutants in their areas, and about the transfer of pollutants to their territory. Although registries are created to meet the needs of the public, the information contained in the registries can be used by governments to demonstrate progress in reducing emissions, monitor the implementation of a number of international treaties, set priorities and assess progress achieved through the implementation of environmental policies and programs.

The register is an effective tool for promoting the improvement of environmental performance, as it increases the accountability of enterprises. The public has the necessary information about the composition and real exposure of toxic substances, which gives a clear idea of their general impact on the environment and on the health of the population. Completeness of information also helps the public to have a constructive dialogue with polluting enterprises, which helps to design and implement more effective measures to reduce pollution.

It allows state bodies to assess progress in reducing environmental pollution, assess the adequacy of modeling and monitoring systems, and expands opportunities for planning the work of state services.

PRTR has been used in the world for decades and has clear positive effects. In particular, there is an obvious reduction in the amount of pollution: companies reduce emissions and introduce corporate responsibility for their reduction.

3.2. European portal of industrial emissions

On the website https://industry.eea.europa.eu/The EU presents information on the largest industrial complexes in Europe, emissions and transfers of regulated substances into the environment, waste movements, as well as more detailed data on energy consumption and emissions for large combustion plants in the EU member states Iceland, Liechtenstein, Norway, Serbia, Switzerland and Great Britain.

The Industrial Emissions Portal covers more than 60,000 industrial facilities from 65 types of economic activity across Europe. This activity is carried out in the following sectors:

- energy,
- production and processing of metals,
- mineral industry,
- chemical industry,
- waste and wastewater management,
- production and processing of paper and wood,
- intensive husbandry and aquaculture,
- products of animal and vegetable origin from the food and beverage sector,
- other activities.

The portal shows the location and administrative data of the facilities, as well as their emissions and transfer of regulated substances into the air, water and soil, as well as the movement of waste. For large combustion plants (LCPs), more detailed data on energy consumption and emissions are available. The data can also be viewed on the map of industrial facilities. Each dot on this map is an emitting enterprise. For each enterprise there is data on the amount and composition of hazardous emissions. In just a few clicks, a resident of Europe can get a comprehensive picture of their country or the companies closest to them.

The information contained in the portal is provided annually and requested under the Industrial Emissions Directive (IED), through the EU Industrial Facilities Register (EU Register) and the European Pollutant Release and Transfer Register (E-PRTR). This portal replaced the E-PRTR website in 2021.

IED (Directive 2010/75/EU) aims to achieve a high level of protection of human health and the environment in general by reducing harmful industrial emissions in the EU, in particular by better application of the best available technologies.

The EU Register is an annual reporting stream that facilitates the annual reporting to the European Environment Agency of administrative and identification data relating to sites and facilities identified under the E-PRTR as well as installations, LCPs or incinerators covered by IEDs.

E-PRTR is introduced by the Regulation (EC) No. 166/2006 and Commission Implementing Decision 2019/1741. Objects that must report under E-PRTR meet certain criteria:

- fall under at least one of the 65 types of economic activity from Annex I to the regulation and exceed at least one of the E-PRTR capacity thresholds;
- emit pollutants that exceed specific limit values defined for air, water and soil in Annex II to the regulation;
- move waste that exceeds certain limit values established in Article 5 of the

regulation outside the enterprise.

91 pollutants are included in the E-PRTR. They are divided into the following seven groups:

- greenhouse gases,
- other gases,
- heavy metals,
- pesticides,
- chlorine-containing organic substances,
- other organic substances,
- inorganic substances.

The register promotes transparency and public participation in environmental decision-making. It implements the PRTR Protocol of the European Community and the United Nations Economic Commission for Europe to the Aarhus Convention on Access to Information, Public Participation in Decision-Making and Access to Justice on Environmental Issues.

Regulation No. 166/2006 has been replaced by the Industrial Emissions Portal Regulation (Regulation 2024/1244), which sets additional reporting requirements and sets the reporting unit at the "installation" level (rather than the plant level). The requirements of the new legislation will apply from 2028. Until then, the E-PRTR Regulation will apply.

Figure. 1. Main page of the website of the European portal of industrial emissions.

3.3. National Register of Emissions and Transfer of Pollutants of Ukraine

For Ukraine, the functioning of RTD is not only a source of important environmental information, it is also an obligation of Ukraine on the way to the EU. The creation of a national PRTR was one of the conditions put forward by the international document.

In 2016, Ukraine ratified the Kyiv Protocol on Emission Registries and the Transfer of Pollutants to the Aarhus Convention. On September 20, 2022, the Law of Ukraine "On the National Register of Emissions and Transfer of Pollutants" was adopted.

The National PRTR will provide an opportunity to:

- track emissions and transport of pollutants in time and space,
- analyze emissions reduction and set priorities in reduction and elimination of potentially harmful emissions,
- to make effective decisions on prevention and reduction of industrial pollution.

In a few years, the national PRTR will be integrated with the European one, and Ukraine will be able to exchange up-to-date, verified data with the competent body of the European Union and synchronize its own environmental policy with the European one.

Public will receive free and convenient access to environmental information, which will increase its opportunities to participate in the formation of state environmental policy in the field of emissions registration.

Therefore, the Ukrainian National Register of Emissions and Transfer of Pollutants is just being created. The relevant Law entered into force in October 2023. According to it, all polluting enterprises would have to register with the PRTR within six months. But currently this is happening "at will", because during martial law, legal entities are exempted from responsibility for failure to submit reports (according to the Law of Ukraine "On Protection of the Interests of Subjects of Submission of Reports and Other Documents During Martial Law or a State of War").

As of June 21, 2024, 412 industrial facilities belonging to 196 business entities are registered in the PRTR. For comparison: the number of business entities that have permits to emit 1, 2, and 3 groups of atmospheric air pollutants is 2,145 (as of June 21, 2024). Representatives of the Ministry of Environment hope to integrate the Ukrainian PRTR with the European one in 2025.

The Government approved the Procedure for maintaining the National Register of Emissions. The document was developed in accordance with the requirements of the Law of Ukraine "On the National Register of Emissions and Transfer of Pollutants", which will enter into force on October 8, 2023. The register will function

as an online service on the "EcoSystem" web portal (figure 2).

In general, the creation and high-quality implementation of registers of emissions and transfers of polluting substances in Ukraine will enable citizens to receive clear and understandable information about emissions into the environment, and to exercise their rights to participate in the decision-making process and access to justice on issues related to the environment. Only by clearly knowing about pollution, Ukrainians will be able to fight it, as well as create effective strategies for protecting and restoring the environment, and, accordingly, will contribute to sustainable development.

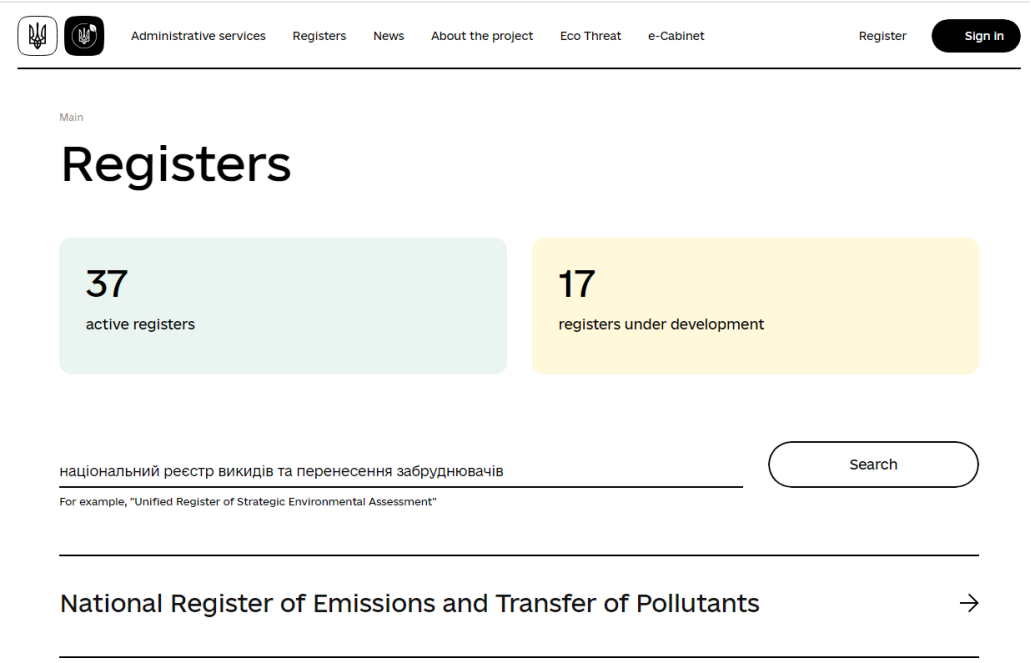

Figure 2. The start page of the National Register of Emissions and Transfer of Pollutants PRPP on the web portal "EkoSystem".

4. The system of environmental permits in the EU and Ukraine

In EU member states that have implemented the Directive 2010/75/EU on industrial emissions (IED) (and related processes), only industrial and agricultural activities (energy, metal production and processing, mineral industry, chemical industry, waste management and other operations (such as animal husbandry) that exceed emission limits require an integrated permit. Other businesses that do not exceed the thresholds can obtain an integrated permit on a voluntary basis. The main intention in obtaining an environmental permit is not to license all industrial and agricultural activities, but only those with a high pollution potential.

4.1. The process of issuing environmental permits in the Czech Republic

The process of integrated pollution prevention and control in the Czech Republic is regulated by the Law on Integrated Pollution Prevention and Control (implementing the IED Directive on Industrial Emissions). The following state and

regional management bodies are involved in this process:

1. Ministry of Industry and Trade – formulates industrial and energy policy in the context of the EU single market and manages the PRTR portal.

2. The Ministry of Environmental Protection – forms environmental policy in the field of air, water and soil protection. (The Ministry of Environmental Protection issues environmental permits only for objects with a significant negative transboundary impact).

3. The Ministry of Agriculture – formulates agricultural policy in accordance with the Law on Integrated Prevention and Control of Pollution.

4. The Czech Environmental Inspectorate – carries out control activities and compliance with the requirements of the Law on Integrated Prevention and Control of Pollution, and imposes sanctions.

5. Czech Environmental Information Agency (CENIA) – provides expert opinions for bodies issuing integrated permits.

6. The State Environmental Fund – controls and manages financial subsidies for environmental initiatives; subordinate to the Ministry of Environmental Protection.

7. Regional authorities – issue integrated permits.

The process of issuing **integrated permits** is decentralized in the Czech Republic. With the exception of environmental permits for objects with negative transboundary impact (which are issued by the Ministry of Environmental Protection), integrated permits are issued at the regional level. Policy related to integrated permits is formulated at the state (ministerial) level. Despite the participation of several government bodies (ministries, inspectorates, agencies) in the process of integrated pollution prevention and control, their competences are clearly defined and do not overlap.

Procedure. In order to **obtain an integrated permit**, the enterprise submits an application to the relevant regional authorities. In the application, it is necessary to comply with the requirements of the law, the template of the application is fixed in regulatory documents.

Requirements for an application for **an integrated permit** are included in Article 4 of the Law on Integrated Pollution Control and Prevention. This is a rather complex document. In addition to identifying the applicant and the industrial or agricultural facility, it must contain a sufficiently detailed description of the operation, processes and technologies used, sources of emissions and measures to monitor emissions and prevent waste. Mandatory operating conditions must be described. A package of documents (for example, a zoning permit, relevant administrative decisions, etc.) must be submitted with the application. If the institution uses, produces or discharges hazardous substances that may contaminate the soil or water, according to Article 4 of the Law on Integrated Pollution Control

and Prevention, the applicant must submit a baseline report ("základní zpráda" in Czech). The report must be prepared by a competent person for approval by the regional authority. The report helps determine the extent of soil or water contamination so that the state of the environment can be compared to what it will be in after the activity is finally completed.

After receiving the application, the regional body assesses its completeness within 20 days from the date of receipt. In the case of receiving an incomplete application, the regional body requires its correction and sets the appropriate period for this correction (as a rule, from one week to 30 days). The process of issuing an integrated permit is suspended until clarifications are made.

In the Czech Republic, holding public hearings is not a mandatory condition of the process of issuing an integrated permit, as it is mainly carried out through the exchange of letters and documentation.

According to the Law on Integrated Control and Prevention of Pollution, public hearings in the format of public meetings-discussions are mandatory only if the participant of the procedure requests it in his comments to the application. Such cases do not happen often. Unlike judicial proceedings, most administrative procedures are conducted without public hearings. The regional body usually conducts hearings on its own initiative in exceptionally complex cases that require a lot of clarification and which are guaranteed to receive comments from all relevant interested parties and from the first party at the same time.

In order to assess the application, the regional authority may, in addition to its inspection, ask **a "competent person"** (Czech, "odborně szálá osoba") for an opinion on the application of BAT or, in exceptionally difficult cases, for the entire application. Competent person (Czech, "odborně pozálá osoba") is a legal or natural person who has relevant knowledge in the areas covered by the Act on Integrated Pollution Control and Prevention (e.g. BATM application, emission limits, environmental legislation, etc.). Competent persons are authorized by the Ministry of Environmental Protection to provide expert opinions and are included in the list of competent persons approved by the Ministry. If necessary, regional authorities can either contact a company on the list of the Ministry of Environmental Protection, or (more often) turn to CENIA, the only competent authority that provides expert opinions to public authorities free of charge.

A key aspect of the process of issuing an integrated permit is the determination of mandatory operating conditions and emission limits for a certain industry based on the principles of BATM. When determining BATM, the regional authorities take into account the aspects specified in Annex 3 to the Law on Integrated Pollution Control and Prevention. The regional authority compares specific and proposed technologies, production and production processes with the BATM, in particular the emission of

pollutants into the atmosphere. The decision on the use of BATM is taken by the regional authority (namely, the relevant official). Despite the fact that the regional authority has the legal authority to determine the BATM, when setting emission limits and deciding on the issuance of an integrated permit, the regional authority must consider the conditions of each case separately in order to establish reasonable conditions for its operation.

The decision of the regional authority on obtaining an integrated permit can be appealed within 15 days after its adoption. After acquiring legal force, the decision is published on the official bulletin board (and online) within 30 days.

The conditions established in the permit for production and agricultural activities are mandatory. According to the Law on Integrated Pollution Control and Prevention, the enterprise must submit an annual report to the regional authority, in which it must describe in detail the fulfillment of the conditions specified in the integrated permit. At least every eight years, the regional body checks whether there have been any changes in the circumstances that may lead to a change in the mandatory conditions of the integrated permit.

If production and applied technologies change during these eight years and allow reducing the environmental impact of production, regional authorities usually apply stricter conditions to the operation of the enterprise in order to motivate investment in new, more environmentally friendly technologies.

If the enterprise does not comply with the conditions of the integrated permit, the regional authority or the inspectorate usually issues prescriptions before imposing fines. The size of the fines is extremely significant.

Depending on the degree of violation of the Law on Integrated Pollution Control and Prevention and the conditions of the integrated permit, the amount of the fine can reach from 2 to 10 million kroner (approximately from 70 to 350 thousand euros) and may be imposed again, which may lead to the liquidation of the enterprise .

Supervision and control. The inspection body (Czech Environmental Inspectorate) checks not only compliance with the conditions of the integrated permit, but also general compliance with the Law on Integrated Pollution Control and Prevention. Each calendar year, the inspection body prepares a plan for facilities subject to the Law on Integrated Control and Prevention of Pollution, on the basis of which it prepares a plan for standard control inspections. The interval between individual monitoring checks is determined on the basis of a systematic assessment of risks from this object for the environment, and ranges from one (highest risk) to three years (lower risk).

Currently, there are approximately 1,708 objects subject to inspection by the inspection body (more precisely, its regional units). Upon request for an additional or more extensive inspection, the inspection body sometimes conducts extraordinary

inspections (for example, in the event of an accident or a complaint from the public) and repeated on-site inspections (for example, in the event of a serious violation of the conditions of the integrated permit). Data for 2017 indicate that 488 inspections were carried out.

The Ministry of Environmental Protection supports the Integrated Pollution Register – a nationwide information system that is part of a unified information system on environmental information and allows the public to receive free and unlimited access to information in accordance with the Law on Integrated Pollution Control and Prevention. The open database allows you to search for operators, issued integrated permits, estimate BATM, information on current processes of issuing integrated permits, etc. The system also serves as a functional archive of published documents related to integrated permits in general, and in particular they disclose the process of integrated pollution control and prevention.

The Ministry has authorized the Czech Environmental Agency to manage the Integrated Pollution Register – as a public database where companies enter information on regulatory emissions and those that exceed set limits. If the company does not submit a report or submits false information, it can be fined up to 500,000 kroner (approximately 25,000 euros).

In the Czech Republic, most large industrial and agricultural facilities have gone through the process of obtaining integrated permits. Although there are sometimes bureaucratic delays requiring a large amount of documents, the process of issuing integrated permits in the Czech Republic is an efficient procedure regulated by a well-structured law (the Law on Integrated Pollution Control and Prevention) with a clear division of rights and responsibilities of interested parties, procedural guarantees rights of participants, and a clear implementation mechanism.

4.2. Environmental permits in Ukraine

In July 2024, the Verkhovna Rada adopted the Law on Integrated Prevention and Control of Industrial Pollution, which implements EU Directive 2010/75/EC into Ukrainian legislation, according to which all enterprises that pollute the environment will receive an integrated environmental permit.

It will be provided on the condition that the enterprise uses the best available technologies and management methods (BATM) for the given industry. BATM is actually a near-circular European standard for industry. Others will have time to close. The law provides for a fairly long transition period for business. Thus, the conclusions of the BATM will enter into force "no earlier than four years" from the date of termination of martial law. And then enterprises can receive up to seven years of "additional time" individually.

Currently, Ukraine has a separate environmental permit system, which provides for a large number of permits for the regulation of various types of pollution (into air,

water, and waste generation), which are issued by various departments. Such a system is costly and creates an administrative burden, both on authorities and on enterprises. The overall environmental impact of the installation is also not taken into account during the issuance of permits - environmental permits are usually limited to maximum permissible emissions without taking into account other operating conditions, such as energy efficiency, use of raw materials and water, emergency preparedness, accident reporting and notification, etc.

In terms of air emissions in Ukraine, enterprises are divided into three groups:

a) the first group – objects that are included in the state register and have production or technological equipment, on which the best available technologies and management methods must be implemented;

b) the second group – objects that are included in the state register and do not have production, or technological equipment, on which the best available technologies and management methods must be implemented;

c) the third group – objects that are not included in the first and second groups.

Permits for atmospheric air emissions for enterprises of II and III groups are issued by regional state administrations, and for I group – by the Ministry of Environment. The Ministry of Environment has the right to revoke any permit approved by regional authorities. A permit for group I is issued for seven years, for group II – for 10 years, and for group III – for an unlimited period of time. The permit is issued free of charge.

Procedure. At the beginning of the procedure for obtaining an environmental permit, the enterprise must conduct an inventory of emissions. The business can do this on its own or hire an external company. The emission inventory must contain information on all available emission sources, types of pollutants and installed measuring equipment.

All this information is further presented in the emission inventory report. This report is an important document because it contains the parameters for calculating the environmental and technical details of the facility. The report is not publicly available as it may contain sensitive (financial) information. The report is submitted to the appropriate authority (according to the above-mentioned groups and geographical/administrative location), and the enterprise begins to prepare documentation to substantiate the volume of pollutant emissions into atmospheric air.

At the same time, the enterprise is obliged to place a notice in the local media about the intention to obtain a permit for emissions. However, it is not specified what exactly these mass media should be. In practice, such advertisements are published in small local newspapers, which are often not available to the general public.

After the announcement of the company's intention to obtain a permit for emissions, the public has 31 days to provide comments and observations to the

relevant Regional State Administration. This is difficult to do because the information that would have to be commented on (the emission inventory report and the materials that justify these emissions) is not publicly available, and the substantiation process for the volume of emissions can take up to six months after the publication of the stated intention. At the end of the 31-day period, the relevant Regional State Administration will usually state that no public comments/objections have been received. The Ministry of Health (or its territorial authority) gives its approval and the package of documents is submitted to the appropriate authority for issuing permits (depending on the group and geographical/administrative location).

Within 30 days from the date of receipt, the competent authority reviews this package of documents. If the body has comments/remarks, the package of documents is returned to the enterprise for making the necessary corrections/additions. In case of their absence, the relevant authority issues a permit.

The permit contains the following conditions:

- the volume of emissions to atmospheric air,
- technological process conditions,
- BAT or, more precisely, maximum permissible emissions,
- methods of reducing emissions to the atmosphere,
- methods of monitoring compliance with permit conditions.

The volume of emissions to atmospheric air, approved in the permit, is calculated on the basis of the documentation submitted by the enterprise. These documents are developed either by the plant itself or by outsourcing companies.

According to the Law "On the Protection of Atmospheric Air", new, reconstructed or expanded industrial facilities must receive permits within the framework of the Environmental Impact Assessment procedure, which is regulated by the Law "On Environmental Impact Assessment" (Environmental Impact Assessment Law). Article 3 of the Law on EIA contains a list of activities subject to the EIA procedure.

The new EIA procedure contains a number of improvements compared to the old "environmental examination procedure". The current EIA procedure covers a larger number of object types and activities. It is even more important that the cross-border impact of the project is considered and assessed during the EIA. A unified EIA register has been created, and the information added to it is freely available to the public via the Internet.

The public has the right to access information about the process of obtaining emission permits and the permits themselves in accordance with the Law "On Access to Public Information". According to this Law, public authorities are obliged to disclose the information they have at their disposal. However, the success of such requests remains low; while authorities sometimes respond, they often do not provide

permits or relevant information. Even when this happens, the information is often incomplete or takes a long time to issue. Public consultations with EIA are required by law, but often they are not held at all or, when they are held, comments and suggestions from the public are not taken into account.

Despite the fact that the new Law on Environmental Protection has strengthened the transparency and openness of the permitting process for new industrial facilities (reconstructed or expanded facilities), the current environmental permitting process for industrial facilities still lacks a clear and effective legal framework, which would prevent biased decisions and guarantee the rights of relevant stakeholders.

Supervision and control. The reform of state environmental control is an important component of Ukraine's accession to the EU. Currently, the State Environmental Inspection (SEI), which is the central body in the field of supervision and control over compliance with environmental legislation, manages its resources and powers inefficiently.

The Ministry of Environment announced the reform of state environmental control as a priority for 2024. The SEI of Ukraine has published the project of the State Ecocontrol Reform Strategy and the operational plan for its implementation in 2024-2028, which prescribes a new model of ecocontrol in Ukraine. The project envisages the transition of environmental control to the standards of the European Union.

In order to carry out the reform, it is necessary to adopt the European integration bill on state environmental control (reg. No. 3091), in which:

- the focus of attention shifts from exclusively business inspections to constant monitoring of the environment and immediate response to damage,
- SEI will have the opportunity to use the data of environmental monitoring systems directly to carry out inspections,
- SEI will receive law enforcement status,
- transparency in the activities of the SEI increases,
- liability for damage to the environment increases.

In 2020, the draft law No. 3091 "On State Environmental Control" was registered in the Verkhovna Rada. In July 2021, the Verkhovna Rada adopted the document as a basis in the first reading, despite public warnings. In October of the same year, under pressure from the eco-community, public eco-activists made amendments to the draft law. As of February 2022, draft law No. 3091 was ready for voting in the second reading, but the Russian invasion of Ukraine prevented the implementation of the plans. Thus, the draft law No. 3091 was put on hold, and the State Inspectorate continued its existence according to the old rules and principles.

According to the results of the meeting of the members of the environmental committee of the Verkhovna Rada with representatives of leading public

organizations in December 2023, it was decided that draft law No. 3091 should be finalized.

The proposed reform of environmental control is really a reform, the set of proposed changes really allows us to talk about building an effective control system. After all, this system includes modern elements of both control models of European countries and the experience of US rangers.

Eco-control of the Western model in Ukraine is not only the elimination of consequences, but also the prevention of damage and restoration of the environment.

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Lecture 6. Monitoring of air pollution in EU countries.

Plan.

1. Air pollution monitoring and environmental inspection systemin the Czech Republic.
2. An example of air quality improvement in the Ostrava/Karvina/Fridek-Mistek agglomeration.
3. Air quality monitoring systems on the example of Poland.
4. Romanian-Ukrainian experience of monitoring transboundary transport of atmospheric pollutants in the Carpathian region.

1. Air pollution monitoring and environmental inspection system in the Czech Republic

1.1. Air quality monitoring systems

Air pollution monitoring in the Czech Republic Air quality monitoring in the Czech Republic is regulated by Law No. 201/2012 "On Air Protection". According to this law, not only air quality is assessed, but also the level of pollution (emissions). Air quality is monitored through a network of automatic observation stations of the Czech Hydrometeorological Institute (ČHMÚ), which is subordinate to the Ministry of Ecology.

The monitoring system was established in the 1990s and underwent major changes in 2015 (thanks to funding from the Environmental Management Program). As part of the monitoring, the content of substances defined by legislation and for which limits are set (based on EU standards) is assessed. Namely:

- dust aerosol/suspended solid particles PM_{10}, $PM_{2,5}$, as well as in some areas PM_1;
- SO_2 , CO, NO/NO_2, O_3;
- volatile organic compounds (benzene);
- content of heavy metals – As, Pb, Cd, Ni.

Substances measured at a specific station are selected according to the specifics of the district. The set of substances is different for different observation stations and sometimes includes additional chemical elements.

The results obtained from the monitoring network are stored in the Air Quality Information System (ISKO) of the Czech Hydrometeorological Institute. Other organizations, including companies, also store information in this system. ISKO data is evaluated annually. The results are published in the report «Air Pollution in the Czech Republic», which is published online and is available for public viewing. The annual report includes infographics and primary data in tables.

The operator of the pollution source ensures monitoring of emissions in

accordance with the Law on Air Protection. The law precisely defines which substances need to be controlled. The Operation Permit clearly states what, where and how to measure. Certain substances are measured continuously (suspended solid particles, sulfur oxides, nitrogen oxides, chlorine compounds, fluorine compounds, carbon monoxide, volatile organic compounds, sulfates), and some are determined by interval measurements (for example, heavy metals contained in PM_{10}). Continuous measurements are carried out at large emission sources. Emissions from smaller sources are determined by the calculation method. The operator reports the measurement results to the authorities electronically through the integrated reporting system (ISPOP). The Ministry of Economy of the Czech Republic carries out an annual inventory of emissions for selected substances and evaluates their dynamics. Aggregate data are published in environmental reports and yearbooks.

The Czech Integrated Pollution Register (IPR) was established in 2003 by Law No. 76/2002 "On Comprehensive Prevention" . The final form of the register was approved by Government Resolution No. 386/2003. This register was created and supplemented not on the basis of the EU model, but on the basis of the model adopted in the USA, where the concept of the pollutant register was first introduced.

The first data were entered into the IPR in 2004 (72 substances). In 2008, the Register was partially harmonized with the EU-PRTR. The number of reporting substances has been expanded, but unlike the E-PRTR (where reports are provided only for certain industries), all companies that exceed the established emission limits for certain substances report their emissions and transfers to the IPR. Thus, the information in the IPR is more complete than in the E-PRTR. This is due to the fact that the American system was adopted as a model, which records more substances than in the EU register. Czech companies must also monitor and report the content of certain substances in waste. In addition, emissions of styrene and formaldehyde (a total of 93 substances) are recorded in the Czech register.

In 2017, 1,332 enterprises reported emissions of pollutants subject to accounting, and 2,359 enterprises reported generated waste. A company that does not report the resulting pollution may be fined (up to 500,000 kroner). Compliance with this requirement is monitored by the Czech Environmental Inspection. In addition to IPR, there is another PRTR in the Czech Republic. It was created on the initiative of the non-profit organization "Arnica" with the aim of making the data received by the Institute of Health and Welfare more accessible to the public. On the website https://znecistovatel.cz you can choose the "top ten" companies with the highest level of emissions not only in the territory of the Czech Republic, but also in individual regions. Businesses can be sorted by their impact on the environment or on public health. In the program, you can build graphs that will show long-term trends. Detailed data on certain substances are not available.

Monitoring may include checking companies subject to so-called "integrated licensing". The Ministry of Natural Resources manages the Integrated Prevention Information System, where it is possible to find out the emission limits set for a specific source, or information on compliance with these limits (enterprises must submit an annual report on compliance with the conditions of the integrated permit).

Air quality information and emissions are used to simulate air quality in computer models (using software developed by the Czech Hydrometeorological Institute ČHMI). Thanks to computer modeling, it is possible to obtain air quality data for the entire territory of the Czech Republic and estimate the size of the area where the limit values were exceeded. In order to level the values of unfavorable scattering conditions, average values for five years are used (at the same time, maps created based on this information are freely available on the Internet). If the limit values are exceeded in a certain region, environmental protection measures are taken. The National Emissions Reduction Program in the Czech Republic, which is updated every four years, serves as a tool to reduce emissions and improve air quality.

If the limit values of air pollution are exceeded only in a certain area (for the purpose of air quality assessment, the republic is divided into smaller units), the Ministry of Economy develops the Air Quality Improvement Program for this industry in cooperation with the relevant region. These programs are also regularly updated. An air quality improvement program can be designed for both small regions and cities.

A medium-term strategy for improving air quality has been developed in the Czech Republic. The strategy defines the main current problems and presents ways to solve them. The strategy was developed at the request of the European Commission, as it allows justifying the attraction of funds from the European Air Protection Fund. Air quality monitoring has been carried out in the Czech Republic for over 50 years. It is worth noting that the Czech Republic had to deal with serious air quality problems in the 1960s and 1970s due to the development of lignite-fired power plants. The territory of Northern Bohemia was one of the most polluted in Europe. Since then, air quality has improved significantly. The example of Ostrava shows that the situation can be improved even in industrial areas.

1.2. The system of environmental inspection in the Czech Republic

Environmental inspections in the Czech Republic are carried out by the Czech Environmental Inspection (ČEI). The inspectorate was established in 1991 under the Act on the Czech Environmental Inspectorate and its powers in the field of forest protection. ČEI is a state body ("organizační složka" in Czech) and is subordinate to the Ministry of Ecology.

The structure of ČEI includes the head office and territorial inspections, since

1995 their number is 10. The head office is the leading, organizational and methodological body in the structure of ČEI. The role of ČEI in the public administration system of the Czech Republic fully corresponds to its legal definition. Its main mission of this specialized administrative body is to supervise compliance with environmental legislation covering all components of the environment (water, air, waste, nature and forests). Thus, ČEI carries out prevention, supervision and control, as well as imposition of sanctions in the field of environmental protection.

ČEI carries out planned inspections, inspections upon request (complaints of citizens, information in mass media, etc.) and monitoring of industrial accidents. The work of the Inspectorate is determined by the activity plan for the current year. In general, 40-45% of the working time of each inspector is scheduled in advance. The rest remains for solving current annual tasks (for example, conducting unscheduled inspections, work inspections at certified points, monitoring the performance of official emission measurements, etc.).

Inspectors have the right to access facilities (with or without prior notice), the right to check documentation, take measurements, suspend the operation of the facility, impose fines or decide on measures to eliminate malfunctions.

According to the legislation, the ČEI is an administrative body of the first instance – that is, its decisions are final or after the end of the appeal period for subjects against whom the proceedings are conducted (or in the case of an appeal based on the results of the appellate body - the Ministry of Ecology).

The Ministry makes second instance decisions in its departments located in Prague and regional cities (České Budějovice, Plzeň, Chomutov, Liberec, Hradec Králové, Brno, Olomouc and Ostrava). After review by the appellate body, the decision of the first instance, issued by the ČEI, can be confirmed or canceled. After that, the case is returned for a new consideration or is canceled.

A trial may be terminated or altered, but never to the detriment of the accused party. If someone feels deprived of their rights by a decision of the Department of Public Administration (in Czech – "odbor prještní státní spravy"), he/she can apply to the administrative court to annul the decision or declare it invalid.

2. An example of air quality improvement in the Ostrava/Karvina/Fridek-Mistek agglomeration

The agglomeration of Ostrava/Karvina/Fridek-Mistek is located on the territory of the Upper Silesian coal basin, which extends over most of Poland. It belongs to the most urbanized and industrial regions of Central Europe. In this agglomeration, unlike other regions of the Czech Republic, emissions mainly come from large organized sources. The main branches of industry are coal mining and processing, iron and steel production. More than 800,000 inhabitants live in the region (from the

Czech side).

Air quality in the agglomeration is measured at more than 20 points/locations. Concentration control is carried out for all substances for which the limit value is set. Exceeding the limit values of dust (PM_{10}, $PM_{2.5}$) and polyaromatic hydrocarbons (benzopyrene) was observed in this region. Unlike other regions, a high level of air pollution was observed throughout the calendar year, and not only in the winter period (in winter, pollution increases due to heating of houses).

2.1. Tools for improving air quality in the agglomeration

The Ostrava/Karvina/Fridek-Mistek agglomeration has been struggling with air pollution for a long time. This is due to the geographical location, historical development, as well as the fact that in the past air pollution was not considered a big problem (Ostrava became an industrial center in the 1950s). Two metallurgical plants are located here – Liberty House, formerly ArcelorMittal Ostrava, and Třinecké železárny (Třinec Metallurgical Plant). Their total annual production volume is 1.8 million tons of coke, 3.6 million tons of iron, 4.3 million tons of steel (information for 2017).

Currently, air quality in the region is significantly higher, but not ideal. Local doctors express concern about the impact of pollution on public health. The annual level of particulate matter (PM_{10}) usually exceeds the standard value at only one monitoring station, but during the 24-hour measurement, the dust concentration is usually exceeded at all stations. The concentration of benzopyrene exceeds the limits several times.

State bodies are taking measures to resolve the situation. The air quality improvement program for the region is regularly updated. Such programs should be developed for each area within which the air quality does not meet the standards. The scope of the program is regulated by law. The program analyzes the situation and develops appropriate measures. Both the program and its renewal must undergo a strategic environmental assessment procedure.

The participation of public and non-profit organizations plays an important role in this process. For this, they need to be given access to information. Thanks to the properly functioning Integrated Pollution Register (IPR/PRTR) in the Czech Republic, non-profit organizations can monitor and record cases of exceeding emission limits from large sources. Civil society organizations in the Czech Republic can participate in integrated permitting processes for certain plants, and have the opportunity to provide comments and suggestions on air quality improvement programs.

Thanks to EU membership, the right to a clean environment is guaranteed by the courts. In this region, public organizations have filed a lawsuit against the state,

claiming that the measures taken are not sufficient and there is no clear schedule for their implementation. It was about a complaint of the adopted air quality improvement program. At the end of 2017, the High Administrative Court ruled that the complaint was well-founded. Therefore, the Ministry of Ecology will have to supplement measures.

2.2. Obtained results

- As a result of the measures:
- Based on the resolution of the Parliament of the Czech Republic in 2010, the Ministry of Ecology prepared a report on the situation in the region. For the implementation of the proposed measures, funds from EU operational programs were attracted.
- An air quality improvement program was developed and updated for the agglomeration. Similar programs have also been developed in some large cities of the region. The program is subject to public consultation and some ineffective measures may be challenged in court (see above).
- Sources of pollution and their share in the total amount of emissions were determined.
- Measures have been taken to reduce emissions from major sources; other projects are being implemented. Between 2002 and 2011, dust emissions decreased by approximately 50%.
- Emission limit values until 2020 have been set for plastics and metalworking industries. These limits also include fugitive emissions from industrial facilities (2015 data showed that fugitive dust emissions can be more than 100% higher than direct emissions measured at an organized source).
- As part of the National Emission Reduction Program (NEP), measures were taken to reduce emissions from both small sources (house heating) and transport.
- Cooperation with Poland has been established. The analysis showed that the cross-border transfer of dust leads to an increase in the level of air pollution in the region, depending on the distance from the border, by 30–50%. On the other hand, from the Czech Republic comes from 5 to 30% of the pollution of the border territory of Poland.

3. Air quality monitoring systems on the example of Poland

At the time of Poland's accession to the European Union (2004), air quality in the country significantly differed from European standards. The most common air pollutants in Poland are: sulfur and nitrogen compounds, carbon dioxide and fine dust. Every year in Poland, air quality is assessed from the point of view of air pollution by 12 substances: sulfur dioxide, nitrogen dioxide, carbon monoxide,

benzene, ozone, PM_{10} and $PM_{2.5}$ and the following pollutants: lead, arsenic, cadmium, nickel and benzopyrene.

Air pollution monitoring in Poland is an element of the National Environmental Monitoring . The main legal act regulating air quality in Poland is the Environmental Protection Act of April 27, 2001. Poland is obliged to form an annual report on air quality in accordance with the "Convention on Long-Range Transboundary Air Pollution" and the Protocol to this Convention on EMEP funding.

To a large extent, the improvement of air quality and the establishment of control of the content of pollutants in the air were influenced by the implementation by Poland of the Directive 2008/50/EC dated May 21, 2008 on the quality of atmospheric air and cleaner air for Europe (eng. Clean Air For Europe program (CAFE)).

Poland, like other countries of the European Union, must fulfill the obligations arising from the NEC Directive 2016/2284.

In addition, according to the provisions of Directive 2004/107/EC of the European Parliament and of the Council on arsenic, cadmium, nickel, mercury and polycyclic aromatic hydrocarbons in the air, part of the measurement is to assess the background of air pollution by heavy metals and polycyclic aromatic hydrocarbons, then, as in accordance with the provisions of Directive 2008/50/EC of the European Parliament and the Council on air quality and cleaner air for Europe, part of the study is aimed at providing information on the concentration and chemical composition of $PM_{2.5}$.

Measurements are carried out at State Environmental Monitoring stations established by the Main Directorate of the Environmental Protection Inspection, in cooperation with other organizational units subordinate to the Ministry of Climate and Environment, and with units subordinate to the Ministry of Health (including the State Sanitary Inspection, the Central Institute of Labor Protection).

The total number of air quality measurement stations in Poland is 287, including 213 automatic or automatic-manual stations. The measurement program is established by the EMEP Governing Body. The following volume is implemented at Polish stations: measurements in the gas phase of SO_2, NO_2, O_3; in aerosol: SO_4^{2-}, NO_3^-, NH_4^+, Cl^- ; in atmospheric precipitation: SO_4^{2-} , NO_3^- , NH_4^+ , Cl^- , Na^+ , Ca^{2+}, K^+, Mg^{2+}, electrolytic conductivity, pH, and at the stations in Leba and Boretski Forest measurement of heavy metals.

In addition, measurements of PM_{10} and heavy metals (As, Cd, Cr, Cu, Ni, Pb, Zn), polycyclic aromatic hydrocarbons (benzopyrene, benzoanthracene, benzofluoranthene, benzofluoranthene, benzofluoranthene, dibenzoanthracene, indenopyrene) and $PM_{2.5}$, organic and elemental carbon, as well as measurements of CO_2 and Hg in air and polycyclic aromatic hydrocarbons in total precipitation.

The results of the hourly automatic measurement of air pollution are available on the "Air Quality" portal in the "Current measurement data" module and in the "Air Quality in Poland" mobile applications. The results of manual measurements of the content of benzopyrene, lead, arsenic, cadmium and nickel in suspended PM_{10}, $PM_{2,5}$ dust become available approximately 1-1.5 months after sampling.

Atmospheric air quality monitoring stations are installed at the expense of the Voivodeship Fund for Environmental Protection and Water Management.

Control. The tasks of the Environmental Protection Inspectorate include control activities, activities within the framework of State environmental monitoring and prevention of serious accidents in the environment.

Inspections are usually carried out by Voivodship Environmental Protection Inspectors (VEPI), while issues related to state monitoring of the state of the environment in general and atmospheric air in particular are carried out by the Main Directorate of Environmental Protection Inspection (MDEPI). Thus, in the field of air quality, MDEPI conducts monitoring, and VEPI conducts inspections of enterprises in the field of compliance with air quality rules. For general information on air quality assessment, you should familiarize yourself with the annual reports prepared by the Main Inspectorate for Environmental Protection.

Emission control of domestic fireplaces and heating devices is carried out by the local head (mayor of the city). And the task of VEPI is to control economic entities that emit into the air, including checking whether they are not illegally burning waste.

According to the 2020 report of the European Environment Agency, the air in Poland is the most polluted in the EU. Poland has the lowest air quality in Europe, partly due to the burning of poor-quality fuel to heat homes, but also due to the country's dependence on coal. In recent years, there have been grassroots initiatives as well as government programs aimed at reducing pollution levels, with mixed results. The report shows that pollution in almost all areas of Poland exceeds European air standards.

After such conclusions, the Polish government took decisive action. The Ministry of Climate and Environment has released an updated energy strategy for the next two decades, which sets out a faster phase-out of coal than previously planned. Shortly after the government agreement reached between the government and the mining unions, it was decided to close all coal mines by 2049.

The monitoring system is constantly developing and improving: the number of measuring stations increases every year, and the systematic measurements allow monitoring the dynamics of air pollution indicators. The availability of sufficient volumes and sources of funding for atmospheric air monitoring and measures to improve air quality in Poland is ensured by the availability of both national funding sources and EU funds. It is obvious that the Polish government understands the

seriousness of the consequences of atmospheric air pollution for the health of the population, as well as the consequences of non-compliance with numerous EU directives on the quality of atmospheric air, so this issue is given considerable attention at the national, regional and local levels.

4. Romanian-Ukrainian experience of monitoring transboundary transport of atmospheric pollutants in the Carpathian region

The importance of monitoring environmental objects in our time cannot be underestimated. Ivano-Frankivsk region has a high integrated indicator of anthropogenic loads on the environment in the cross-border region with such EU countries as Romania, Hungary, Slovakia and Poland.

The borders of the Ivano-Frankivsk region run along a very winding line, so their total length is about 760 km (figure 1).

The configuration of the territory of the Ivano-Frankivsk region resembles a rhombus, each side of which borders one of the neighboring regions. In the northeast – with Ternopil, and in the southeast along the White Cheremosh and Cheremosh itself – with Chernivtsi. From the northwest, the border adjoins the Lviv region. The southwestern border of the Ivano-Frankivsk region passes through the main Carpathian watershed, which separates the Tysa basin from the Dniester and Prut basins. Along this stretch, it borders with Ukrainian Transcarpathia, and along the Chivchyn ridge – with the Maramures County of Romania, the length of the state border with which is is 45 km. The geological structure of the region in the northeast is represented by the edge of the East European platform (Volyn-Podilsky plate), which borders the Carpathian mountain-fold region through the Precarpathian marginal depression in the southwest. The increase in the usage of natural resources, their depletion and degradation necessitates the development and implementation of strategies and tactics of tireless usage of nature and constant monitoring of changes in the course of natural and anthropogenic processes for the integrated management of natural resources and the state of the environment.

In some areas (Rozhnativ, Kalush, Nadvirna and Halytch districts and in the village of Broshniv, the city of Kalush, the city of Nadvirna and the city of Burshtyn), the ecological situation and the quality of the environment were characterized in the past years as unfavorable for human health. Natural resource use was irrational and ecologically unbalanced, and the efficiency of natural resource use was quite low.

Air monitoring in cities and towns of Ukraine and their further analysis, evaluation, comparison of the obtained results to identify certain patterns, tendencies, variables and their dynamics in the Ivano-Frankivsk region is extremely important. In particular, by carrying out constant monitoring of air purity in the cross-border region of the Ukrainian Carpathian (Ivano-Frankivsk region), bordering the natural and

territorial complexes of neighboring countries of the European Union.

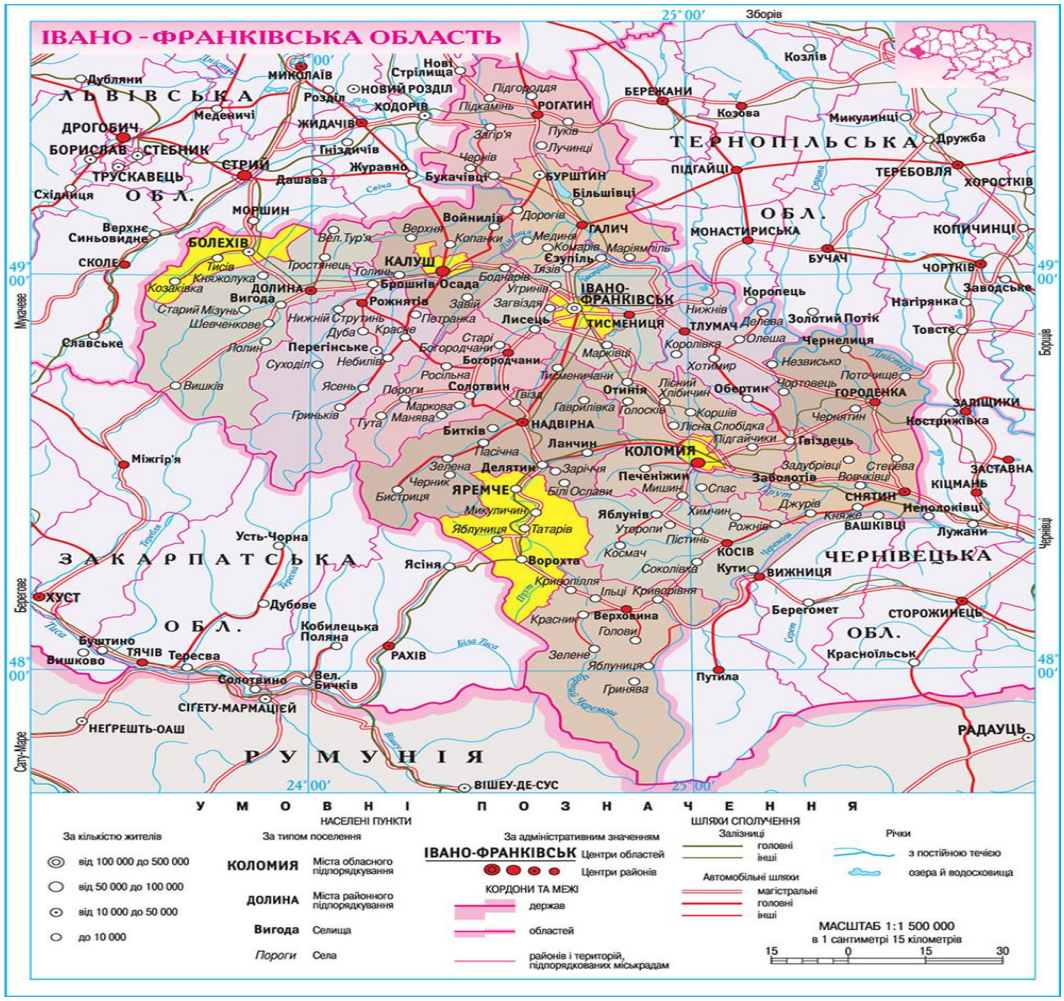

Figure 1. The location of the Ivano-Frankivsk region of Ukraine in the cross-border region with Europe.

For this purpose, for 10 years – from 2014 to 2024 – monitoring of air pollution was carried out in more than 126 settlements of the region along more than 12 routes with a total length of about 1500 km in the Ivano-Frankivsk region to monitor air quality and transboundary transport of atmospheric pollutants in Carpathian region of Ukraine. For monitoring, the performers used one-component individual signal analyzers DOZOR-S-P on CO, CO_2, H_2S, NO_2, SO_2 and gas analyzer for formaldehyde MIS-98170.

Atmospheric soil pollution. According to the data of the Main Department of Statistics, in 2013 a total of 251,500 tons of polluting substances entered the atmospheric air of the Ivano-Frankivsk region, which is 3.1% more than in 2012, and the largest of them – 52% – is sulfur dioxide, 139.6 thousand tons, of which 90% percent falls on the Burshtyn thermal power plant and 8% on motor vehicles. In addition, 4.1 million tons of carbon dioxide entered the atmosphere, which also affects climate change. An increase in harmful emissions into the atmosphere occurred in Kalush, Nadvirna, and Rozhnyativ districts. The reduction of harmful

emissions into the atmosphere was most significant in the Rohatyn district.

In 2013, 14.1 tons of harmful substances were released per square kilometer of the region's territory, which is 2.0 tons less than in 2008. Per inhabitant of the Ivano-Frankivsk region in 2013, it was 182.5 kg/person of waste, which is significantly less than in 2008 – 215 kg/person. In Halytch district, at the expense of the Burshtyn thermal power station, the specific weight of which was 89.2% of the total emissions in the region, the average volume of emissions per 1 km2 amounted to 264.7 tons. The atmospheric air in the territory of Verkhovyna district experienced the least anthropogenic load (7.5 kg per 1 km^2), Tlumatch (10.28 kg per 1 km^2), Horodenka (62.9 kg per 1 km^2) districts and Bolekhiv city council (149.3 kg per 1 km^2).

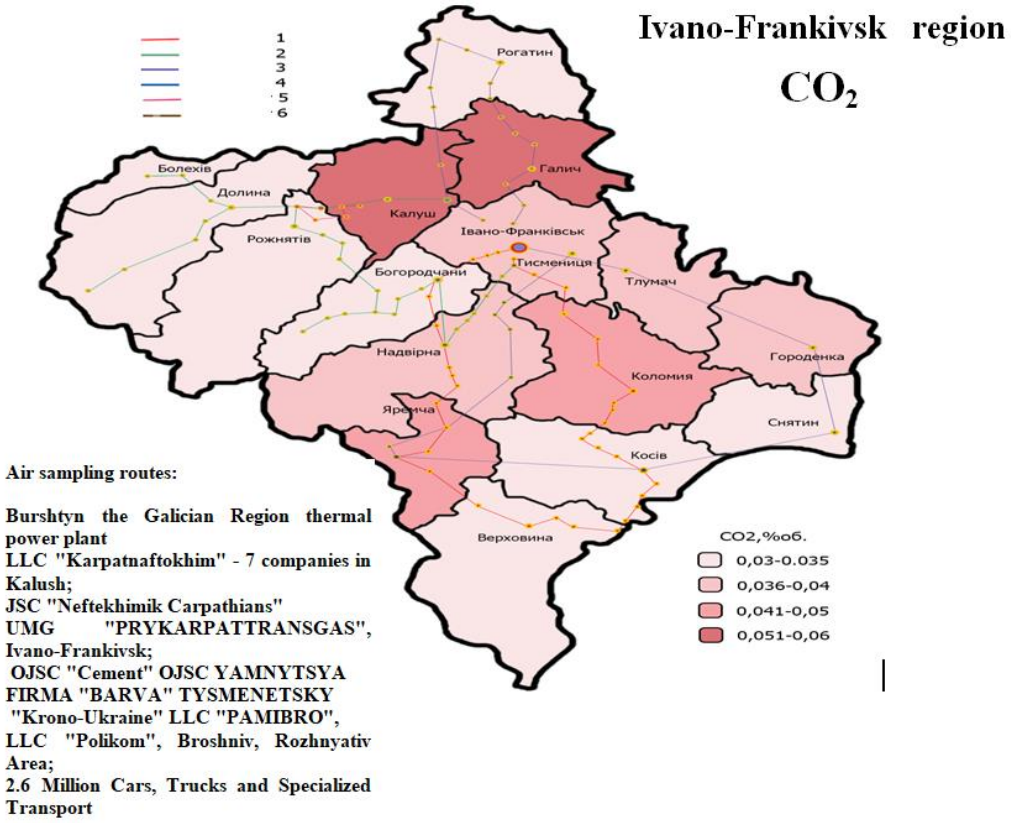

Figure 2. Concentration of carbon dioxide (CO_2) in the air of the Ivano-Frankivsk region and the Ukrainian Carpathian for the period 2014-2024.

The main air polluters are enterprises for the production and distribution of electricity, gas and water, transport and communication. These enterprises are: Burshtyn TPP, UMG "Prykarpattransgaz", Ivano-Frankivsk cement and slate plant, Kalush complex of 12 chemical enterprises, Broshniv LLC "Krono-Ukraine", and enterprises of Nadvirna. From them, 200,876 thousand tons of harmful substances entered the environment, which is 12.3% less than in the previous year, since most of them were stopped in 2013.

Since Burshtyn TPP's emissions make up 91.2% of all emissions from stationary sources in the Ivano-Frankivsk region, environmental protection measures for this enterprise are of primary importance, their implementation will significantly reduce

the actual volume of emissions throughout the region. But it must be understood that at present it is about one of the strategic energy facilities of Ukraine, which primarily provide the warring country with energy and heat.

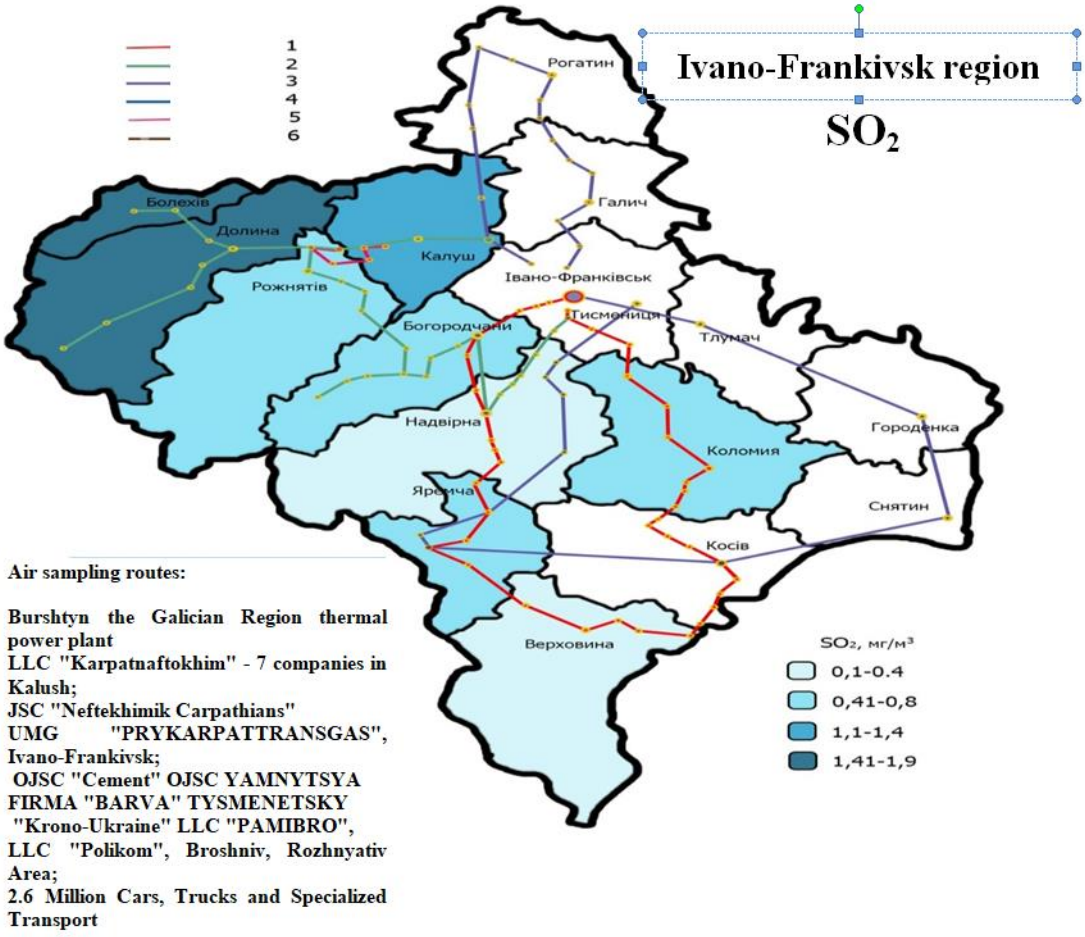

Figure 3. Concentration of gaseous sulfur dioxide (SO_2) in the air of the Ivano-Frankivsk region and the Ukrainian Carpathian for the period 2014-2024.

The issue of reducing the impact of motor vehicles on the state of atmospheric air in cities and settlements of the region is urgent. Reducing this impact is possible by improving traffic patterns, arranging car parking areas, improving fuel quality, and roads.

In order to implement Resolution No. 1655 of the Cabinet of Ministers of Ukraine dated December 13, 2001, "On approval of the Procedure for State Accounting in the Field of Air Protection," work continues in the region on state accounting of enterprises and organizations that have emissions into the atmosphere. As of January 1, 2010, there were 561 such facilities in the region. Other enterprises remain on the register as sources of pollution below the specified criterion and, accordingly, are subject to less strict control.

To a large extent, the state of the atmospheric air is affected by transboundary transfers of harmful substances from the countries of Central Europe, however, the lack of networks of control posts does not make it possible to realistically assess the

magnitude of the impact of transboundary pollution to the general assessment of the state of the atmospheric air in the region.

Monitoring of the level of atmospheric air pollution is carried out by specialists of the Ivano-Frankivsk Regional Sanitary and Epidemiological Station. In 2013, they recorded an increased content of sulfur dioxide, carbon monoxide, dust, nitrogen dioxide, and formaldehyde emitted by enterprises and motor vehicles, the number of units of which (cars, trucks, and special vehicles) has already exceeded 2.6 million cars. 10% have been operated for more than 10 years. That is, each inhabitant of the region has 2 or more cars, which causes a large environmental load and the surrounding environment.

The highest level of pollution in the region is caused primarily by Burshtyn TPP (sulfur dioxide, nitrogen dioxide, carbon monoxide, dust), OJSC Naftohimik Prykarpattia, Nadvirna, (carbon monoxide), Lk Interplit Nadvirna LLC, Nadvirna (dust, formaldehyde), LLC "Karpatnaftohim" and other chemicals. Enterprises of the city of Kalush (carbon monoxide, carbon dioxide, organic substances), KP "Ivano-Frankivskvodoekotehprom" (hydrogen sulfide), LLC "Krono-Ukraine" Broshniv village (formaldehyde, dust, carbon monoxide).

Radiation pollution of atmospheric air. In 2013, gamma background was measured on the territory of Ivano-Frankivsk region in five settlements of the region, in the cities of Ivano-Frankivsk, Dolyna, Kolomyia, Yaremcha and at the Pozhezhevska station.

In 2013, the background gamma was measured by a DRG-01T type device. The general indicators of radioactive air pollution in the region for 2013 do not exceed the level of the natural gamma-background; in comparison with the previous year, these values did not change significantly.

The usage of ozone-depleting substances and their impact on the environment. In order to fulfill the requirements of the Montreal Protocol for ozone-depleting substances and the "Program to stop the production and usage of ozone-depleting substances for 2004-2030", the following measures were taken at the enterprises of the region. At LLC "Karpatnaftohim" in Kalush, in the workshops where air conditioning systems are installed, their conservation was carried out in 2009. In 2009, the air conditioning systems were dismantled at OJSC "Zakhidenergo" Burshtyn TPP.

Impact of pollutants on human health and biodiversity. According to Article 36 of the Law of Ukraine "On Ensuring the Sanitary and Epidemiological Welfare of the Population", the determination of this assessment is carried out by scientific institutions of a hygienic and epidemiological profile. The regional sanitary-epidemiological station deals with the impact of air quality on human health in the Ivano-Frankivsk region.

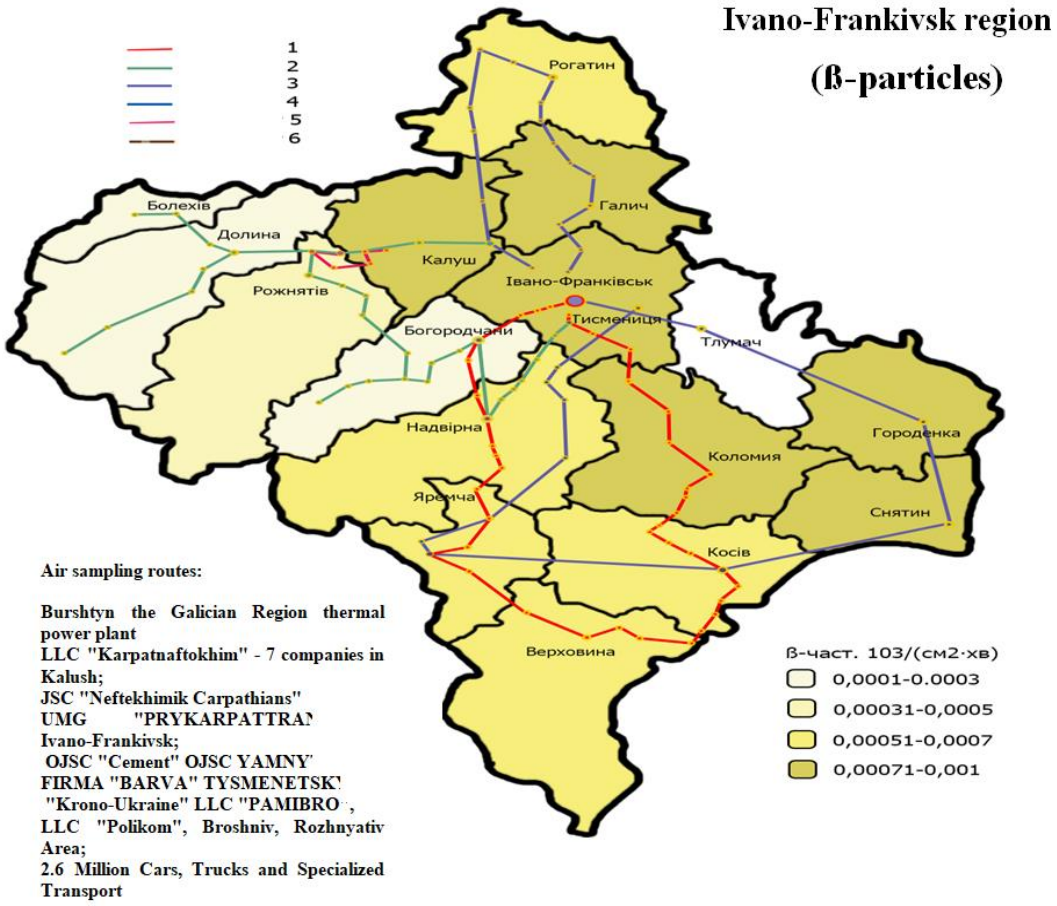

Figure. 4. The magnitude of the radiation background (ß-particles) in the air of the Ivano-Frankivsk region and in the Ukrainian Carpathian for the period of 2014-2024.

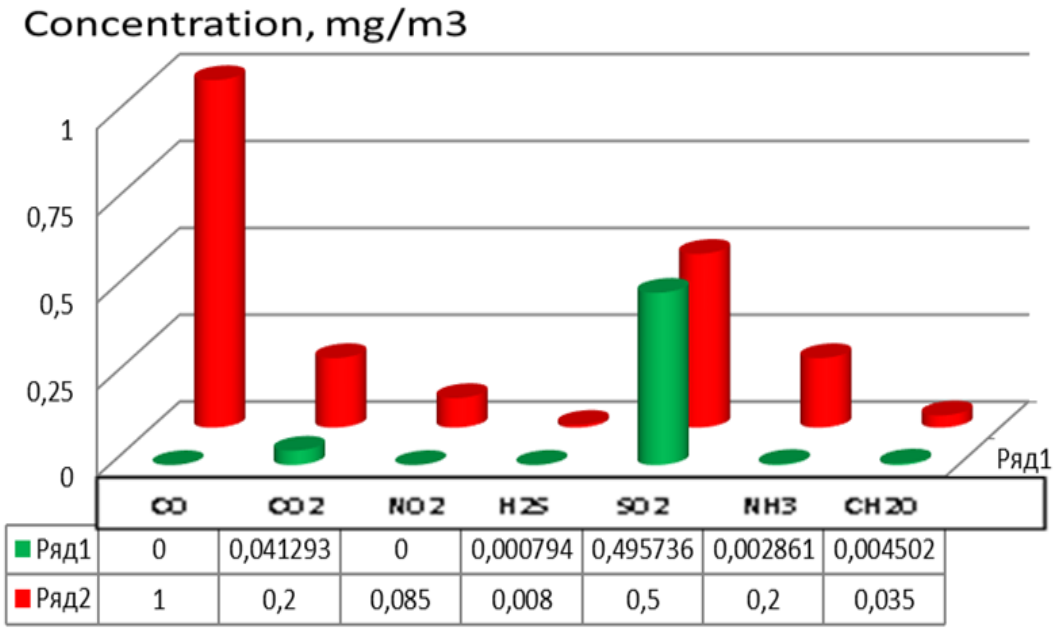

Figure 5. Histogram of the average content of gases in the air of Ivano-Frankivsk region and in the Ukrainian Carpathian for the period of 2014-2024 (green histograms), and their MPC (red histograms).

Conclusions. The main air polluters of the Ivano-Frankivsk region are enterprises for the production and distribution of electricity, gas and water, transport activities, and chemical enterprises. It should be noted that in recent years there has been a clear tendency to decrease emissions of pollutants into the air in the region. The main air pollutants in the region are:

- Burshtyn TPP, Burshtyn city, Halytch district;
- LLC "Karpatnaftohim" as part of 6 chemical enterprises of the LUKOIL company and additionally 7 chemical enterprises of the city of Kalush and the district;
- OJSC "Naftohimik Prykarpattia" and LLC "LK Interplit-Nadvirna", Nadvirna;
- UMG "Prykarpattransgaz", KP "Ivano-Frankivsk-vodoekotehprom", Ivano-Frankivsk;
- OJSC "Ivano-Frankivskcement" and OJSC firm "Barva", Yamnytsia village of Tysmenytsia district;
- "Krono-Ukraine" LLC, "Pamibro" LLC, "Policom" LLC, Broshniv village, Rozhnyativ district;
- Passenger, cargo and special automobile transport, more than 2.6 million cars.

As a result of air monitoring carried out during the years 2014-2024 in more than 126 settlements of the region along more than 12 routes with a total length of about 1500 km in the Ivano-Frankivsk region, exceeding the maximum permissible limit for 7 poisonous gases (CO, CO_2 , NO_2 , H_2S, SO_2 , CH_2O) were not detected in the ambient air.

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Lecture 7. Technical support of air quality monitoring in the EU.

Plan.

1. Approaches to air monitoring in the EU.
2. Organizational and logistical aspects of ensuring the implementation of atmospheric air monitoring.
3. Modern methods and means of air pollution control.
4. Recommendations of EU experts for the modernization of the air quality monitoring system in Ukraine.

2. Approaches to air monitoring in the EU

The main structural elements of international and European air quality monitoring are:

- the presence of an extensive system of monitoring stations,
- availability of a methodology for measuring the main indicators of air quality together with monitoring the meteorological condition,
- availability of a system for collecting, analyzing and transmitting data on the state of atmospheric air quality,
- existence of a strategy for support and development of the monitoring system,
- availability of communication tools regarding the state of atmospheric air quality.

Approaches to conducting monitoring include a wide range of organizational, personnel, technical, material and other logistical solutions that involve significant financial costs.

Approximately, such approaches can be divided into the following groups:

1) land and surface monitoring methods, which include both automatic and semi-automatic sensors to ensure constant monitoring of the state of atmospheric air and water resources, as well as methods that involve going out and conducting research directly at monitoring stations (observation points). This group also includes photo and video recording with the help of UAVs and the organization of stationary photo and video surveillance;

2) the use of methods of remote sensing of the earth's or water surface involves obtaining space images of the required resolution, followed by their deciphering and interpretation. This group of methods also involves the usage of photo and video recording with the help of UAVs.

Stationary air quality monitoring is the primary tool provided by the Ambient Air Quality Directive (AAQD) to verify compliance with limit or target values for certain air pollutants that have been established to protect human health.

There are two main types of monitoring sites: those where the highest concentration with risk of general exposure to the population is measured over a

period of time, and locations where more general exposure is measured.

To ensure comparability across Europe, the AAQD defines criteria for the location and number of monitoring sites. In addition, these criteria should ensure a certain representativeness of the results, since their number is limited, including due to financial constraints.

2. Organizational and logistical aspects of ensuring the implementation of atmospheric air monitoring

EU member states at all relevant levels appoint competent bodies and institutions responsible for:

- assessment of atmospheric air quality;
- approval of measurement systems (methods, equipment, network and laboratories);
- ensuring accuracy of measurements;
- analysis of assessment methods;
- coordination on its territory, if quality control programs at Community level are organized by the Commission;
- cooperation with other member states and the Commission.

If necessary, competent authorities and institutions shall comply with the provisions of section C of Annex I of Directive 2008/50/EC.

Atmospheric air quality is assessed for sulfur dioxide, nitrogen oxides, ozone, solid particles, lead, benzene and carbon monoxide.

2.1. Evaluation criteria

1. Member States assess the quality of atmospheric air relative to the above-mentioned pollutants in all their zones and agglomerations in accordance with the criteria defined in Annex III of Directive 2008/50/EC.

2. In all zones and agglomerations in which the level of pollutants exceeds the upper assessment threshold established for these pollutants, the method of fixed measurements is used to assess the quality of atmospheric air. Such fixed measurements can be supplemented by modeling methods or indicative measurements to provide adequate information on the spatial distribution of atmospheric air quality.

3. In all zones and agglomerations, in which the level of pollutants is lower than the upper assessment threshold established for these pollutants, a combination of fixed measurements and modeling methods or indicative measurements can be used to assess the quality of atmospheric air.

4. In all zones and agglomerations, in which the level of pollutants is lower than the lower assessment threshold established for these pollutants, the use of modeling

methods or objective assessment, or both, will be sufficient to assess the quality of atmospheric air.

5. In addition to the assessment, measurements should be made at sites in rural areas, away from significant sources of air pollution, in order to obtain, at a minimum, information about the total mass concentration and the concentration of individual chemical components of small solid particles ($PM_{2.5}$). Such measurements are carried out annually and must take into account the following criteria:

(a) one sampling point shall be established for every 100,000 square kilometers;

(b) each Member State shall establish at least one measuring station, or may, by agreement with neighboring Member States, establish one or more joint measuring stations covering relevant adjacent areas to achieve the necessary spatial distribution;

(c) where necessary, monitoring is coordinated through the monitoring strategy and measurement program of the Joint Program for the Monitoring and Evaluation of Long-Range Transport of Air Pollutants in Europe (EMER);

Member States inform the Commission about the measurement methods used in measuring the chemical composition of small solid particles ($PM_{2.5}$).

2.2. Network and observation posts

Member States establish zones and agglomerations throughout their territory. Air quality assessment management is performed in all zones and agglomerations.

2.2.1. Sampling points

1. The location of sampling points for measuring sulfur dioxide, nitrogen dioxide and nitrogen oxides, solid particles (PM_{10}, $PM_{2.5}$), lead, benzene and carbon monoxide in atmospheric air is determined using the criteria specified in Annex III.

2. In each zone or agglomeration where fixed measurements are the only source of information for air quality assessment, the number of sampling points for each relevant pollutant shall not be lower than the minimum number of sampling points defined in Section A of Annex V.

3. For zones and agglomerations in which information from sampling points for fixed measurements is supplemented by information from modeling or indicative measurements, the total number of sampling points specified in Section A of Annex V may be reduced by up to 50%, provided that the following requirements are met:

(a) additional methods provide sufficient information to assess air quality in relation to limit values and danger thresholds, as well as to adequately inform the public;

(b) the number of sampling points to be established and the spatial distribution of other methods are sufficient to establish the concentration of the relevant pollutant in accordance with the data quality objectives set out in Section A of Annex I and

allow the results of the assessment to satisfy the criteria set out in Section B of the Annex I.

The results of modeling or indicative measurements are taken into account when assessing air quality in relation to the limit values.

4. The application of the criteria for the selection of sampling points in the member states is monitored by the Commission in order to facilitate the harmonization of the application of these criteria throughout the territory of the European Union.

2.2.2. Reference measurement methods

In order to ensure that the collected information on air pollution is sufficiently indicative and comparable between the countries of the Community, it is important that standardized measurement methods and common criteria regarding the number and location of measurement points are used for the assessment of ambient air quality. Methods other than measurement can also be used to assess ambient air quality, and therefore it is necessary to define criteria for the application and required accuracy of such methods.

The EU monitoring system applies reference measurement methods and criteria defined in Section A and Section C of Annex VI of Directive 2008/50/EC, and other measurement methods may be used under the conditions set out in Section B of Annex VI.

Reference methods for assessing pollutant concentrations.

1. Reference method for measuring sulfur gas.

The reference method for measuring sulfur gas is described in standard EN 14212:2005 "Atmospheric air quality – Standard method for measuring the concentration of sulfur gas by ultraviolet fluorescence".

2. Reference method for measuring nitrogen dioxide and nitrogen oxides.

The reference method for measuring nitrogen dioxide and nitrogen oxides is described in standard EN 14211:2005 "Atmospheric air quality - Standard method for measuring the concentration of nitrogen dioxide and nitrogen oxides by chemiluminescence".

3. Reference method for lead sampling and measurement.

The reference method for lead sampling is described in Part 4 of Section A of this Annex. The reference method for measuring lead is described in standard EN 14902:2005 "Standard method for measuring Pb/Cd/As/Ni in the PM fraction of $_{10}$ suspended solid particles".

4. Reference method for sampling and measuring PM_{10}.

The reference method for the sampling and measurement of PM_{10} is described in the standard EN 12341:1999 "Air quality – Determination of the PM_{10} fractionof

suspended particulate matter – Reference method and field study procedure to confirm the equivalence of reference measurement methods".

5. Reference method of sampling and measuring $PM_{2.5}$.

The reference method for the sampling and measurement of PM $_{2.5}$ is described in EN 14907:2005 "Standard gravimetric measurement method for the determination of the mass fraction of PM $_{2.5}$ suspended solids".

6. Reference method for sampling and measurement of benzene.

The reference method for measuring benzene is described in parts 1, 2 and 3 of standard EN 14662:2005 "Ambient air quality - Standard method for measuring benzene concentrations".

7. Reference method for measuring carbon monoxide.

The reference method for measuring carbon monoxide is described in standard EN 14626:2005 "Atmospheric air quality - Standard method for measuring the concentration of carbon monoxide by non-dispersive infrared spectroscopy".

8. Reference method of ozone measurement.

The reference method for measuring ozone is described in standard EN 14625:2005 "Ambient air quality – Standard method for measuring ozone concentration by ultraviolet photometry".

Reference measurement methods for the main pollutants (sulfur dioxide, nitrogen dioxide and nitrogen oxides, benzene, carbon monoxide, solid particles (PM_{10}, $PM_{2.5}$), ozone) provide for the possibility of measuring their levels in automatic mode. For other pollutants from the list of main ones (arsenic, cadmium, nickel, benzo(a)pyrene), in accordance with the Procedure for State Monitoring in the Field of Air Protection, standard methods have been defined, which include sampling and their further analysis by chemical laboratories.

In addition, in accordance with the requirements of the EU Directives on ambient air quality, where possible, modeling methods should be used to enable the interpretation of coordinate data depending on the geographical location of the concentration. The use of measurement data in combination with pollutant emission data, geographic and meteorological indicators can serve as a basis for calculating the collective risk vulnerability of the population living in the relevant area.

To control the quality of the assessment of atmospheric air quality , to guarantee the accuracy of measurements and compliance with data quality goals, the relevant competent authorities and structures of the EU countries guarantee that:

- all measurements carried out in connection with the assessment of ambient air quality must be monitored in accordance with the requirements established in Section 5.6.2.2. ISO/IEC 17025:2005,
- institutions that operate networks and individual stations establish systems of assurance and quality control, which provide for regular support in order to ensure the

accuracy of measuring devices,

- a quality assurance/control procedure is in place for the data collection and reporting processes and that the institutions designated to carry out this task actively participate in relevant quality assessment programs at Community level,
- national laboratories, if designated by the relevant competent authority or organization, participating at Community level in the comparison of pollutants governed by the provisions of this Directive, accredited according to EN/ISO 17025 until 2010 for the reference methods defined in Annex VI. Such laboratories are involved on the territory of the Member States in the coordination of quality assessment programs organized by the Commission at Community level, and coordinate at the national level the appropriate implementation of reference methods and confirmation of the equivalence of non-reference methods.

Confirmation of equivalence.

1. A Member State may use any other method which as confirmed gives results equivalent to any of the methods specified in Section A or, in the case of particulate matter, any other method which, as the Member State can confirm is compatible with the reference method. In such a case, the results obtained using this method must be adjusted to obtain results equivalent to those that would be obtained using the reference method.

2. The commission may require the member states to prepare and submit a report on confirmation of equivalence.

3. In assessing the acceptability of the report, the Commission will refer to its guidelines on the confirmation of equivalence (which must be published). If Member States used intermediate factors to approximate equivalence, the latter should be confirmed or modified with reference to the Commission's guidelines.

4. Member States shall ensure, where appropriate, that the adjustment is also applied to data from past measurements in order to achieve better data comparability.

Standardization.

For gaseous pollutants, the volume should be standardized at a temperature of 293 K and an atmospheric pressure of 101.3 kPa. For solid substances and substances to be analyzed in solid impurities (for example, lead), the volume of the sample expresses the conditions of the atmospheric environment in relation to the temperature and atmospheric pressure at the time of measurement.

Introduction of new equipment.

All new equipment purchased to implement the provisions of this Directive must be brought into compliance with the reference method or its equivalent by 11 June 2010.

All equipment used in fixed measurements must be brought into compliance with the reference method or its equivalent by 11 June 2013.

Mutual recognition of data

When carrying out type approval to confirm that the equipment meets the performance requirements of the reference methods specified in Section A, the competent authorities and institutions designated in accordance with Article 3 shall accept test reports issued in other Member States by laboratories accredited in accordance with the standard EN ISO 17025 for such testing.

3. Modern methods and means of air pollution control

3.1. Remote sensing of the Earth

One approach to environmental monitoring is remote sensing of the Earth. The use of environmental protection allows obtaining information about the state of the environment and its components at the international, regional, and local levels. The data obtained with the help of RSE can be combined with the data of ground observation methods, as well as with the modeling method, which allows to comprehensively determine the state of the environment, forecast it, and trace changes in dynamics.

Among the best examples of international observation and decision-making systems using remote sensing of the Earth is the European Union's Copernicus program, which provides all parties (countries) with timely and accurate geospatial information obtained from satellites of the RSE and other sources, necessary for effective elimination of the consequences of natural disasters, man-made emergencies and humanitarian crises.

The Copernicus program was created in 2011, and the program began to function fully in 2014. The space part of the Copernicus information system is served by a set of dedicated Sentinel family satellites and support missions (operational commercial and public satellites). Sentinel satellites are specifically designed to meet the needs of Copernicus services and their users. Since the launch of Sentinel-1. And in 2014, the European Union launched a program to put a family of nearly 20 satellites into orbit by 2030.

This program offers information services on Earth observation satellite data and local data (not from space). The program is coordinated and managed by the European Commission. Copernicus is implemented in partnership with EU Member States, the European Space Agency (ESA), the European Organization for the Exploitation of Meteorological Satellites (EUMETSAT), the European Center for Medium-Range Weather Forecasts (ECMWF), EU agencies, Mercator Océan and countries with which international agreements have been signed . In the light of the dissemination policy of the Data Access Program, Copernicus is of increased interest, so in this context the EU is looking for opportunities to share data for the benefit of the Copernicus Program. Thus, the fastest way to access the Copernicus program data

in the part of the data that requires authentication to access is the offer to exchange data of local observations from Ukraine. On May 25, 2018, the State Space Agency of Ukraine and the European Commission signed an Agreement on cooperation in the field of data access and data use of Sentinel satellites of the Copernicus program. In exchange for this, the SSA of Ukraine provides free open access to the data of its own satellites for use in the Copernicus program. Information services to authorized users of the Copernicus Program are provided free of charge with open access. This applies only to data with low and medium spatial resolution.

Depending on the level of access, the user has the opportunity to work both with raw data of direct observations and to use the results of processing and predictive calculations in a form that is convenient for perception. Detailed user instructions are provided for working with raw direct observation data streams, detailing the data structure and format.

Copernicus also collects information from insitu systems (local data), such as ground stations that deliver data obtained by many sensors on the ground, at sea or in the air. As a result, not only data from satellite observations, but also data from local terrestrial, atmospheric, and marine measurement systems are used to model processes in the atmosphere, oceans, and on the earth's surface. The main purpose of local observation data is to refine satellite observation data and for periodic calibration of satellite observation systems.

As a result of processing observation and modeling data, various current and forecast thematic maps are created, features and anomalies are revealed, and statistical data can be reviewed and clarified.

The information received by the system is optimized through six thematic streams of Copernicus services:

1. Atmospheric Monitoring Service (CAMS).
2. Marine Environment Monitoring Service (CMEMS).
3. Land Monitoring Service (CLMS).
4. Climate Change Service (C3S).
5. Copernicus Security Service.
6. Copernicus EMS emergency service.

The Copernicus space observation system is based on the use of observation data from six families of satellites: Sentinel-1, Sentinel-2, Sentinel-3, Sentinel-4, Sentinel-5, Sentinel-6. Each family of satellites consists of two or four satellites. Some of the satellites have already been put into orbit, and some are still at the stage of development or preparation for launch.

CAMS is one of six services that make up Copernicus, the European Union's Earth observation program. The main concept of Copernicus work is to provide information on air quality and atmospheric composition within and outside of Europe

based on satellite and ground observations in combination with forecasting models (see Figure 11).

Copernicus provides data to users through various services. These include the Climate Change Service (C3S) and the Atmospheric Monitoring Service (CAMS), both managed by the European Center for Medium-Range Weather Forecasts (ECMWF). The Copernicus Atmosphere Monitoring Service (CAMS) provides continuous data and information on the composition of the atmosphere.

The main tasks of Copernicus atmospheric monitoring are: description of the current situation; forecast of the situation for several days ahead; analysis of consecutive retrospective data over recent years. The service supports many applications in various fields, including health care, environmental monitoring, renewable energy, meteorology and climatology.

CAMS services are focused on five main areas:

1. Air quality and composition of the atmosphere;
2. Ozone layer and ultraviolet radiation;
3. Waves and surface currents;
4. Solar radiation;
5. Impact on the climate.

The service provides daily information on the overall composition of the atmosphere using monitoring and forecasting components such as greenhouse gases (carbon dioxide and methane), reactive gases (e.g. carbon monoxide, oxidized nitrogen compounds, sulfur dioxide), ozone and aerosols; provides hands-on real-time analysis and 4-day forecasts, as well as re-analysis of European air quality, allowing for a continuous assessment of the air we breathe; provides public and private organizations involved in the use of solar energy with relevant and accurate information about the solar radiation resources on the Earth's surface, which is important in areas such as health care, agriculture and renewable energy sources.

All information data is provided free of charge and without restrictions in order to increase the level of awareness of the state of the surrounding atmospheric environment among politicians, businessmen and citizens.

The CAMS service is based on seven modern air quality models developed in Europe:

1) CHIMERE from INERIS (France),
2) EMEP from MET Norway (Norway),
3) EURAD-IM from the University of Cologne (Germany),
4) LOTOS- EUROS from KNMI and TNO (Netherlands),
5) MATCH from SMHI (Sweden),
6) MOCAGE from METEO-FRANCE (France),
7) SILAM from FMI (Finland).

In addition to them, there is also the ENSEMBLE model, which is a combination of all the above-mentioned models. Data from this model are available for the whole of Europe (25°W-45°E, 30°N-70°N).

CAMS is implemented by the European Center for Medium-Range Weather Forecasts (ECMWF) on behalf of the European Commission. ECMWF is an international independent organization supported by 34 countries. It is both a research institute and a 24/7 operational service that produces and distributes numerical weather forecasts for its member countries.

To provide and further develop CAMS, ECMWF works with many service providers across Europe. In doing so, CAMS combines the expertise and infrastructure that exists in Europe to provide a range of services unmatched by any other organization in the world. CAMS is implemented by the European Center for Mean Annual Weather Forecasts (ECMWF) and with the support of more than 30 organizations located across Europe.

CAMS can provide forecasted data. Just like a weather forecast, this information is based on advanced mathematical models and reflects the laws of physics in combination with past observations. As a result, the possibility of an inaccurate forecast is not excluded. However, an evaluation of the last six months of 2017 showed that forecasts were correct within one index value (were accurate, more or less by one value) more than 98% of the time.

The data it provides is obtained using a computational grid method with cells measuring approximately 10 km by 10 km horizontally, which means that it cannot reflect local effects (such as a road with heavy traffic within a few hundred meters, etc.) . In large cities, the values provided by CAMS also reflect the so-called "urban background" concentrations, corresponding to areas of the city that are not directly affected by local sources such as vehicular traffic (eg in the middle of a large park or in a residential area). Areas influenced by local sources are expected to have higher concentrations of NO_2 , $PM_{2.5}$, PM_{10} , and SO_2 and lower concentrations of O_3.

3.2. Application of sensors for air quality monitoring

The increasing commercial availability of micro sensor technology is facilitating the rapid adoption of low-cost sensors for air quality monitoring by both public science initiatives and government agencies. One of the advantages of using low-cost sensors for monitoring is increased spatial coverage when monitoring air quality in cities and remote locations.

In general, government agencies want to increase the density of monitoring measurements and often want to rely on low-cost sensors because they cannot afford enough reference air quality monitoring stations (AQMS). Inexpensive sensors can provide real-time measurements at a lower cost, allowing wider spatial coverage than

current reference methods for measuring air pollutants.

In addition, air pollution monitoring using reference measurement methods requires skilled operators to maintain and calibrate the measuring devices. Conversely, low-cost sensors are expected to be operated without human intervention, allowing unskilled users to monitor air pollution without the need for additional technical expertise.

Many institutes responsible for air quality monitoring for regulatory purposes, as well as local authorities, are considering incorporating low-cost sensors into their routine measurement methods to complement the monitoring of reference measurements. However, the lack of comprehensive and accessible information to compare the performance of low-cost sensors and the wide range of commercial offerings make it difficult to select the most suitable low-cost sensors for monitoring purposes.

To classify and understand the deployment of sensors, a distinction should be made between a single sensor detector produced by an original equipment manufacturer (hereinafter such sensors are called OEM or OEM sensors) and sensor systems (SSys), which include OEM sensors together with a protective box, sampling system, power system, electronic equipment and software for data acquisition, analog-to-digital conversion, processing and data transmission. Hereinafter OEM and SSys are referred to as low-cost sensors (LCS). From a user perspective, SSys are ready-to-use off-the-shelf systems, while OEM users need to add hardware/software components for weather protection, data storage, data sending, data compatibility, and overall LCS calibration.

The use of LCS is of great interest for public science initiatives. Therefore, small and medium-sized enterprises offer SSys that can be used by citizens who want to monitor the air quality in their chosen environment.

LCSs are commercially available on the market today , ranging in price from a few hundred to several thousand euros. At the same time, the scientific literature currently contains independent information on the performance of sensor systems against reference measurements for about 110 sensor systems. In fact, the data quality of inexpensive sensors is often questionable. It is affected by atmospheric conditions, pollutant concentration levels and, therefore, the location where the measurements are taken.

There are only a few commercially available sensor systems that, according to studies, show good agreement with reference measurements (coefficient of determination, R^2, above 0.75 and slope of the regression line within 1 ± 0.5) and an overall price lower than 3 thousand euros. Information on such studies is obtained from research institutes that have an LCS testing program , e.g. California Council - Air Quality Sensor Performance Evaluation Center (AQ-SPEC), European Union

Joint Research Center (EUJRC) and US Environmental Protection Agency (USEPA). Other information was taken from peer-reviewed journals that tested different types of sensors in studies. The conclusion of this market analysis is that the only sensor system that meets the requirements of the multi pollutant, availability of raw data, transparency of all applied data processing, availability of sensor system performance evaluation with a high coefficient of determination (>0.85) is AirSensEURv.2.

These LCSs for monitoring gaseous air pollutants are grouped into four categories based on the principles of operation and technologies, which are based on:

- metal oxide sensors,
- electrochemical or amperometric sensors,
- non-dispersive infrared absorption (NDIR),
- photoionization detectors.

In particular, metal oxide sensors consist of a metal oxide (resistive or semiconducting MeO), whose resistance or conductivity changes under the influence of oxidizing gas(es). The reaction of such gases with heated MeO leads to the capture and accumulation of electrons on the surface of the sensor, which creates a negative charge, acting as a barrier for electrons, thus changing the conductivity. Conductivity changes are usually proportional to the concentrations of oxidizing gases in the air and can be controlled by an external loop. MeO-LCS can measure non-methane hydrocarbons, CO, carbon dioxide CO_2, NO, NO_2 and O_3.

4. Recommendations of EU experts for the modernization of the air quality monitoring system

Ukraine and EU countries are strengthening cooperation to develop a modern air quality monitoring system, which will allow Ukraine to come closer to the implementation of EU standards in the field of atmospheric air quality and increase the ability of state bodies to determine the impact of war on air quality.

According to the recommendations of European experts on bringing the national observation network of Ukraine into compliance with EU legislation, with the zoning system proposed by the experts (25 zones and 25 agglomerations), there is a need to create a network with a total of approximately 160 fixed (reference) observation points in zones and agglomerations, as well as 12 fixed observation points on rural outskirts throughout the territory of Ukraine.

Fixed measurements in accordance with the Procedure for state monitoring in the field of atmospheric air protection involve the use of reference measurement methods that are already used in the EU monitoring system.

Reference measurement methods for the main pollutants (sulfur dioxide, nitrogen dioxide and nitrogen oxides, benzene, carbon monoxide, solid particles (PM_{10}, $PM_{2.5}$), ozone) provide for the possibility of measuring their levels in

automatic mode. For other pollutants from the list of main ones (arsenic, cadmium, nickel, benzo(a)pyrene), in accordance with the Procedure for State Monitoring in the Field of Air Protection, standard methods have been defined, which include sampling and their further analysis by chemical laboratories. In addition, in accordance with the requirements of the EU Directives on the quality of atmospheric air, new methods of monitoring the quality of atmospheric air – modeling and objective assessment, which involve the use of measurement data in combination with data on pollutant emissions - are being introduced into the state system of atmospheric air monitoring substances, geographical and meteorological indicators.

Thus, under the condition of creating a network of fixed observation points with automatic analysis of pollutant levels in accordance with EU legislation, the state air monitoring system requires new elements:

- The National Reference Laboratory, which ensures the unity, accuracy, and traceability of measurements in the entire atmospheric air monitoring system by means of calibration, verification of measuring equipment, determination of compliance of equipment and observation networks with the requirements of legislation;
- A system of collection, analysis, exchange, and publication of data on the quality of atmospheric air, capable of providing such functions for the entire state network of observations - automatic, laboratory -analytical, modeling, and objective evaluation.

At the same time, due to the decrease in the number of measurements carried out by sampling and laboratory analysis, there is a need to optimize the system of laboratories in the field of atmospheric air quality analysis.

According to the report of international experts, the modernization of the atmospheric air monitoring system is recommended to be carried out in stages.

At the first stage, as part of the pilot project, it is recommended to start measuring selected priority pollutants in different types of territories depending on the priority source of pollution (urban background, traffic, industry). One of the reasons for using a step-by-step approach, according to the report, is to create conditions for familiarizing the personnel of the monitoring subjects with new measurement techniques and technologies, as well as acquiring the skills necessary to work with automated observation points, starting procedures for ensuring and controlling the quality of data in newly created networks observations

Pollutants from lists A and B of Annex 2 to the Procedure for State Monitoring in the Field of Air Protection, which can be measured automatically at the first stage of modernization, include: SO_2, H_2S, NO_2, PM_{10}, $PM_{2.5}$, O_3, CO, VOCs, trace elements and surfactants**.**

After familiarization with the new automatic measurements, it is recommended

to start the expansion of the automatic observation network, which will continue during the second and third stages of modernization.

According to the preliminary assessment of international experts, the chemical laboratories for air quality analysis (laboratories of UGMC) need significant modernization, in particular the renovation of their premises, the purchase of equipment for the analysis of pollutant levels, and auxiliary laboratory equipment. It is recommended to start the modernization of chemical laboratories at the first or second stages of modernization, when a network of automatic observation points will be created, where, in particular, continuous sampling for further chemical analysis will be carried out. The cost of modernization of one chemical laboratory is estimated at approximately 0.5-2 million euros.

Another element of the atmospheric air monitoring system in accordance with the EU legislation is the functioning of the national reference laboratory, as part of the data quality assurance and control system. As stated in the report of international experts on the results of the analysis of the compliance of the existing air monitoring system with the requirements of the EU Directives on air quality, the quality of air pollution data is of crucial importance for reliable analysis of air pollution levels, health effects and planning measures to reduce pollution levels. Establishing a national reference laboratory is a complex task and is recommended only after gaining some experience in using automatic instruments and measurement methods that meet the requirements of EU air quality directives. In the report of international experts, it is recommended to create a reference laboratory at the second stage of modernization. The cost of creating a national reference laboratory in accordance with EU Directives is estimated at 1.5 million euros.

In addition to the above, an important element of the modern atmospheric air monitoring system is the monitoring data collection and processing system, which includes a nationwide air quality database. According to the report on the results of the analysis of the compliance of the existing air monitoring system with the requirements of the EU Directives on air quality, the national database must contain all verified (verified) data on air quality. The report proposes the creation of a procedure in Ukraine, which consists in the fact that observation networks (local, industrial) will be responsible for verifying data in their own network and for sending verified automatic data to a central database. Manual results will be periodically sent to the database from the chemistry laboratory/laboratories. The air quality database must be connected to software that includes tools for publishing real-time air quality data on the Internet.

The authority responsible for the administration of the national database should also ensure an annual assessment of air quality (for exceeding limit values based on verified data), reporting on air quality and dissemination of relevant information to

public authorities, zoning or agglomeration authorities and other interested parties for further actions.

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Lecture 8. Practice of European satellite remote monitoring.

Plan.

1. Satellite monitoring system.
2. Satellite observations of the water cycle.
3. Air quality monitoring.
4. Monitoring life under water.
5. Earth observation for ecosystem accounting.
6. Monitoring the amount of carbon.
7. Using methods of remote sensing of the earth and water surface.
8. Air pollution – a view from space.
9. Sentinel Copernicus satellites.

1. Satellite monitoring system

Satellite remote monitoring is a system of obtaining information about an object or phenomenon based on measurements made at a considerable distance from the object of observation.

Currently, there are two methods of satellite remote monitoring.

The first is based on obtaining an image of the Earth's surface. This method focuses on image analysis. The use of this method is carried out for many applied tasks, since it is sufficiently perfect and economically justified.

The second direction collects data that can be interpreted in quantitative terms. The development of this direction began in the 50s and 60s of the 20th century, when it was possible to obtain data using sensor systems, primarily it concerns the registration of energy in the infrared part of the spectrum. In this method, the main thing is a multispectral scanner, which registers data in a wider partof the electromagnetic spectrum, in comparison with the equipment of the first method.

In the European Union, the use of a remote satellite monitoring system is also providedregulation of the Common Agricultural Policy (CAP). CAP has a long history of using satellite or aerial imagery. Although these images usuallyhave very high resolution, until 2017 they were not available with enoughperiodicity to allow verification of activities carried out on agricultural land throughout the year. Since March 2017, the EU-owned Copernicus Sentinel 1 and 2 satellites have been making high-resolution images freely available, markinga game changer in Earth observation technology for agricultural monitoring. [1]

On September 13, 2022, the European Parliament adopted a resolution on the new EU forest strategy for 2030 – Sustainable Forest Management in Europe, which emphasizes the strengthening of monitoring of European forests. The Strategy states that to ensure the availability of reliable, transparent and high-quality data, new innovative approaches, such as remote sensing technologies, must be tested and

combined with data obtained through ground monitoring. The collection and maintenance of reliable high-quality data, the sharing of knowledge and best practices, and well-funded and well-coordinated research are central to addressing the challenges, given that forest data available at EU level are incomplete and of varying quality , which hinders the coordination of the EU and member states regarding the management and conservation of forests; since, in particular, there is a need for better monitoring of the state of the forest ecosystem, as well as the impact of forestry activities on biodiversity and climate. Copernicus products are also recommended. [2]

2. Satellite observations of the water cycle

Water is the foundation of sustainable development and is critical to the survival of people and the planet. It is at the heart of many areas, including food and agriculture, climate, health, education and poverty reduction efforts. This means that the CAP strategy direction "Clean water" "addresses not only drinking water, sanitation and hygiene, but also the quality and sustainability of water resources worldwide." Satellites provide repeatable and objective observations of the water cycle with regional and global consistency, supporting implementation and scalability of monitoring systems. [3]

Satellite observations of the water cycle cover a wide range of parameters, and currently hydrometeorological and space agencies around the world use instruments to monitor all phases of the water cycle. [3]

The satellite's capabilities include monitoring clouds, precipitation (rain and snow), soil moisture, groundwater supplies, inland water bodies, surface levels of rivers and lakes, the cryosphere (e.g. snow, ice, glaciers) and a number of ocean parameters. These observations support holistic management approaches, including hydrological modeling and the implementation of integrated water management (IWRM), identified as a key aspect of sustainable water management in the 2002 Johannesburg Implementation Plan. Strategy development is the main focus of non-EU water-related development assistance, with water management projects accounting for 5% of the total. [3]

One example of Earth observation support for IWRM development is the Water Observation and Information System (WOIS). WOIS helps solve the problems that arise in the collection, analysis and use of geoinformation related to water, and the software is available free of charge. [3]

Global monitoring of surface waters

The availability of inland and coastal surface water affects the well-being of people and ecosystems around the world. Although national and regional inventories, statistical extrapolation, and satellite imagery are used to obtain surface water snapshots, systematic monitoring of long-term changes at high resolution remains a

challenge. Many efforts have been made using long time series (Landsat) images (since 1984) to try to solve this problem, including the involvement of the European Commission's Joint Research Center (JRC) Global Surface Water Explorer (GSWE). [3]

Using the massive parallel computing power provided by Google Earth Engine, GSWE maps the location and temporal distribution of water surfaces using 3 million images, quantifying the volume and changes of the global water surface each month at 30-meter resolution. For example, the maps show that between 1984 and 2015 permanent surface water disappeared from an area of almost 90,000 square kilometers, equivalent to slightly more than the area of all surface water in Europe, although new permanent surface water bodies of 184,000 square kilometers appeared, formed in another place. More than 70% of global net permanent water loss has occurred in the Middle East and Central Asia, attributable to drought and human activities, including river diversion or damming and unregulated abstraction. [3]

GSWE provides a freely accessible dataset to the public, scientists and policymakers to help countries improve surface water modelling, provide evidence of changes in water-related ecosystems, and inform water management decisions, including supporting indicator 6.1.1. [3]

3. Air quality monitoring

Sustainable cities and communities

Satellite monitoring with a spatial and temporal resolution suitable for urban developments is becoming increasingly possible. The data can be accessed on a free and open basis, creating products designed specifically for urban planners, as well as supporting tools and platforms that greatly increase the availability and usability of observations. Urban growth and air quality are two important urban management topics where satellites are increasingly contributing. [3]

World Health Organization Data Integration Model for Air Quality Monitoring

Air pollution poses a significant environmental risk to health, and is also linked to climate change and ecosystem damage (e.g. through acid rain) through the release of CO_2, soot, sulfur dioxide, nitrogen oxides and other greenhouse gases. Monitoring the emissions of these pollutants and their impact on air quality in the urban environment is the key to a more informed policy and assessment of the sustainability of decisions regarding the development of environmental security. [3]

The World Health Organization (WHO) is an agency that uses a variety of observations, including ground-based and satellite measurements, as input to models to estimate human exposure to harmful particulate matter less than 2.5 micrometers in diameter, known as PM2.5. WHO maintains an air quality database to support

reporting and has developed a Data Integration Model for Air Quality (DIMAQ) that incorporates data from multiple sources to provide a global 0.1° × 0.1° exposure estimate of PM2.5. [3]

At the national level, the US AirNow system provides the public with real-time air quality data, forecasts and health information. The system was established in 1998 when access to air quality data was not easy and a real-time national dataset was not available, and has since encouraged and supported air quality monitoring efforts around the world. The system quickly uses data from multiple satellite instruments to supplement ground-based monitor measurements, which increases the accuracy of air quality forecasts. [3]

4. Monitoring life under water

Satellite images can help monitor and maintain marine resources. This includes monitoring coastal eutrophication and the density of floating plastic debris, as well as regulating and monitoring illegal fishing activities. Satellites can help solve the problems of a huge scale and the difficulty of access to many areas of the World Ocean. [3]

Great Barrier Reef World Heritage Area

The eReefs Marine Water Quality Dashboard provides real-time, near real-time information on the water quality of Australia's Great Barrier Reef. Remote sensing provides measurements of marine indicators (such as chlorophyll, sediment, and dissolved organic matter) that can help marine park management assess ecosystem health and coastal water quality. Observations from NASA's Aqua satellite have provided accurate, regionally tailored information on water quality, allowing managers and policymakers to inform, evaluate and improve the results of their management decisions. [3]

Satellites regularly and systematically provide observations of chlorophyll-a on the surface of the ocean. Chlorophyll-a is a key indicator of microscopic green algae (phytoplankton), and although phytoplankton is a natural part of the reef ecosystem, elevated levels signal elevated levels of nutrients, especially nitrogen. These elevated nutrient levels can disrupt the balance of the ecosystem and lead to coral bleaching and dieback. Typical sources of nitrogen are runoff from excess fertilizers applied to crops and urban sewage pollution. [3]

The satellites facilitate informed decisions about the management and regulation of fertilizer use and wastewater management, meaning that the overall condition of the Reef can be monitored for conservation and assessed on a systematic, quantitative and transparent basis. [3]

5. Earth observation for ecosystem accounting

Ecosystem records

Ecosystem records organize information about the extent or area of different types of ecosystems that exist in a country or region. Land cover data classified according to the SEEA Central Framework standard classification and supplemented with additional characteristics such as land use, elevation and ecosystem services provided help further classify land into ecosystem types. Land cover data is directly linked to several indicators, including indicator 15.3.1 on land degradation, indicator 6.6.1. on freshwater ecosystems or indicators 11.3 and 11.7 on land use. Ecosystem-scale data supporting these indicators typically consist of the use of EA (ecological accounting) data combined with statistical observations and ground checks. [3]

SEEA EEA includes environmental indicators for water, carbon and biodiversity. Thematic accounts are compiled for different types of ecosystems to support assessments of specific management objectives, including land management and planning, and water management. [3]

Ecosystem services directly related to water include water provision in terms of the volume of water used for various purposes (e.g. drinking, irrigation, cooling, hydropower generation, etc.); water regulation (for example, filtering pollutants or regulating water flow); and cultural services such as recreational (e.g. swimming, boating). This information is critical for monitoring water availability and sustainable water management. [3]

Example: Water monitoring in the Netherlands

Indicators focused on water efficiency – 6.4.1 and water shortage – 6.4.2. Data for these two indicators can be obtained from a variety of sources, including statistical sources, simulation-based data, and EA data. In particular, the estimation of actual evapotranspiration (AET) is quite important for the measurement of water-related indicators, including the measurement of agricultural water use and water availability. AET is defined as the sum of plant evaporation and transpiration from the Earth's surface to the atmosphere and can be calculated using algorithms that use EA data as a source. [3]

To estimate AET, a number of remote sensing data are freely available (e.g., MODIS, Landsat, Proba-V, and Sentinel-2), and several AET databases have been developed, such as MOD16 (NASA) and Land Surface. Analysis Satellite Applications Facility (LSA SAF). Statistics Netherlands, in partnership with eLEAF (Dutch high-tech company that provides satellite-based applications), an EA analysis company, produced an AET map for the Netherlands to obtain a spatial and temporal resolution superior to publicly available data sources. The resulting map is shown in Figure 1. [3]

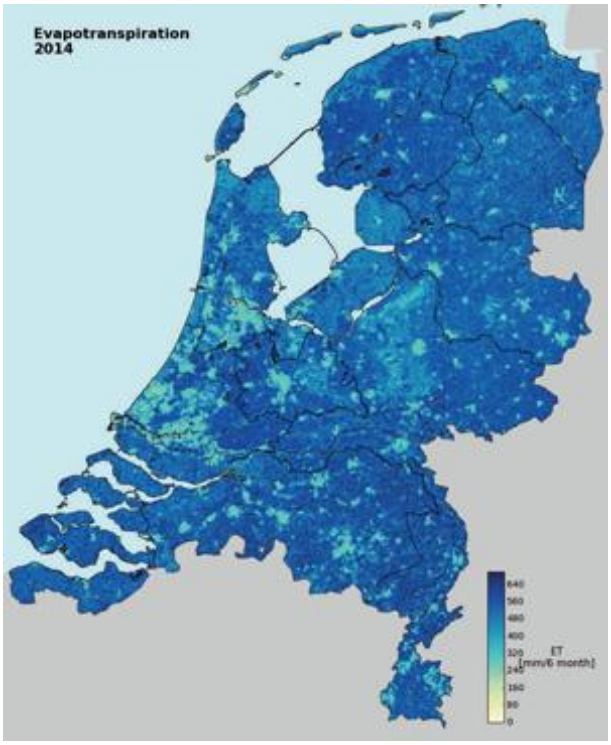

Figure 1. Actual evapotranspiration (in mm) for the Netherlands at 250 m resolution.Source: Graveland et al., 2016 [4]

6. Monitoring the amount of carbon

In the SEEA EEA, the scope of carbon accounting includes the measurement of carbon stocks and flows for all parts of the carbon cycle and carbon pools. Measuring carbon stocks and flows can support discussions on many policy issues, including analysis of greenhouse gas emissions, energy use, and deforestation rates. Thus, carbon accounting supports the measurement of several indicators, including indicator 15.3.1, which identifies carbon stocks as one aspect of land degradation. Carbon calculations can be made using existing land cover maps, as well as directly using EA data using Normalized Difference Vegetation Index (NDVI) or other methods. [3]

Recent methodological developments in the field of remote sensing methods make it possible to measure carbon stocks, as well as changes in carbon stocks, directly with sufficient accuracy (see Figure 2). Such approaches can be important when alternative sources of ground truth data are scarce. [3]

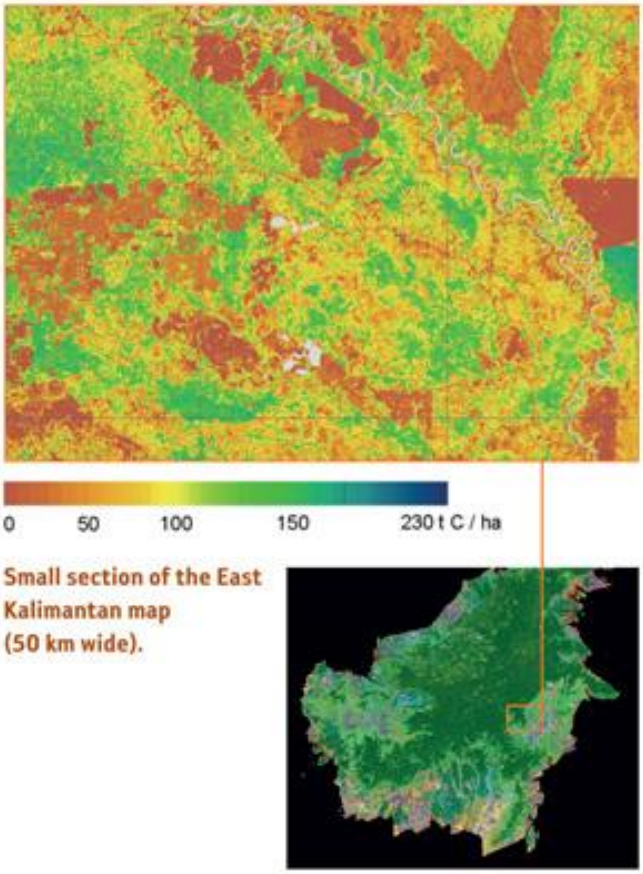

Figure 2. Biomass and carbon monitoring using EO data. Source: http://eohandbook.com/sdg/part2_3.html [5]

7. Use of methods of remote sensing of the earth and water surface

One of the approaches to environmental monitoring is remote sensing of the Earth (RSE). The application of the RSE allows obtaining information about the state of the environment and its components at the international, regional and local levels. Data obtained with the help of RSE can be combined with data from ground-based observation methods, as well as with a modeling method, which allows comprehensively determining the state of the environment, forecasting it, and tracking changes in dynamics. Among the best examples of international observation and decision-making systems using remote sensing of the Earth is the European Union's Copernicus program, which provides all parties (countries) with timely and accurate geospatial information obtained from satellites of the RSE and other sources, necessary for effective elimination of the consequences of natural disasters. man-made emergencies and humanitarian crises. The Copernicus program was created in 2011, and the program began to function fully in 2014. The space part of the Copernicus information system is served by a set of dedicated Sentinel family satellites and support missions (operational commercial and public satellites). Sentinel satellites are specifically designed to meet the needs of Copernicus services

and their users. Since the launch of Sentinel-1A in 2014, the European Union has launched a program to put a family of nearly 20 satellites into orbit by 2030. [6]

This program offers information services on Earth observation satellite data and local data (not from space). The program is coordinated and managed by the European Commission. Copernicus is implemented in partnership with EU Member States, the European Space Agency (ESA), the European Organization for the Exploitation of Meteorological Satellites (EUMETSAT), the European Center for Medium-Range Weather Forecasts (ECMWF), EU agencies, Mercator Océan and countries with which international agreements have been signed . In the light of the dissemination policy of the Data Access Program, Copernicus is of increased interest, so in this context the EU is looking for opportunities to share data for the benefit of the Copernicus Program. Thus, the fastest way to access the Copernicus program data in the part of the data that requires authentication to access is the offer to exchange data of local observations from Ukraine. On May 25, 2018, the State Space Agency of Ukraine and the European Commission signed an Agreement on cooperation in the field of data access and data use of Sentinel satellites of the Copernicus program. In exchange for this, the SSA of Ukraine provides free open access to the data of its own satellites for use in the Copernicus program. Information services are provided free of charge and there is open access to authorized users of the Copernicus Program. This applies only to data with low and medium spatial resolution. [6]

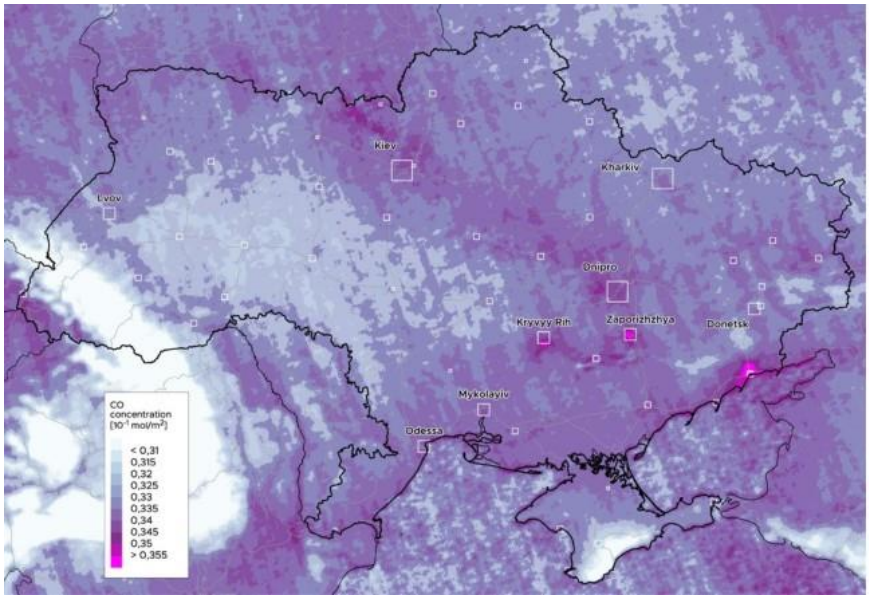

Figure 3. Average CO concentrations on the territory of Ukraine in the period from May 2018 to April 2020. Source: Bochkova, Simona, et al. "Air pollution in Ukraine from space." (2020).[7]

The processing of information flows in Copernicus is presented in Figure 3. Depending on the level of access, the user has the opportunity to work both with raw data of direct observations and to use the results of processing and predictive

calculations in a form that is convenient for perception. Detailed user instructions are provided for working with raw direct observation data streams, detailing the data structure and format. [6]

Copernicus also collects information from insitu systems (local data), such as ground stations that deliver data obtained by many sensors on the ground, at sea or in the air. As a result, not only data from satellite observations, but also data from local terrestrial, atmospheric, and marine measurement systems are used to model processes in the atmosphere, oceans, and on the earth's surface. The main purpose of local observation data is to refine satellite observation data and for periodic calibration of satellite observation systems. As a result of processing observation and modeling data, various current and forecast thematic maps are created, features and anomalies are revealed, and statistical data can be reviewed and clarified. [6]

Processing of information flows in Copernicus.

The data system in Copernicus includes satellite data, UAV data, and local data. [6].

The information received by the system is optimized through six thematic streams of Copernicus services: [6]

1. Atmospheric Monitoring Service (CAMS).
2. Marine Environment Monitoring Service (CMEMS).
3. Land Monitoring Service (CLMS).
4. Climate Change Service (C3S).
5. Copernicus Security Service.
6. Copernicus EMS emergency service.

Figure 4. Physical map of Ukraine. Source: Bochkova, Simona, et al. "Air pollution in Ukraine from space." (2020). [7]

For example, the final processed monitoring data on the composition of the atmosphere, obtained on the basis of Sentinel-5P (Precursor) satellite data for Kyiv, are shown in Figure 4, which shows the concentrations of ozone and nitrogen dioxide in μg/m^3, while the primary raw data of the satellite observations are measured radiation spectra in the wavelength range from 270 nm to 2385 nm. That is, the concentration values are calculated on the basis of data on the absorption of electromagnetic radiation when passing through the atmosphere. [6]

8. Air pollution - a view from space

The Sentinel-5P (S5P) mission is an atmospheric monitoring satellite launched into Earth orbit in October 2017 as part of the EU Copernicus program. This satellite carries the TROPOMI (TROPOspheric Monitoring Instrument) spectrometer with selective coverage of wavelengths between the ultraviolet and short-wave infrared ranges. SP5 daily carries out remote measurement of such gases as NO_2, O_3, HCOH, SO_2, CH_4, CO and PM aerosols with a spatial resolution of about 5.5 km x 3.5 km (from 7 km to 5.5 km until August 2019). [7]

Data from the Sentinel-5P satellite are uploaded through the Sentinel Hub (SH), managed by Sinergise. Sentinel Hub supports Sentinel-5P level data packets

2 (L2), which are geolocated, are mostly pre-processed and contain the label "qa_value". The label "qa_value" stands for "quality assurance value" and indicates the state and quality of each ground pixel. It is a continuous variable ranging from 0 (error) to 1 (no errors). For most Sentinel-5P data packets, pixels smaller than 0.5 are filtered out (for NO_2 it is 0.75). The “qa_value” is an important parameter that limits the continuous coverage of the desired areas by S5P data, and the proposed methodology takes it into account. Data packages for NO_2, SO_2, HCHO and CO (May 2018 to April 2020) downloaded via SH. [7]

SP5 satellite data packages are mostly calculated and provided in special units of measurement - moles per square meter (mol/m^2). [7]

Data packages are provided on the general atmospheric scale of NO_2 between the Earth's surface and the upper boundary of the troposphere (tropospheric column). TROPOMI observations of CO are provided on a total CO scale with sensitivity to the outermost layer of the troposphere. Observations of HCHO and SO_2 are given on a common scale between the Earth's surface and the tropopause. [7]

Due to several detected satellite images with errors, instead of average values for SO_2 observations were used average concentartions. [7]

When using SP5 satellite data, it is important to consider the difference in the way the values are measured. Maximum allowable concentrations of pollutants are usually given in units used for ground-based measuring devices (μg/m^3). Therefore,

the conversion of values from satellite images (mol/m^2) into terrestrial units of measurement (μg/m^3) is not recommended. [7]

Quality indicators and monitoring frequency.

It is important to consider that the quality of available pixels strongly depends on weather conditions (including cloudiness), spectrometer sensor errors, and other parameters. In general, this is usually defined at the "qa_value" level. The frequency of viewing S5P for Europe (including the territory of Ukraine) is more than once a day. At higher latitudes, scan overlaps are observed due to the near-polar, sun-synchronous orbit of the satellite. Thus, the processed data includes all available satellite measurements. Using all available data means combining data from multiple satellite orbits with different grid sizes and orientations. To address this issue, all S5P satellite observations were downscaled to obtain a regular 1x1 km grid across the SH. Data were pre-processed automatically and uploaded to the cloud using custom Python scripts using the SH service. The final stages of processing are performed on GIS screens with the calculation of average monthly and sample seasonal average values per pixel over the entire area. Season was defined as a 3-month winter (December–February) and summer (June–August) period to simplify weather-driven air quality data. For each individual pollutant, the overall average value per pixel for the entire specified period is additionally calculated. [7]

Copernicus Atmospheric Monitoring Service (CAMS)

Since Sentinel-5P does not monitor particulate matter concentrations (PM2.5 and PM10), data on their content are obtained through the Copernicus Atmospheric Monitoring Service (CAMS). [7]

CAMS is part of the Copernicus program implemented by the European Center for Medium-Range Weather Forecasts (ECMWF). CAMS provides global, quality-controlled information related to air pollution, solar energy. [7]

In Europe, CAMS performs daily specialized air quality analysis and forecasting at a spatial resolution of 0.1 × 0.1 degrees (approximately 10 × 10 km). In the monitoring process, nine European air quality forecasting systems are used, forming the median distribution of individual results. In addition, the analysis combines model data with real ground observations provided by the EEA into a complete and consistent set. [7]

9. Sentinel Copernicus satellites

Sentinel-1. The Sentinel-1 mission consists of two sun-synchronous, polar-orbiting satellites in the same orbital plane with a 180° orbital phase difference, operating day and night, performing C-band synthetic aperture radar imaging that allows them to acquire images regardless of weather . The satellite works in four exclusive shooting modes with different resolutions (up to 5 m) and coverage (up to

400 km). It provides dual polarization, very short replay time and fast image transmission. Accurate position measurements are available for each observation. [8]

Figure 5. Sentinel-1. Source: https://www.esa.int/

Sentinel-1 operates in a pre-programmed mode of operation to avoid conflicts and create a consistent long-term data archive designed for long time series applications. [8]

Sentinel-1 is the first of five missions developed by ESA for the Copernicus initiative. Its measurement capabilities include landscape topography, multi-purpose imagery (land and ocean), ocean surface winds, ocean topography/currents, ocean wave height and spectrum, sea ice cover, snow cover, soil moisture, and vegetation. [8]

The main goals and applications of Sentinel-1: [8]

- Global Land Monitoring
- Sea ice monitoring
- Monitoring land and ice
- Ocean and sea monitoring
- Marine surveillance
- Responding to emergency situations

Chronology of launch [8]

Sentinel-1A was launched on April 3, 2014.

Sentinel-1B was launched on April 25, 2016. The spacecraft suffered a power failure related to the instrument electronics supplied by the satellite platform, preventing it from providing radar data from 23 December 2021, and as a result ESA and EC announced the end of the Sentinel-1B mission on 3 August in 2022.

Sentinel-1C is scheduled for launch in early 2024.

Orbit [8]

Sentinel-1 is in a near-polar sun-synchronous orbit with a 12-day cycle and 175 revolutions per cycle for one satellite. Both Sentinel-1A and Sentinel-1B have the

same orbital plane with an orbital phase difference of 180°. When both satellites are operational, the repeat cycle is six days.

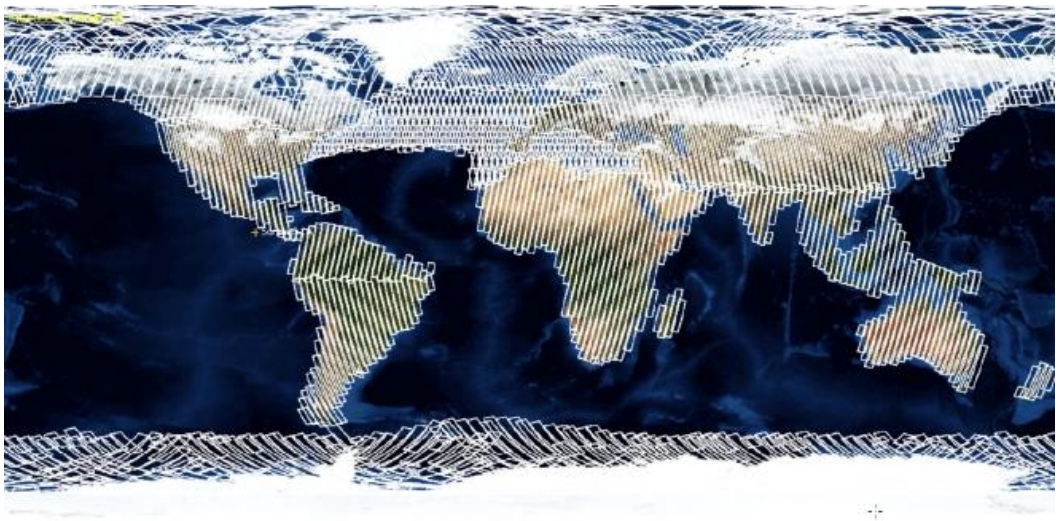

Figure 6. Potential global coverage of Sentinel-1. [8]

During normal operation, the reference orbit will be maintained within a 120 m diameter (RMS) orbit tube anchored around the Earth.

Geophysical measurements

The active C-band SAR sensor Copernicus Sentinel-1 can observe the Earth's surface at any time of the day or night, regardless of weather and environmental conditions. SAR has the advantage of operating at wavelengths that are not affected by cloud cover or lack of illumination. [8]

Unlike passive optical sensors that require sunlight, an active SAR instrument transmits its own microwave signal to illuminate the Earth's surface at an angle. SAR actively transmits microwave signals to Earth and receives some of the transmitted energy as backscattering from the ground. The backscattering echo of the scene is received by the antenna of the instrument after some time in a slightly different place, when the satellite moves in its orbit. The brightness amplitude of the returned signal, along with its phase information, is recorded to create an image. [8]

Sentinel-2. Sentinel-2 is a European wide-area high-resolution, multispectral imaging mission. The full mission specification of twin satellites flying in the same orbit but with 180° phase is designed to provide a high equatorial revisit frequency of 5 days. [8]

Sentinel-2 carries an optical instrument payload that captures 13 spectral bands: four bands at 10 m, six bands at 20 m, and three bands at 60 m. The width of the orbital band is 290 km. [8] The Sentinel-2 mission consists of two identical satellites, Sentinel-2A and Sentinel-2B, which were launched using the European launch vehicle VEGA. Each of these satellites weighs approximately 1.2 tons. [8]

Figure 7. Sentinel-2. Source: https://www.esa.int/

Sentinel-3. Sentinel-3 is a European Earth observation satellite mission designed for ocean, land, atmospheric, emergency monitoring, security and Copernicus cryosphere programs. [8]

Figure 8. Sentinel-3. Source: https://www.esa.int/

It is jointly operated by ESA and EUMETSAT to provide operational ocean and land observation services. [8]

The main objective is to measure sea surface topography, sea surface and land temperature, and ocean and land surface color with high accuracy and reliability to support the ocean forecasting system, environmental monitoring and climate monitoring. Sentinel-3 also provides observations of vegetation, fires, inland waters (the height of the water surface in rivers and lakes), the cryosphere (e.g. the thickness of land ice and sea ice), and the atmosphere. [8]

Sentinel-5P. The Copernicus Sentinel-5 Precursor mission is the first Copernicus mission dedicated to monitoring our atmosphere. Copernicus Sentinel-5P is the result of a close collaboration between ESA , the European Commission, the Netherlands Space Office, industry, data users and scientists. [8]

Figure 9. Sentinel-5. Source: https://www.esa.int/

The mission consists of one satellite with the TROPOspheric Monitoring Instrument (TROPOMI). The TROPOMI instrument was jointly funded by ESA and the Netherlands. [8]

The main objectiveof the Copernicus Sentinel-5P mission is to conduct atmospheric measurements with high spatio-temporal resolution, which will be used to determine air quality, the ozone layer and UV radiation, as well as climate monitoring and forecasting. [8]

The satellite was successfully launched on October 13, 2017. [8]

The satellite's local ascension crossing time of 13:30 was chosen to facilitate a so-called free-to-share operation with NASA's Suomi-NPP spacecraft. This concept will allow the use of cloud technology data. [8]

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Lecture 9. Climatic and environmental consequences of Russia's war against Ukraine.

Plan.

1. The impact of the Russian war in Ukraine on the climate.
2. Environmental and economic damage from Russia's military aggression for the world and Ukraine.
3. Assessment of damage from military impact on the environment.
4. The main sources of pollutants entering the environment during hostilities.
5. The impact of hostilities on certain components of Ukraine's environment.

The global climate crisis has clearly shown how interconnected we all are – human health depends on the health of the environment. What happens in one country affects the environment everywhere.

The often mentioned global triple threat – rising pollution, climate stress and biodiversity loss – is tragically happening in Ukraine: hostilities, and especially the manner ofRussian attacks, are having a devastating impact in all three areas.

1. The impact of the Russian war in Ukraine on the climate

Russia's invasion of Ukraine became a human tragedy with countless loss of life and health, millions of displaced persons, causing a humanitarian crisis. The war damaged and destroyed civilian infrastructure and other important public facilities, businesses and roads, deprived citizens of the necessary resources - water, electricity and medical care.

Russian armed aggression against Ukraine causes significant damage not only to the economy and cultural heritage, but also to the environment of our country. It destroyed natural ecosystems and polluted the environment. Numerous cases of purposeful destruction of natural resources and infrastructural objects have features of ecocide against Ukrainian people.

In addition to the pollution of environmental objects, the direct impact of war includes significant emissions (GHG).

As the world struggles to significantly reduce greenhouse gas (GHG) emissions to limit the rise in global average temperatures to 1.5°C, additional emissions of carbon dioxide and other GHGs from war are further complicating global efforts to stop the climate crisis.

According to the latest report of the IGGAW War Greenhouse Gas Accounting Initiative (created with the support of a research group of experts by the European Climate Fund (ECF) and the "Environmental Policy and Advocacy Initiative in Ukraine" (EPAIU)), over the past 2 years the damage caused to the world climate, estimated at 32 billion US dollars. The report was published on June 13, 2024 by the

Ministry of Environmental Protection and Natural Resources of Ukraine in cooperation with climate protection groups.

Russia's war in Ukraine in 24 months caused emissions of approximately 175 million tons of carbon dioxide CO_2 or so-called "conflict carbon". For the convenience of calculations, all greenhouse gases (GHG) are converted into the so-called "CO_2 equivalent", so often all greenhouse gases are simply called "carbon".

175 million tons of CO_2 is more than the annual GHG emissions of a highly industrialized country like the Netherlands, or the emissions from putting 90 million new gasoline cars on the road or building 260 coal-fired power units with a capacity of 200 MW each (figure 1).

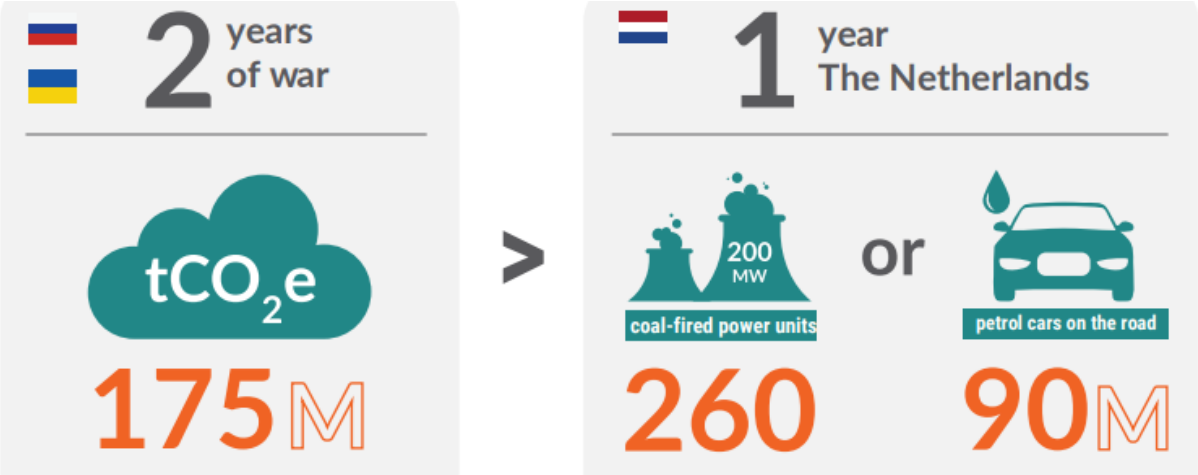

Figure 1. Infographic of equivalents of 175 million tons of CO_2 emissions

As the war continues, GHG emissions continue to rise. Today, after two years of war, the largest share of emissions are caused by fighting, wildfires and damage to energy infrastructure.

The main sources of emissions identified in the report include:

1) military operations: the largest share of emissions, approximately 51.6 million tons of CO_2, is accounted for by operation and supply (burning of fuel) and production of military equipment and weapons, construction of fortifications;

2) energy infrastructure: targeted attacks on energy facilities have contributed significantly to the release of an estimated 17.2 million tons of CO_2 from the destruction of oil depots, refineries, and uncontrolled releases of greenhouse gases, particularly SF_6 from electrical equipment, which is the most powerful GHG; damage to the Nord Stream 1 and Nord Stream 2 gas pipelines led to a week-long underwater methane eruption, another powerful GHG, with an impact on the climate equivalent to 14 million tons of CO_2;

3) landscape fires: military strikes caused large-scale forest fires, which added 22.9 million tons of CO_2 to the total emissions; satellite images provided information on 27,000 fires on an area of almost 1 million hectares;

4) aviation diversions: commercial aircraft rerouted due to restrictions and security concerns affecting 18 million km^2 of sky over Russia and Ukraine; rerouting between Europe and Asia led to additional fuel use, increasing emissions by an additional 24 million tons of CO_2;

5) reconstruction: the post-war reconstruction of damaged and destroyed civilian infrastructure is expected to be a significant source of emissions, as the reconstruction of buildings and other infrastructure is very carbon-intensive due to the use of large volumes of concrete and steel, potentially leading to an increase of 56.0 million tons of CO_2;

6) displacement of almost 7 million Ukrainians and Russians; total emissions associated with refugees and IDPs amount to 3.27 million tons of CO_2.

The Association of Carbon Accounting Experts, funded by Western governments and foundations IGGAW, is developing new techniques to measure "conflict carbon". Using the latest methodology, the researchers determined the cost of each ton of carbon emissions. A recent study published in the journal Nature concludes that a desirable average social value of $185 US per ton of CO_2 emitted is the best available estimate at this time.

IGGAW's assessment of emissions from Russia's war in Ukraine relies heavily on satellite data, government information, open-source research and intelligence, expert interviews, and industry reports, among other information. Data on carbon emissions during conflict are often lacking. Obstacles to assessing "conflict carbon" are incomplete data availability, wartime secrecy, and physical danger for experts.

The report emphasizes the need to hold the Russian Federation accountable for these environmental and climate damages, and recommends using the social cost of carbon to quantify the monetary value of emissions. It also calls for international cooperation to address these impacts, which is critical to achieving global emission reduction targets under the Paris Agreement.

The Ukrainian government welcomed the report, saying it would be an important component of the reparations case against Russia.

In 2022, the UN General Assembly resolution called on Russia to compensate Ukraine for the war, and the Council of Europe created a damage register. The Climate Emissions Report should become part of this register.

The leading expert of IGGAW and the author of the report, author Leonard de Klerk, said at the presentation of the report that Russia is harming both Ukraine and the climate – a significant amount of "conflict carbon" will be felt throughout the world. The Russian Federation should be forced to pay for this the debt it owes to Ukraine and the countries of the Global South that will suffer the most from climate damage. This will cost Russia almost 30 billion euros in reparations today.

Ukraine now needs effective mechanisms for collecting compensation from the

aggressor for crimes against the environment. One of such mechanisms can be the criminalization of ecocide in national and international law. However, other mechanisms for collecting compensation from the aggressor should not be neglected.

2. Environmental and economic damage from Russian aggression for Ukraine and the world

War is not only a human tragedy. It is also always the death of nature – an ecological disaster. As of October 2023, Russia has committed more than 2,500 environmental crimes in Ukraine.

Since the beginning of the war in Donbas in 2014, almost 40% of ecologically valuable territories of Ukraine have been occupied, most of them since February 2022. As of the end of 2023, according to experts, about 10% of the territory of Ukraine has suffered moderate or very significant damage. The Russian army commits ecocide and deliberately damages the environment, often irreparably. One of these crimes was the blowing up of the Kakhovska HPP in the summer of 2023.

Environmental damage from military aggression of the Russian Federation:

- dangerous chemical emissions and pollution from damaged industrial facilities;
- impact on air quality due to destruction of cities and settlements and burning of forests;
- economic and ecological consequences of damage to agricultural areas, forests and nature reserves;
- water pollution and destruction of water infrastructure;
- pollution of sensitive ecosystems, in particular, in coastal and marine areas.

The Ministry of Environmental Protection and Natural Resources of Ukraine collects data on environmental threats caused by the occupiers of the Russian Federation, develops a plan for their further elimination and works on the restoration of ecological objects after the occupation. On the official resource of the Ministry of Environmental Protection and Natural Resources of Ukraine "EkoZagroza" https://ecozagroza.gov.ua/ damage calculations are made by the State Environmental Inspection (SEI) in accordance with approved methods, and statistics of recorded cases of burning of oil products, forest fires, ignition of other objects, soil pollution, littering of land, violations of objects of the nature reserve fund, etc. and are made public in real time, with geographic reference to the area.

As of September 2024, losses incurred:

- atmospheric air for 730.43 billion UAH,
- land resources for 1.15 trillion. UAH
- water resources for 84.65 billion UAH.

The information posted on the official pages of the State Environmental

Inspection of Ukraine and the Ministry of Environmental Protection and Natural Resources of Ukraine in social networks, where the latest news is quickly covered, makes it possible to support the activity of citizens of Ukraine, as well as citizens of other countries, in this information field.

Environmental risks and damages also extend beyond Ukraine, so that the world at large is directly affected by this war.

The war increased greenhouse gas emissions, diverting attention from critical climate goals in Europe and elsewhere. Ukraine's neighbors suffer from air pollution due to war, those bordering the Black Sea struggle with mining and damage to marine wildlife. The threat of a nuclear catastrophe should attract special attention, therefore it is necessary to urgently stop targeted shelling and military occupation of nuclear power plants.

Russian aggressors are destroying Ukrainian lands, including the unique black soils. They not only commit a crime against the environment, but also create a global problem: the risks of a food and environmental crisis and the impossibility of guaranteeing food security for humanity in the future are increasing. Food availability and prices have been affected throughout the developing world.

It is worth noting that the consequences of the war will affect not only Ukraine. It is obvious that the biggest war in Europe since the Second World War has already become the cause of global militarization. For example, total global military spending reached $2.4 trillion (€2.2 trillion) in 2023, an increase of 6.8 percent in real terms from 2022. This is the sharpest annual increase since 2009, taking into account factors such as the production of military equipment and the long-distance delivery of heavy weapons, which contribute to carbon emissions.

Further, these trends will only intensify. This means an additional environmental burden on the entire planet and a reduction in the priority of environmental goals for a significant number of countries – a serious challenge for all humanity in the conditions of the existing climate and a number of other global problems for the biosphere.

3. Legal support for damage determination and damage assessment from military impact on the environment

International investigations into human rights in Ukraine must consider the environmental consequences of the war as a matter of human rights. This includes the Independent International Commission of Inquiry into the situation in Ukraine, established by the UN Human Rights Council; The UN Human Rights Monitoring Mission in Ukraine. They should, in particular, consider attacks on environmental objects, which are a violation of international humanitarian law, as well as a violation of the human right to a clean, healthy and sustainable environment, which was clearly

defined by the UN Human Rights Council.

Ukraine has recognized the jurisdiction of the International Criminal Court (ICC) and closely cooperates with the Prosecutor of the ICC. Thus, the ICC has the right to investigate and prosecute actions committed in Ukraine by persons of any nationality, starting from November 2013. Responsibility for the massive destruction of the environment caused by Russian troops must come.

According to Article 50 of the Constitution of Ukraine, everyone has the right to an environment safe for life and health and to compensation for damage caused by violation of this right. Ukraine has taken significant steps to ensure justice for military environmental crimes. A database of evidence is being collected, which will be properly verified, in particular, the indiscriminate use of explosive devices will be among the charges brought against Russia in international tribunals . These data will form the basis of indictments, which will be sent to the International Criminal Court and to the Register of Damages Caused by the Russian Federation's Aggression Against Ukraine, which was created in The Hague in the form of an international organization.

From the very beginning of the large-scale invasion, Ukraine began to record the damage caused by the aggressor.

In order to create a unified system of control over threats resulting from armed aggression of the Russian Federation against Ukraine, in accordance with the Law of Ukraine "On the Legal Regime of Martial Law", Resolution of the President of Ukraine dated February 24, 2022 No. 64/2022 "On the Introduction of Martial Law in Ukraine", Law of Ukraine "On Environmental Protection", Regulations on the State Environmental Inspection of Ukraine, on the basis of the order of the State Environmental Inspection of Ukraine dated 01.03.2022 No.73, the Operational Headquarters was organized on the basis of the SEI of Ukraine. The tasks of the headquarters are: recording, calculation and systematization of damages caused to the surrounding natural environment as a result of emergency situations or dangerous events (incidents) caused by the military actions of the aggressor state.

At the Operational Headquarters, a working group was created for the development of methodological documents and the procedure for determining damage and calculating damages caused to natural resources and the surrounding natural environment as a result of the armed aggression of the Russian Federation, which includes the following subgroups:

- international legislation and practice;
- registration of cases, formation of evidence base;
- atmospheric air;
- soil, land, waste;
- water area of seas;

- surface water;
- subsoil, incl. underground water;
- forest resources;
- nature-reserve fund, bio resources;
- radiation

The Working Group included more than 60 experts of various profiles.

In particular, in order to comprehensively respond to offenses in this area, to ensure within the competence of the prosecutor's office the constitutional right to a safe environment, the Specialized Environmental Prosecutor's Office was established within the structure of the Prosecutor General's Office - an independent structural unit of the Prosecutor General's Office . This structure was created to investigate and prosecute environmental war crimes and use numerous international channels to bring Russian aggressors to justice. The specialized environmental prosecutor's office involves specialists from various scientific institutions and institutions of forensic expertise.

There are already many important new initiatives to achieve this justice, and there is scope for more. In particular, in June 2023, the leadership of Ukraine created a high-level working group on the environmental consequences of war. It was composed of Ukrainian and international members, who were tasked with carefully examining the damage caused by the war to the environment, assessing how justice can be strengthened, and recommending steps toward "green" reconstruction and recovery. As a result, a very important document was developed - the Environmental Agreement.

It is necessary to carefully record and calculate the environmental damage caused by Russian armed aggression. This is a base for receiving reparations for the environment destroyed by the aggressor and another step on the way to the EU.

At the state level, the State Environmental Inspection of Ukraine (SEI) deals with this. In order to record information on environmental damage as a result of Russia's military aggression, the territorial and interregional territorial bodies of the State Environmental Inspection are involved by law enforcement agencies in conducting investigative actions in criminal proceedings and carrying out environmental sampling and subsequent relevant instrumental and laboratory measurements. For most of the incidents that occurred as a result of Russia's armed aggression on the territory of Ukraine, criminal proceedings have been opened and a pre-trial investigation is being carried out by the prosecutor's office.

The SEI of Ukraine calculates the amount of damage, losses and losses caused to the surrounding natural environment and natural resources of the state on issues that belong to its competence, as a result of accidents, emergency situations, military aggression, military, terrorist or other criminal acts, including from the beginning of

the legal regime of martial law.

Accurate and reliable collection and preservation of evidence is critical to supporting both criminal prosecutions and claims for damages. There is no single established international standard for collecting data on the state of the environment in wartime, but there are general methodological standards that indicate best practices. To ensure full reparation for environmental damage caused by war, it is important that data will be collected and stored in a scientifically and legally sound manner. The collected data must be of high quality, and the methodologies of selection, processing and storage must meet international standards.

In early 2022, the government developed a monetary damage assessment methodology, an approach that is useful for reporting massive losses and for overall planning of resources needed for recovery.

As of the beginning of 2024, the government estimates that the damage caused by the war to the environment is about 56 billion euros.

Currently, a number of methods approved by the Ministry of Environmental Protection and Natural Resources of Ukraine and Resolution of the Cabinet of Ministers of Ukraine of March 20, 2022 No.326 "On approval of the Procedure for determining damage and losses caused to Ukraine as a result of the armed aggression of the Russian Federation" are in force in Ukraine.According to which damages and losses to the surrounding natural environment are calculated. In the Procedure, the areas by which damage and losses are determined are highlighted:

- the negative impact on land resources, as a habitat for geobionts, is calculated in accordance with the methods of determining the extent of damage caused by pollution and clogging of land resources, land damage, violation of the regime, regulations and rules of their use;
- the impact on water resources as a habitat for hydrobionts is calculated in accordance with the methodology for calculating the amount of compensation for damages caused to the state as a result of violating the legislation on the protection and rational use of water resources, the methodology for calculating the amount of damages from oil pollution, the procedure for calculating the amount of compensation and payment of damages caused as a result of pollution from vessels, ships and other floating means of territorial and internal sea waters of Ukraine; separately approved fees for calculating the amount of compensation for damage caused as a result of illegal extraction (harvesting) or destruction of valuable species of aquatic biological resources;
- regarding the objects of the plant world - fees for calculating the amount of damage caused to the forest were approved;
- regarding the territories and objects of the nature reserve fund – fees for calculating the amount of damage caused by the violation of the legislation on the

nature reserve fund were approved;

- natural ecosystems, including the territories and objects of the nature reserve fund, were under intense man-made influence even before the full-scale invasion (and the natural territories of the Donetsk and Luhansk regions until 2014). As a result of hostilities, not only territories where active hostilities are being or were being waged suffer, but also territories that are subjected to regular rocket attacks or other types of impacts.

The procedure for assessing the ecological consequences of military influence on the environment is a complex, lengthy and expensive process. It contains a primary description of the objects of observation; primary toxicological tests or rapid analysis. The laboratory initially conducts screening studies to identify the component composition of unknown substances. Chromatography with tandem mass spectrometry (GC-MS/MS, HPLC-MS/MS), infrared spectroscopy (FTIR), IRS, nuclear magnetic resonance spectroscopy (NMR), atomic adsorption analysis (AAS), etc. are used to detect chemicals. .

After screening, targeted studies are conducted to determine the quantitative content of identified hazardous substances. At the same time, ecological and toxicological studies are carried out using the methods of bioindication and biosensory analysis, which makes it possible to determine the integral pollution of the ecosystem and assess the impact of the habitat on living biological organisms.

Next – data examination, standardization of test results, formation of a protocol and an expert opinion. The conclusion is sent to institutions that conduct forensic examinations.

The cost of research, in particular, of one soil sample for environmental damage research from the Russian Federation is an average of one thousand dollars. This includes the determination of toxic elements, heavy metals, pesticide residues, polychlorinated biphenyls and polyaromatic hydrocarbons and a complex of physical and chemical indicators of soil quality.

Assessment and calculation of the final damage caused to the environment in general and its individual components, including biodiversity, as a result of Russian aggression, is a large-scale task and is fully possible after the end of hostilities. A comprehensive assessment will require monitoring studies, including studies of the dynamics of populations of living organisms.

Dealing with wartime damage requires close coordination between these various structures and possibly the creation of new structures as well as the development of new skills and capacities. Ukraine should continue to build its data collection and evaluation system, as well as improve coordination at the government level and with independent organizations.

In particular, SEI should be reformed according to the European model. The

European Commission notes this in its recommendations to Ukraine, and there is a clear understanding of this at the state level. In recent years, the foundation for the development of a new format environmental control system has been laid. The reform of the State Environmental Inspection of Ukraine is among the TOP-5 environmental priorities in 2024.

4. The main sources of pollutants entering the environment during hostilities

During the war, due to the impact of hostilities on the environment, there are significant disruptions of ecosystems. Russia's invasion of Ukraine took place along the entire length of the common border and partly from the territory of Belarus. In fact, the hostilities covered all climatic zones of Ukraine, so as a result, hundreds of hectares of various and rare biogeocenoses were destroyed. It will be possible to assess the real scale of ecosystem losses only after the complete deoccupation of our territories.

One of the most serious long-term consequences is the chemical contamination of places of mass use of ammunition.

Man-made disasters also cause significant damage to the environment as a result of bombing and shelling of enterprises and critical infrastructure facilities of our country. Moreover, Russia's use of long-range missiles creates man-made disasters throughout the territory of Ukraine, especially in industrially developed regions where energy, mining, processing, chemical and other industries are concentrated.

In addition, Ukraine is a large agricultural country and a significant part of our economy is the production and export of agricultural products. Ukraine belongs to the countries with high arable land. Agricultural lands occupy 70.5% of the total area of the country, of which 57% is arable land (up to 86% in some regions). As a result of hostilities, we have significant mechanical damage to fields and long-term chemical and biological contamination of fertile soils. Thousands of fired shells, detonated and burned military equipment abandoned in fields and gardens are a significant and long-lasting source of contamination of our soils and groundwater with iron, aluminum, copper, other heavy metals and their compounds for hundreds of years.

Ukraine belongs to the countries with insufficient supply of water resources (surface and underground water suitable for use in the national economy of Ukraine), it is one of the countries with the least water supply in Europe. Flooded military equipment and munitions, leaching into ground water and getting into surface water of harmful substances that are formed as a result of munition explosions - all this is a factor of negative impact on water resources.

Before considering in detail the impact of hostilities on individual components of ecosystems, such as atmospheric air, water resources, soils, it is worth noting the

main sources of pollutants that have a long-term impact on the environment. First of all, these are ammunitions that are widely used on the battlefield.

4.1. Chemical composition and features of use of some types of ammunition

In modern armor-piercing subcaliber projectiles, the armor-piercing part (core) is most often made of depleted uranium. The use of this metal is related to its physical properties – the ability to self-ignite and burn as a result of contact with armor and its penetration. At the same time, small fragments of the uranium core of the projectile spread and contribute to the burning of combustible materials or the detonation of ammunition inside the target. Almost up to 70% of the entire mass of depleted uranium contained in the projectile burns out and turns into an aerosol of radiotoxic uranium oxides (U_3, O_8, UO_2) with particles from 0.5 to 5 microns during the explosion. A significant amount of dispersion aerosols remains in the air for a long time, gradually settles on the surface and subsequently migrates into the soil and groundwater.

The main danger from depleted uranium occurs when it enters the body in the form of dust particles. Such particles ofdepleted uranium can remain in the lung tissues, especially in the lymph nodes, for up to several years. Since depleted uranium is mainly an alpha emitter (alpha particles are easily intercepted by minor obstacles, even a sheet of plain paper), it is precisely its deposition in body tissues, where there is no protection from alpha radiation, that is dangerous. It should also not be forgotten that uranium is a heavy metal, the accumulation of which in the body can lead to impaired functioning of the kidneys, liver and other organs.

The toxic content of ammunition capsules – devices designed for igniting powder charges in firearms or for detonating charges of explosive substances (for example, grenade fuses) – has a significant impact on the environment. The contents of these capsules are initiating explosives. They are used, most often, as initiators of the detonation of explosive substances (substances capable of crushing and destroying objects in the explosion zone) or for igniting gunpowder and other combustible substances. Initiating explosives are characterized by the ability to detonate from a simple initial impulse (impact, friction, pressure, spark).

Usually, the contents of the capsules are a shock-incendiary mixture of substances. Most often, the components of the shock-ignition mixture are: mercury $Hg(ONC)_2$; antimony Sb_2S_3 (stibium sulfide); Bertolet salt $KClO_3$ (potassium chlorate).

In fuzes for grenades, the detonator capsule with an aluminum body consists of a shock mixture, lead azide ($Pb(N_3)_2$) – 0.2 g and TNRS (trinitro-lead resorcinate $C_6H(NO_2)_3\,O_2\,Pb$ – 0.1 g. Taking into account the molecular weight of the substances, it is possible to calculate that one fuse detonator capsule contains approximately 200

mg of lead.

A significant number of additional stabilizing and initiating substances are also used in ammunition, including tin and its compounds, bismuth and its compounds (bismuth oxide, bismuth carbonate, bismuth nitrate, etc.), strontium nitrate ($Sr(NO_3)_2$), magnesium powder and many others.

By understanding the components and content of ammunition, it is possible to predict the significant emissions of various pollutants that result from their use. The most noticeable pollution, in particular by heavy metals, is predicted in the places where ammunition warehouses are blown up.

4.2. Missile weapons and their use

Among the weapons that are actively used by Russia throughout the territory of Ukraine, there are missiles of various types, in particular, missiles launched by multiple rocket launchers (RSVs), and large long-range cruise missiles (X-22, X-101, X-555, "Kalibr", "Iskander", etc.). Such missiles, in addition to the danger from an explosive-equipped warhead, carry a significant danger from the use of toxic fuel.

Rockets with solid fuel engines and with engines running on liquid fuel are produced. Solid-fuel rockets can be stored for quite a long time, launch quite reliably, but their engines have lower performance than liquid-fueled ones. The anti-aircraft missiles used by Russia in the S300 complexes are a two-stage solid-fuel missile with gas-dynamic control bodies of the first stage.

The difference in the designs of missiles of various modifications is mainly related to the increase in the fuel supply in the first stage, which increases their range or flight speed. Such anti-aircraft missiles are equipped with a high-explosive warhead weighing about 150 kg. Air-to-ground missiles, such as the X-101, are cruise missiles that are launched from tactical bombers and have a turbojet engine on liquid rocket fuel, which provides the ability to fly at an altitude of up to 10 km at a distance of up to 5,500 km. The weight of such a rocket together with a full fuel tank is approximately 3500 kg, its length is 7.45 m. The rocket is equipped with a warhead with an explosive mass of up to 400 kg.

Rockets launched on Ukrainian territory are hundreds and thousands of kilograms of chemical substances, which, when completely burned and when the remains fall into the environment, carry significant pollution and are toxic to all living things. That is why it is dangerous to approach the remains of missiles.

One of the danger factors is the remnants of rocket fuel from downed missiles remaining at the point of fall. Even simple inhalation of liquid rocket fuel vapors can be fatal. Due to its aggregate state, solid fuel is less toxic to the environment, but it is difficult to stop its burning, and it is the products of combustion of such fuel that are dangerous. Combustion or disposal of ballistic rocket fuel used in anti-aircraft

missiles (Uragan, Grad, etc.) is accompanied by the formation of a number of toxic components: CO, HCN, NO, NO_2, etc. Lead in the products of combustion or explosion of solid rocket fuel is present in the form of aerosols of lead and its oxide PbO .

In general, burning or disposal of solid rocket fuel leads to the formation of: CO up to 416.2 g/kg, C up to 86.4 g/kg, Pb up to 6.7 g/kg, PbO up to 1.8 g/kg, NO up to 161.6 g/kg, NO_2 up to 2.9 g/kg, CH_4 up to 55.0 mg/kg, NH_3 up to 0.3 g/kg, HNO_2 up to 0.4 g/kg , HSN up to 5.2 g/kg.

Combustion products of electronics, which are equipped with rockets, are toxic [9]. More complex high-precision anti-aircraft missiles use fuel based on ammonium perchlorate (NH_4ClO_4). In the flame torch, the formed substances continue to interact with each other. The final products of the decomposition of ammonium perchlorate are considered to be: H_2O, N_2O_2, Cl_2, HCl, NO_2, N_2O_3. Additionally, the mixture contains rubber combustion products, metal oxides, rocket electronics combustion products.

4.3. Ammunition with white phosphorus

Ammunition with white phosphorus is very often used. In military affairs, white phosphorus is used in mortar and artillery shells, aerial bombs and grenades.

The intense emission of smoke during the burning of phosphorus serves as an effective masking, therefore white phosphorus is actively used in smoke grenades.

Active burning of white phosphorus in the air is used to burn out designated targets and manpower. During the burning of white phosphorus, white smoke is formed in the air, which consists mainly of trioxide (P_4O_6) and pentaoxide (P_4O_{10}) of phosphorus. Formed phosphorus oxides are extremely hygroscopic and quickly absorb even minor traces of moisture, forming a number of phosphorus-containing acids, such as orthophosphoric (H_3PO_4), pyrophosphoric ($H_4P_2O_7$), orthophosphoric (H_3PO_3), hypophosphoric (H_3PO_2), polyphosphoric acids of the general formula $H_{n+2}P_n O_{3n+1}$ (where n =2–8) and a number of other linear and cyclic polyphosphates P_6 - P_{16} .

In conditions of insufficient amount of oxygen during the burning of white phosphorus, phosphine (PH_3) can be formed. Due to its gaseous state, low solubility in water and low reactivity, phosphine, which is formed during the burning of white phosphorus, is able to stay in the air longer than other reaction products. Phosphine can also be formed when white phosphorus enters water with a low oxygen content. The phosphine formed in the water quickly enters the air from the water. The breakdown of phosphine in the air into safe substances occurs within one day. Elemental phosphorus can be present in the air for a short time (from minutes to several days) due to rapid oxidation to oxides and acids. But during active

combustion, aerosol particles of phosphorus can become stuck with oxides, "preserving" elemental white phosphorus. Phosphorus, which has entered the soil or water environment, behaves in a similar way. White phosphorus covered with oxides, with low oxygen content in water or soil, can be there for up to several years. During the use of white phosphorus ammunition, approximately 10% of the phosphorus remains, which does not burn completely and settles in the soil or water. A significant amount of aerosols from the burning of phosphorus overcomes the buffering capacity of the soil (the property of the soil to maintain a constant reaction of the soil solution) and strongly disturbs its pH level.

The interaction of metals with phosphoric condensates can lead to their leaching and subsequent migration. Exposure to white phosphorus on plants results in a variety of harmful effects that depend on plant species, smoke concentration, duration of exposure, relative humidity, and wind speed. These effects may include: leaf tip burn, leaf curl, leaf drop, flower drop, chlorosis, necrotic spots, wilting, desiccation, and complete dieback.

4.4 Indirect consequences of the use of ammunition

In addition to contamination by the "cocktail" of chemical compounds contained in ammunition, the consequences of their use also cause enormous damage: the destruction and burning of buildings, enterprises, and critical infrastructure facilities.

Analysis of man-made disasters that occur on the territory of Ukraine as a result of shelling almost every day since the beginning of the Russian invasion shows that the main targets for the Russian Federation are oil depots, power plants, communication infrastructure and large industrial enterprises that ensure the economy and defense capability of our country.

Fires and explosions in such locations are a separate environmental disaster every time. For example, the burning of electrical equipment at enterprises leads to heavy pollution of the environment with polychlorinated biphenyls (PCBs) and dioxins.

Dioxins are formed during thermal exposure to polychlorinated biphenyls (at temperatures below 1000 °C). Polychlorinated dibenzofurans (PCDFs), commonly known as "dioxins" and polychlorinated biphenyls (PCBs), are a group of toxic and persistent chemicals whose effects on human health include skin immunotoxicity, effects on the reproductive system, teratogenicity, adverse effects on the nervous system, and carcinogenicity.

Dioxins, like polychlorinated biphenyls, are very well adsorbed on any materials: their adsorption capacity is enormous. At low air temperatures, these poisonous substances are better adsorbed by suspended impurities, their content in the air is significantly reduced. In water, dioxins and PCBs, due to their hydrophobic

properties, are adsorbed by solid particles and sediment in the sediments of reservoirs. These substances are well transported through food chains (for example, algae – plankton – fish – humans or soil – plants – animals – humans). The half-life of dioxin in the soil is 8-10 years, polychlorinated biphenyls is 5 years, and the period of partial elimination of these substances from the human body is 3-8 years.

In addition, mass emissions of chemicals from damaged chemical plants and storage tanks make a significant contribution to the pollution of ecosystems. As you know, concentrated nitric acid actively evaporates in the air with the formation of nitrogen dioxide. This compound dissolves well in water with the repeated formation of nitric acid, causes acid precipitation and strongly affects living organisms. When inhaling nitric acid vapors, a person feels a sharp pain in the throat, chest, and stomach. There is a dry cough, nausea with discharge of mucus and blood. Mucous membranes are quickly affected, the throat and lungs swell, which leads to the death of a person. Due to good solubility in water, nitric acid vapors quickly enter soils and groundwater, significantly increasing their acidity. This leads to the mass death of biocenoses of individual polluted areas.

Ammonia as a gas causes significant damage to the environment. Ammonia oxidation, for example, contributes to the formation of greenhouse gases and the leaching of nutrients from ecosystems. In addition, high concentrations of ammonia in the aquatic environment can cause death and problems with the development of fish. The negative impact of this component on the environment is related to its alkaline nature. Excessive human contact with ammonia can cause health problems. Ammonia begins to interact with moisture on the surface of the skin, eyes, mouth, mucous surfaces and forms a caustic substance that leads to tissue necrosis. Symptoms such as irritation or burns of the skin, eyes and throat, lung problems that can cause respiratory failure, are serious risks for people in the area of ammonia emission. Each fired projectile carries a whole range of impacts on the safety of the environment and is capable of causing an environmental disaster in case of damage to large industrial enterprises.

5. Impact of hostilities on individual components of Ukraine's environment

5.1. The influence of hostilities on the state of atmospheric air

As of September 2024, the SEI recorded 5,842 facts of environmental destruction as a result of hostilities.

Military actions on the territory of Ukraine, resulting in fires in industrial and infrastructure facilities, the residential sector and natural ecosystems, emissions of volatile compounds as a result of damage to industrial facilities cause large volumes of emissions of greenhouse gases and other pollutants into the atmospheric air .

According to information from the Ministry of Environmental Protection and Natural Resources of Ukraine, according to preliminary estimates, due to the increased consumption of fuel and lubricants by military equipment, almost 4 million tons of CO_2 carbon dioxide entered the atmosphere only in the first 150 days of the full-scale air invasion .

As of September 12, 2024, according to official data published on the resource of the Ministry of Environmental Protection and Natural Resources of Ukraine, emissions of pollutants into the atmospheric air were recorded as a result of:

- burning of petroleum products, oil and gas – 56,693,685 tons;
- forest fires – 55,726,554 tons;
- fire and destruction of other objects – 211,616 tons.

Among the industrial objects exposed to shelling, the following should be noted: thermal power plants, production and storage facilities of enterprises of various industries and various scales of production, etc. Some facts of shelling concern damage to tanks where dangerous volatile substances were stored.

They regularly occur as a result of enemy shelling, which leads to emissions of a large amount of combustion products into the atmosphere. The danger of fires in production and warehouse premises is that products and materials of various origins are often stored in warehouses, under such conditions a chemical "cocktail" can be formed, the total impact of which on the environment is difficult to establish.

As a result of shelling of energy infrastructure facilities, in addition to emissions into the atmosphere, which are associated with direct damage to such enterprises, there are emergency and scheduled power outages for businesses and citizens. Currently, to ensure production processes, the operation of shops, the post office, etc., generators of various capacities that operate on the basis of gasoline and diesel fuel are widely used.

For heating homes in the private sector, the use of wood and pellets in solid fuel boilers, which are sources of combustion products in atmospheric air, has increased.

Fires in natural ecosystems caused by shelling can have significant consequences due to the fact that they cannot be eliminated for a long time and, often, their extinguishing is accompanied by additional danger for firefighters due to combat operations. Although it is currently difficult to estimate the actual volumes of emissions into the atmospheric air and their structure as a result of military actions, it is possible to speak with confidence about the negative direct and indirect impact on the state of the atmosphere caused by Russian aggression.

5.2. Impact of hostilities on the state of water resources of Ukraine

Taking into account the different natural and climatic conditions of the regions of Ukraine, the problem of their water supply is solved at the expense of territorial

and seasonal redistribution of water resources. In providing water-scarce regions with water resources, large state trunk canals of complex purpose play a significant role, which supply about 3 billion m^3 of water every year.

In order to provide the population and economic sectors with the necessary amount of water, 1,103 reservoirs with a total volume of over 55 billion m^3 and about 49,000 ponds, 7 large canals with a total length of 1,021 km, and 10 large-diameter water pipelines were built in Ukraine. low-water regions of Ukraine.

Conducting active hostilities on a large territory of Ukraine is an inevitable factor of significant damage to its water resources, especially in the southern regions, where water supply is naturally low, and in the eastern regions, where there was already a significant load of industry on water resources.

Among the main consequences of hostilities, which cause an ecological disaster for the water resources of Ukraine, three key ones can be distinguished:

- disruption of the operation of sewage treatment facilities that purify city wastewater;
- violation of water supply to the population and enterprises in large cities;
- direct mechanical and chemical pollution of reservoirs and groundwater as a result of hostilities.

According to data from the Ministry of Environmental Protection and Natural Resources of Ukraine, as of April 2024, 744 water infrastructure facilities were destroyed and damaged.

5.3. The impact of hostilities on the natural ecosystems of Ukraine

Ukraine's natural ecosystems have been directly and indirectly affected by hostilities. Taking into account the specificity of the impact, both ecosystems and their individual components (soil, water area, tree stands, etc.) were damaged in various situations.

Ecosystems consist of two interconnected subsystems – a set of organisms (biocenosis) and an abiogenic environment (biotope).

The complete destruction of the ecosystem is the destruction of all its components: the death of plants, animals, microorganisms, the undermining of the fertile soil layer, sometimes the transformation of the micro relief.

Destruction of individual components of the ecosystem is also a serious impact that will most likely lead to degradation or complete transformation of the ecosystem.

The direct impact of projectiles on the territory of natural ecosystems leads to the physical destruction of ecosystems or their individual components, as a result of which the vegetation and animal life in the affected area die. Also, the micro-relief of the area changes, pollutants are introduced, there is a temperature effect due to fires, etc. It is in natural ecosystems that most of the biodiversity is concentrated, including

species that have a protective status.

Plants and animals (invertebrates and vertebrates) living in urban ecosystems are also affected, including residents of parks, squares, green areas that do not have nature conservation status, territories of nature reserves within settlements.

Natural ecosystems and biodiversity as a result of military aggression are subject to the following impacts by type of origin:

- mechanical (debris, solid particles);
- chemical;
- physical (noises, vibrations, etc.).

According to the Ministry of Environmental Protection and Natural Resources of Ukraine, as of April 2024, 850,000 hectares of forests are occupied or in the war zone, 2.5 million hectares of forests have been freed from occupation and need to be restored.

According to the data on the official resource of the Ministry of Environmental Protection and Natural Resources of Ukraine "Ekozagroza", from February 2022 to April 2024, facts were registered that had an impact on the state of natural ecosystems in the nature reserve fund: the destruction of vegetation on an area of 21,051 hectares and 773 hectares of burned forests and other plantations as a result of projectiles hitting and fires in forest areas of forest farms, steppe and reed biogeocenoses, 10,000 hectares of contaminated soils. 21% or 0.9 million ha is the total area of protected areas currently affected by the war.

Land resources, which are the habitat of soil organisms, are subject to mechanical and chemical pollution. As a result of each shelling, in addition to the impact of the projectile itself, land resources are littered with debris from buildings and equipment, components or parts of products and their packaging, spillage of liquid components, including toxic ones. Water bodies are similarly affected, resulting in the death of hydrobionts.

In addition, the environment suffers from the influence of physical factors – noise, vibration, infrasound, ultrasound, electromagnetic radiation, etc.

Taking into account the ecological consequences of the war in Ukraine should become a warning for the future and contribute to the formation of a new global security system for all living things.

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Lecture 10. Cooperation with institutions of civil society in the system of state European monitoring. The role of public monitoring.

Plan.

1. Civil society.
2. Involvement of public organizations in environmental management.
3. Strengthening environmental governance by building the capacity of non-governmental organizations.
4. The role of civil society organizations in facilitating monitoring at the community level.
5. Air quality monitoring and management – public participation in decision-making.
6. The main problems of practical application of citizens' rights.

1. Civil society

Any state directly affects the environment through its activities. Therefore, this activity should be carried out with the involvement of both the government and business, and most importantly representatives of civil society. Only civil society is fully interested in ensuring that all citizens of the state live as well as possible. Civil society is primarily public organizations.

Public organizations should have the determining authority if any decisions that can change the environment need to be made. Therefore, even the smallest local public organization should be able to provide transparent reporting and the ability to manage natural resources, influence the fair distribution of costs and preferences. This is possible only when the practices of natural resource management are based on democratic principles, which primarily consist in the transparency of environmental monitoring.

What is civil society? In the broadest sense, civil society is characterized as a sphere of social life that is public, but excludes government activity [1]. Michael Bretton describes civil society as a social interaction between the household and the state, characterized by community cooperation, voluntary associations, and social networks [2]. The term "civil society" is commonly used to classify individuals, institutions, and organizations that aim to advance or express a common goal through ideas, actions, and demands on governments [3]. Membership in civil society is quite diverse, from individuals to religious and academic institutions and groups that focus on specific issues. The structure may differ depending on the country, for example, civil society may include local and international non-governmental organizations, various charitable and religious organizations, associations, and other social groups. In the field of environmental monitoring, non-governmental organizations are the most prominent actors. [4]

The United Nations Conference on Environment and Development declared the need to consult with non-governmental organizations, take measures to improve existing or, where they do not exist, establish mechanisms and procedures within each agency to draw on the experience and views of non-governmental organizations in the development of policies and programs, implementation and assessment of the environment. (UN, 1994: Chapter 27) [4]

The most famous global non-governmental organizations (NGO) in the field of ecology: [5]

- Greenpeace. An international non-governmental organization with the goal of "ensuring the Earth's ability to nurture life in all its diversity."
- Center for Ecological Research and Environmental Protection of the Earth Institute. Think Tank on Sustainable Development at Columbia University.
- Institute of the Island of Earth. Founded by David R. Brower, it acts as an environmental umbrella organization, empowering individuals and groups to develop initiatives.
- Earthly justice. An environmental organization headquartered in San Francisco that focuses on environmental litigation.
- Environmental Protection Fund. Works on global warming, ecosystem restoration, oceans and human health.
- International fauna and flora. Works to preserve endangered species and ecosystems, taking into account human needs.
- Nature Friends International. Global environmental umbrella organization.

One of the most important roles that NGOs can play in the global environment is to provide timely information on critical issues. Governments often turn to NGOs to fill gaps in research for effective decision-making. Some NGOs, for example formulated their groups around the role of information provider. These groups aim to conduct accurate, up-to-date research. As government and intergovernmental bodies often lack analytical capacity or are hampered by bureaucratic constraints and other commitments, NGOs can focus on a dynamic research agenda and rapidly address emerging issues. [4]

Global system assessment of ecosystems using The NGO is integrated with local environmental reporting. NGOs and other non-governmental organizations such as academic and research institutions are the main contributors who provide up-to-date reports and data analysis. [4]

Civil society is the name of a community of non-governmental organizations that has a special power to bring environmental governance to the global level. Creativity, flexibility, entrepreneurship, ability to see and long-term thinking, increased ability to adapt to local conditions often allow NGOs to play the main role in environmental monitoring. For ecosystem assessment processes, NGOs have much

to offer in terms of information collection, dissemination and analysis. There are other examples of NGOs serving key information. [4]

Although officials may read NGO review articles and research papers, this is often not enough to effectively take into account the views of civil society organizations. Additional communication mechanisms include formal advisory groups and other informal mechanisms for information exchange. [4]

It is important to support institutions that generate knowledge. Universities are key generators of knowledge, but they are among the most underfunded institutions in developing countries. Funding and transfer of communications technologies will be critical to their ability to perform these functions. [4]

2. Involvement of public organizations in environmental management

The EU provides grants to support public organizations that participate in environmental management and, in particular, in environmental monitoring.

For example, the EU LIFE program is the main financing mechanism in the field of ecology and climate in the EU. The program's budget has increased dramatically from €3.4 billion in 2014-2020 to €5.4 billion in 2021-2027, reflecting the Green Turn and the EU's overall efforts to protect the environment and climate. The LIFE program funds projects to support collaboration between different levels of social organization, sectors and fields of knowledge with the aim of obtaining replicable results and, by providing 55-60% of the project budget, allows attracting investment in the sector. The European Commission develops the program, disposes of funds, approves or rejects project proposals in accordance with program recommendations and conducts audits of their results. Member States approve projects, provide co-financing and participate in projects. Member States also initiate projects. Civil society and commercial organizations usually propose and manage projects and involve landowners in projects. The project budget ranges from 0.5 to 15 million euros and lasts from two to seven years. Thus, since 2005, EU funding has accounted for approximately 10% (and up to 20% in 2010–2013) of the Estonian state budget. While the LIFE program is by no means the largest funding instrument, it is focused on the areas of environmental management. The EU creates national contact points in potential member countries. Their main goal is to inform civil society and commercial organizations and inspire them to apply for funding. These organizations interact with projects through a liaison officer. This is long-term and effective support of public organizations, for example, since 1992, 39 LIFE projects have been implemented in Estonia. [6]

3. Strengthening environmental governance by building the capacity of non-governmental organizations

Another project aimed at supporting NGOs in the field of environmental monitoring is the EU-NGO project "Strengthening Environmental Governance by Building the Capacity of Non-Governmental Organizations" — this is a global project funded by the European Union (EU) and implemented by the United Nations Development Department. The program is implemented and co-financed by the Global Environment Facility (GEF) Small Grants Program (SGP). The project is aimed at promoting sustainable development and improving environmental management in the countries of the European region thanks to more effective participation of civil society in environmental governance. [7]

The Global Environmental Fund provides 1:1 co-financing of the project. EU-NGO projects are checked by national coordinators in each country. They are committees consisting mainly of representatives of civil society organizations, as well as representatives of the government, academia, the United Nations Development Program (UNDP) and other donors and stakeholders, and carry out the selection and approval of grants in a decentralized manner. Grants are then given directly to public organizations and local NGOs, which take a leading role in planning and implementing local projects. Each country has a National Coordinator, and the Program often supports local grantees in planning and implementing project activities, assessing the progress of goals and achieved indicators, communicating and sharing experience with other grantees and stakeholders, assessing compliance with the formal requirements of the granting process and partnership agreements. [7]

Civil society has become an important participant in environmental decision-making processes and a valuable partner in the implementation and monitoring of environmental policies at the local, national, and global levels. When their capacities are properly developed, civil society organizations (CSOs) and non-governmental organizations (NGOs) can provide technical assistance to communities and support for environment and development programs at the local level, provide policy advice to local and national authorities, and facilitate communication between government and local organizations [7]

The EU-NGO project is primarily focused on strengthening the external and internal potential of NGOs and developing professional skills in environmental governance. It provides small grants for several NGO-led projects per participating country, approaching improved environmental governance from different perspectives. The EU-NGO project improves the work of NGOs and gives them the ability to take a qualified part in the formation of environmental policy and the management of natural resources. NGOs cooperate in making decisions on key issues, represent the interests of citizens and communities in discussions about the

environment and sustainable development. By developing coordination and exchange between non-governmental organizations and other partners, the project aims to have a broader impact on civil society's ability to communicate with governments on environmental governance tasks and activities. [7]

UNDP has more than two decades of experience working with local civil society on environmental management programs. As such, it is well positioned to support CSOs and NGOs in taking coordinated action to deepen their activities and participation in environmental governance, creating both local and global benefits for sustainable development. In 2012, the UNDP-EU NGO Project provided support to 13 countries in the east and south of the European Union - more than 60 projects that contribute to the effective participation of civil society in environmental governance. The program started its first phase in eight countries: Armenia, Belarus, Egypt, Jordan, Lebanon, the occupied Palestinian territory, Tunisia and Ukraine. During the second phase of the project in 2014, five additional countries joined the project: Algeria, Azerbaijan, Georgia, Moldova and Morocco. [7]

EU-NGO methodology

All EU-NGO projects must select at least one important environmental priority project at the national level and contribute to the development of one or more of the following capacity outcomes: [7]

1. Ability to engage.

Increasing the capacity of stakeholders to participate in national or sub-national policy analysis and dialogue processes related to environmental governance and management. In particular, promoting the formation of civil society networks, multilateral round tables that enable civil society to provide information to government officials. [7]

2. Opportunities to generate, access and use information and knowledge.

Improving and strengthening the role of NGOs in raising awareness of environmental issues, policies, and disseminating environmental information and knowledge among civil society and government to address environmental issues and find adequate solutions. [7]

3. Ability to develop strategy, policy and legislation.

Strengthening the capacity of organizations to participate in the development of policy and legislative framework for environmental governance and management. This includes the integration of environmental issues into sectoral policies at the national level and the promotion of constructive dialogue between the government and civil society actors, the formation of environmental policy with their participation. [7]

4. Opportunities for management and implementation.

Improving organizational capacity, including skills in project development,

resource mobilization, business planning and administrative capacity to participate in the implementation and management of environmental projects and programs, as well as in policy dialogue and reforms. [7]

4. The role of civil society organizations in facilitating monitoring at the community level

One of the most important functions of a public organization is providing the population with environmental information. This is greatly facilitated by electronic information technologies via the Internet. Regular submission of environmental monitoring data will contribute to effective communication with the public and will be an important element in the development and implementation of environmental policy.

Information provided to the public should be in an accessible and convenient form. Therefore, public organizations must interpret, analyze and structure information. At the same time, they should not forget about the ownership of information. It is necessary to widely use the practice of European satellite remote monitoring. No less important is the presentation of information on the results of local environmental monitoring, which will often be more interesting to the public, as it has a direct practical function.

Public organizations must develop and then implement environmental action plans. This often requires consulting or financial assistance from governing bodies.

Industries should be required to report the use of toxic substances and any possible exposure to toxic chemicals in the workplace, including the transport of chemicals through communities and the placement of chemicals in consumer products. Toxic emissions that pose a health risk should be communicated to the public, such as dioxins, mercury and other heavy metals, which are extremely dangerous to children and are known or suspected to cause cancer, neurological damage, birth defects and are highly resistant at very low levels, can be better controlled. Manufacturers and importers of baby products must disclose the presence of substances that cause cancer, reproductive and neurological damage.

Civil society organizations can request reports from businesses on the use of toxic substances, especially if they are transported through communities. Of course, this is quite difficult to implement. If the received information is inaccurate, it can deprive you of the opportunity to take certain precautionary measures and as a result can lead to serious negative consequences - in some cases, literally cost your life. Therefore, those who have such information should be obliged to immediately make it freely available.

One of the foundations of the development of a public organization is the training of its members. This can be both in the form of self-education and with the

use of state educational institutions. This will help them to be much more efficient in their activities. At the same time, they will be able to transfer this knowledge to the citizens of the area where this organization operates. This will increase their environmental literacy and facilitate the activities of the public organization in all areas: from environmental monitoring to close cooperation with government managers.

5. Air quality monitoring and management – public participation in decision-making.

Legal basis for public participation in issues of environmental protection

According to Article 13 of the Constitution of Ukraine, the land, its subsoil, atmospheric air, water and other natural resources located within the territory of Ukraine, natural resources of its continental shelf, exclusive (marine) economic zone are objects of property rights of the Ukrainian people. On behalf of the Ukrainian people, the rights of the owner are exercised by state authorities and local self-government bodies within the limits specified by this Constitution. [8]

According to Article 50 of the Constitution of Ukraine, everyone has the right to an environment safe for life and health and to compensation for damage caused by the violation of this right. Everyone is guaranteed the right of free access to information about the state of the environment, about the quality of food products and household items, as well as the right to its distribution. Such information cannot be classified by anyone. [9]

According to Article 6 of the Law of Ukraine "On the Protection of the Natural Environment", central and local bodies of executive power, as well as local self-government bodies, during the development of environmental programs, involve the public in their preparation by publishing projects of environmental programs for their study by citizens, preparing public comments and proposals on proposed projects, holding public hearings regarding environmental programs. [10]

Article 9 of the Law of Ukraine "On Protection of the Natural Environment" defines a wide list of environmental rights of Ukrainian citizens, and important for us is the right to: [10]

1) a natural environment that is safe for life and health;

2) participation in the discussion and submission of proposals to projects of regulatory and legal acts, materials regarding the placement, construction and reconstruction of objects that may negatively affect the state of the environment, submission of proposals to state authorities and local self-government bodies, legal entities, that participate in decision-making on these issues;

3) participation in the development and implementation of measures for environmental protection, rational and integrated use of natural resources;

4) free access to information about the state of the natural environment (ecological information) and free receipt, use, distribution and storage of such information, except for limitations established by law;

5) appeal in the court procedure of decisions, actions or inaction of state authorities, local self-government bodies, and their officials regarding the violation of the environmental rights of citizens in the manner prescribed by law.

Article 10 of the same Law defines the guarantees of citizens' environmental rights. It is also determined that activities that prevent citizens from exercising their right to a safe natural environment and their other environmental rights are subject to termination in accordance with the procedure established by this Law and other legislation of Ukraine. [10]

Article 11 of the Law of Ukraine "On Protection of the Natural Environment" defines that Ukraine guarantees its citizens the realization of environmental rights granted to them by legislation. Local councils, state authorities in the field of environmental protection and the use of natural resources are obliged to provide comprehensive assistance to citizens in the implementation of environmental protection activities, take into account their proposals for improving the state of the environment and the rational use of natural resources, and involve citizens in solving issues environmental protection and use of natural resources. Violated rights of citizens in the field of environmental protection must be restored, and their protection is carried out in court in accordance with the legislation of Ukraine. [10]

According to Article 36 of the Constitution of Ukraine, citizens of Ukraine have the right to freedom of uniting in public organizations to protect their rights and freedoms and satisfy political, economic, social, cultural and other interests, with the exception of restrictions established by law in the interests of national security and public order , public health protection or protection of rights and freedoms of other people. No one can be forced to join any association of citizens or have their rights restricted due to belonging or not belonging to political parties or public organizations. [9]

It is important to know how the right of citizens to interact with authorities should be implemented. The main requirements for the organization and holding of consultations with the public on issues of formation and implementation of state policy by executive authorities are defined in the Procedure for conducting consultations with the public on issues of formation and implementation of state policy, which was approved by the Resolution of the Cabinet of Ministers of Ukraine dated November 3, 2010 No. 996 79. Consultations with the public are held with the aim of involving citizens to participate in the management of state affairs, providing an opportunity for their free access to information about the activities of executive authorities, as well as ensuring the publicity, openness and transparency of the

activities of these bodies. The results of consultations with the public are taken into account by the executive authority when making a final decision or in its further work. Consultations with the public are organized and conducted by the executive authority, which is the main developer of the project of the normative legal act or prepares proposals for the implementation of state policy in the relevant sphere of state and public life. [11]

Public associations, religious, charitable organizations, creative unions, professional unions and their associations,employers' organizations and their associations, bodies of self-organization of the population, non-state mass media, other non-business societies and institutions, legalized in accordance with the law (hereinafter referred to as civil society institutes), may initiate consultations with the public on issues not included in the indicative plan by submitting relevant proposals to the public council or directly to the executive authority. In the event that a proposal to hold consultations with the public on one issue is received from at least three institutions of civil society, such consultations must be held. Public councils can also initiate public consultations not included in the indicative plan. [11]

Summarizing the experience of public participation in the work of environmental commissions and councils at executive authorities at the national and regional levels

In Ukraine, representatives of public organizations began to be included in commissions working in the field of ecology. For example, in accordance with the Resolution of the CMU of August 14, 2019 No. 827 [12], the commission on issues of state monitoring in the field of atmospheric air protection and atmospheric air quality management includes representatives of public associations that conduct their activities within the zone or agglomeration (by consent). In accordance with the Order of the Ministry of Environment No. 261 dated 04/20/2021 [13], an Interdepartmental Commission on Monitoring in the Field of Air Protection was established, the commission includes 26 people, including the head of the sector of the Laboratory of Environmentally Safe Nature Use, Means and Methods of Environmental Monitoring of the Scientific and Research institution "Ukrainian Research Institute of Environmental Problems", head of the atmospheric air monitoring laboratory of the Ukrainian Hydrometeorological Institute, chairman of the Committee of Entrepreneurs on Nature Use and Environmental Protection at the Chamber of Commerce and Industry of Ukraine, chairman of the executive body of the Public Formation for Protection of Public Order "Ecological Patrol". Unfortunately, few public organizations are represented.

Key players of non-governmental institutions of civil society of Ukraine

The Law of Ukraine "On Public Associations" [14] fixes the following definition of "public association" - as a non-state institution of civil society:

A public association is a voluntary association of individuals and/or legal entities under private law for the exercise and protection of rights and freedoms, satisfaction of public, in particular economic, social, cultural, environmental and other interests.

A public association can carry out activities with or without the status of a legal entity. A public association with the status of a legal entity is a non-entrepreneurial society, the main purpose of which is not to make a profit. Each public association develops its charter, which specifies the main goal of the organization and the main directions of activity.

Therefore, it is worth noting that those non-governmental public organizations, which in our opinion are key players, spend a significant part of their work on solving the problems of air quality protection and management. Each of the organizations has its own vision of solving the problems of atmospheric air protection and occupies its niche in this process. [15]

The public organization "Green World – Friends of the Earth" has extensive experience in monitoring and managing air quality in Ukraine. The public organization has its origins in the informal association "SOS", which was created in the early 1970s in Dnipro. The organization was officially registered in 1997 and primarily focused attention in the field of sustainable development. Members of the organization paid special attention to working with executive authorities, local self-government bodies on environmental policy issues, the spread of renewable energy sources and environmentally friendly technologies, and the implementation of national and international environmental legislation. Thus, members of the "Green World" initiated the creation of a public environmental council under the Dnipro Regional State Administration. [15]

Later, the experts of "Green World" became the initiators of including the development of the system of automated monitoring of environmental parameters of the region to the Dnipro regional comprehensive program (strategy) of environmental safety and climate change prevention for 2016-2025. Later, when the members of the "Green World" team received their parliamentary mandates in the Dnipropetrovsk Regional Council, on their initiative, specific measures were introduced into the mentioned Program, which allowed the development of a new system of automated environmental monitoring in the Dnipropetrovsk Region to begin. Subsequently, a budget was allocated for the creation and operation of the specialized enterprise "Environmental Monitoring Center". NGO specialists also took part in the development of the draft Regulations on the Environmental Monitoring System of the Dnipropetrovsk Region. [15]

Another example is: the Ukrainian network of public monitoring of air quality EcoCity is a non-profit project of the Ukrainian network of public monitoring of air quality, which is implemented by the NGO "Free Arduino" together with partner public organizations and scientific and technical advisors. This project was born on the initiative of activists and inventors in 2018 in the city of Ivano-Frankivsk and in 6 years has spread throughout the territory of all regions of Ukraine. Currently, EcoCity is the largest network of over 600 installed public air quality monitoring stations. [15]

The influence of the EcoCity project on the development of air quality monitoring and management is focused in three main directions: [15]

1) motivation of the youth of Ukraine for socially useful inventions and the study of natural and technical sciences;

2) informing the population about air quality in industrial agglomerations and the most remote corners of the country;

3) stimulating the development of state and municipal air quality monitoring systems.

Over the past 4 years, the EcoCity team, with the support of the Czech non-governmental organization "Arnika" and other partners, has implemented several innovations in public air quality monitoring. [15]

The Ukrainian network of public air quality monitoring EcoCity develops active partnerships with civil society institutions and academic communities. More than 20,000 people and local self-government bodies in Ukrainian cities use the electronic air quality map (www.eco-city.org.ua) every month. [15]

The public organization "Save Dnipro" started its work in 2017 (the first few years as an initiative informal association) and in 4 years had a significant impact on the spread information about atmospheric air quality in Ukraine. The "Save Dnipro" team achieved this result through the environmental bot SaveEcoBot, designed for the dissemination of environmental information in social networks and messengers (Telegram, Viber, Facebook Messenger), and quality maps air https://www.saveecobot.com/maps. [15]

It is worth noting that the development of air quality monitoring and management (in the form of civil society participation) involved many public organizations and initiatives throughout Ukraine, among them: [15]

The Center for Environmental Initiatives "Ecodiya" is a public organization based in the city Kyiv, but its sphere of influence extends beyond the Kyiv region. The main areas of work are the analysis of the possibilities of introducing European legislation and standards regarding of environmental protection and monitoring, analysis of environmental impact assessment reports of enterprises, permits for emissions into atmospheric air, communication with executive authorities regarding the improvement of existing legislation in the field of monitoring. [15]

Public organization "Dzyga" is a public organization whose scope of activity extends to the territory of the city of Zaporizhzhia. Members of the organization take care of issues of environmental monitoring, development of a public system for monitoring atmospheric air, climate change, landscaping. This public organization has a non-trivial experience of an advocacy campaign, regarding resumption of operation of the mobile air quality monitoring laboratory, as well as included in member of the Commission on State Monitoring in the Field of Air Protection and Air Quality Management of ZaporizhzhiaAgglomeration. [15]

Coalition of public organizations "Enough to poison Kryvyi Rih" is a union of 19 institutions of civil society. The main work of the coalition is aimed at participation in public discussions of reports on EIA and public discussions before obtaining emission permits pollutants. [15]

The movements «Kharkiv without Coke» and «Anti Coke» are an informal associations of environmental activists of the city of Kharkiv, united by joint actions against environmental pollution, which causes the so-called "Kharkiv Coke Chemical Plant" and other industrial enterprises on adjacent territories. These movements have accumulated a lot of practical experience in information management and advocacy campaign against industrial pollution, as well as detection and dissemination in the information space of environmental crimes in the city of Kharkiv. [15]

Thus, there is a positive practice of using European experience in the work of public organizations in Ukraine.

6. The main problems of practical application of citizens' rights

Problem 1. There is no prescribed procedure for the involvement of representatives of public associations in commissions dealing with environmental issues. Exactly this is the reason for the low representation of the public and the expert community within these Commissions. After all, it is currently impossible to understand how the decision about necessity of representatives' involvement of one or another NGO or experts and scientists is made. [15]

Problem 2. "Closeness" of the primary data of the monitoring results of the state and quality of atmospheric air from the monitoring subjects. For example, as of July 1, 2021, on the portal open data data.gov.ua, there are no data on the state of the atmospheric air according to the data of the territorial bodies of the Hydrometeorology Department, which are structural subdivisions of the apparatus of the State Emergency Service of Ukraine, - Dnipropetrovsk Regional Center of hydrometeorology and the Zaporizhia Regional Center for Hydrometeorology. It is worth noting that Department of hydrometeorology, regional hydrometeorology centers of Kyiv, Kharkiv and Donetsk regions in the list of managers of the open data portal are missing. It should be added that some of these data are published on the

website of the Ministry of Environment. [15] Therefore, there is no clearly defined mechanism of interaction between monitoring subjects in the field of information exchange. There is no procedure for providing access to the results of atmospheric air monitoring, scheme, format, etc protocols of information accumulation and exchange, hierarchy at the zone and agglomeration level. Missing requirements for the creation of an information and analytical system at the state level and at the level of the agglomeration zone. The date of creation of such a system is uncertain. It is not defined how to implement information interaction in its absence. There is no notification procedure population about the state of atmospheric air. [15]

Problem 3. "Closeness" of these enterprises, institutions, organizations, whose activities lead to deterioration of the atmospheric air. Most of such enterprises do not have automated air quality monitoring stations. Status monitoring results of atmospheric air are not published on the open data portal, and they cannot be monitored online. Some companies publish average results on their websites. [15]

A successful case is the cooperation between the ME "Environmental Monitoring Center" and PJSC «Kryvyi Rih Cement». Data from the company's automated air quality monitoring station are transferred to the system of the Center for Environmental Monitoring, but are not posted on the open data portal, because the manager of this information is PJSC "Kryviy Rig Cement". [15]

One of the main problems is the low interest of citizens in public organizations. Members of such organizations are quite few. This is due to the low level of education in the field of environmental safety, in the field rights and opportunities for citizens, with a focus on providing basic needs in connection with the economic situation in the country, with the aggression of the Russian Federation. A low level of trust in authorities has a great influence and local self-government, the position that the opinion of citizens is never taken into account when making decisions.

Therefore, it is necessary to strengthen the work in the direction of environmental education for the citizens of our society.

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Lecture 11. European and Ukrainian experience in calculating air quality indices and access to environmental informationю

Plan.

1. Use of air quality indices for the purpose of promptly informing the population about air pollution and health risks.
2. The procedure for alerting and informing the population about the deterioration of air quality through WEB services or social networks.
3. Ukrainian state information resources designed to display information on monitoring of environmental objects.

1. Use of air quality indices for the purpose of promptly informing the population about air pollution and health risks

1.1. Concept of air quality index

The main structural elements of international air quality monitoring are:

- the presence of an extensive system of monitoring stations ,
- availability of a methodology for measuring the main indicators of air quality together with monitoring the meteorological condition,
- availability of a system for collecting, analyzing and transmitting data on the state of atmospheric air quality,
- availability of a monitoring system support and development strategy,
- availability of communication tools regarding the state of atmospheric air quality.

Basic chemical indicators need to be converted into such an indicator that would show the connection between the observed data and the consequences for the health of the population.

There is the international experience of the US environmental protection agency EPA USA (an agency in the US federal government that was created to protect human health and the environment, also the US Environmental Protection Agency) and the European Environmental Agency EEA EU (the EU agency to ensure independent information on the state of the environment; there are also names – European Environmental Agency, European Environmental Protection Agency) calculation of air quality indices AQI and the practice of their application for the purpose of promptly informing the population about air pollution and risks to public health.

Air quality index – a value used by government agencies of various countries to convey to the public the level of air pollution at this time. If the index increases, a large part of the population will face serious health consequences. Different countries have their own air quality indicators according to different national standards.

The air quality index allows you to monitor air quality indicators in real time on the territory of those countries that have implemented data transfer protocols in real time.

Features of air index calculation:

- the calculation of the Air Quality Index is based on the average values of the concentration of pollutants for a separate period, which are obtained from atmospheric air monitoring;
- the level of pollutants in the air is taken as the concentration and time of fixation of this concentration;
- the air quality index is combined into ranges. Each range is assigned an identifier, a color code, and recommendations for the public regarding the protection of their own health;
- the index is presented in the order in which a significant part of the population will face serious health consequences.

AQI (Air Quality Index) is an air quality index developed by the US Environmental Protection Agency and used in many countries around the world. The higher the AQI value, the higher the level of air pollution and the more negative the impact on health.

Some European countries have their own indices. In particular, the British daily air quality index (Daily Air Quality Index), which is used by UK government institutions, has a 10-digit scale, which is divided into 4 parts, in which (1) is taken as the lowest value with the least danger to health, and (10) as the highest and the most threatening to health.

The following AQI air quality levels are distinguished:

AQI Basics for Ozone and Particle Pollution

Daily AQI Color	Levels of Concern	Values of Index	Description of Air Quality
Green	Good	0 to 50	Air quality is satisfactory, and air pollution poses little or no risk.
Yellow	Moderate	51 to 100	Air quality is acceptable. However, there may be a risk for some people, particularly those who are unusually sensitive to air pollution.
Orange	Unhealthy for Sensitive Groups	101 to 150	Members of sensitive groups may experience health effects. The general public is less likely to be affected.
Red	Unhealthy	151 to 200	Some members of the general public may experience health effects; members of sensitive groups may experience more serious health effects.
Purple	Very Unhealthy	201 to 300	Health alert: The risk of health effects is increased for everyone.
Maroon	Hazardous	301 and higher	Health warning of emergency conditions: everyone is more likely to be affected.

1.2. European air quality index

Information on air quality in EU countries is evaluated using the European Air Quality Index, which corresponds to the definition of the EEA (https://www.eea.europa.eu/themes/air/air-quality-index).

The European Air Quality Index allows users to better understand the air quality where they live, work or travel. Displaying up-to-date information for Europe, users can get an idea of air quality in individual countries, regions and cities.

The index evaluates air quality according to five indicators:

- solid dust particles ($PM_{2.5}$ and PM_{10} – suspended particles with a diameter of less than 2.5 micrometers and 10 micrometers, respectively),
- ground ozone (O_3),
- nitrogen dioxide (NO_2),
- sulfur dioxide (SO_2).

Each of the mentioned indicators is evaluated in accordance with the standards approved by the European Union Directives (http://ec.europa.eu/environment/air/quality/standards) EU legislation establishes air quality standards for both short-term (hourly or daily) and for long-term (annual) air quality levels. Since the standards provide for a distinction between indicators in the long-term and short-term perspective, the Index provides information on air quality only in the short-term perspective. It does not reflect the long-term air quality situation, which can vary significantly. Standards for long-term levels are more stringent than for short-term levels because long-term exposure to pollutants can have serious health effects.

The Air Quality Index is not a tool to verify compliance with air quality standards and cannot be used for this purpose.

The European air quality index is calculated for different air pollutants separately by concentration (depending on the air pollutant, on average for a day or immediately after): the higher the concentration, the higher the index. For each pollutant, the index value ranges from 1 (good) to 5 (very bad). The European air quality index is represented as an integer corresponding to the five concentration ranges characteristic of each pollutant.

By default, the air quality index reflects the situation for the last 3 hours. Users can select any hour in the previous 48 hours and view forecasted values for the next 24 hours.

The total daily European Air Quality Index is the highest value of the total hourly European Air Quality Index for the relevant day. It is defined as the highest value of five individual pollutant indices calculated for the same time. For example, if the indexes of O_3, NO_2, SO_2, $PM_{2.5}$ and PM_{10} are equal to 1, 3, 1, 2, 2, respectively,

the average index will be equal to three. The overall daily European Air Quality Index is used in the news on the Euronews channel.

The index bands are complemented by health messages that contain recommendations for both the general population and sensitive population groups. The latter include both adults and children with respiratory diseases, as well as adults with heart diseases.

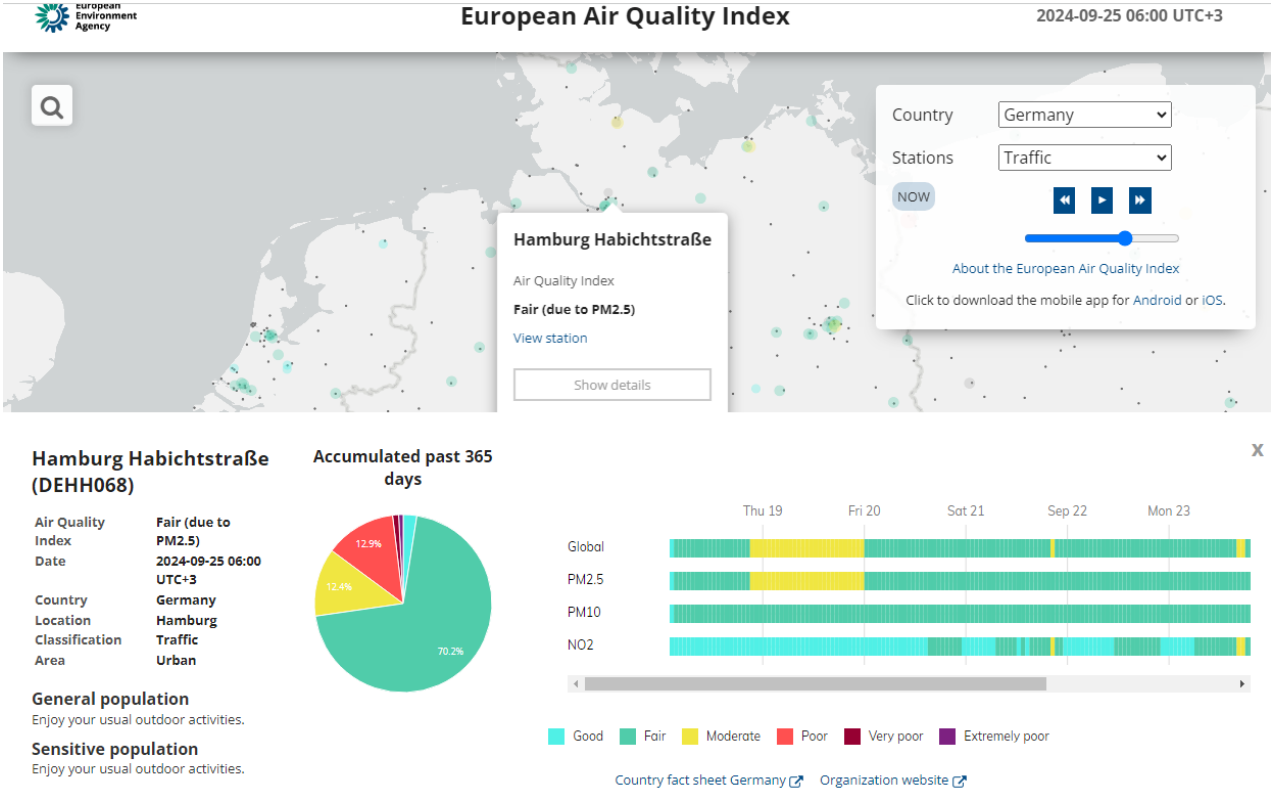

Figure 1. Visual representation of the Air Index of the European Environmental Agency

Air index calculation methodology

The index is calculated hourly from data from more than 3,500 air quality monitoring stations across Europe, using up-to-date hourly data officially provided by EEA (European Economic Area) member states, supplemented where necessary with simulated air quality data from the Copernicus Atmospheric Monitoring Service (CAMS) EU (http://atmosphere.copernicus.eu/).

The index allows citizens to use an interactive map to check station-level air quality based on five key pollutants that harm human health and the environment. Circles and dots on the map indicate the location of air quality monitoring stations. The colors represent the air quality at a particular hour at that station.

When you click on a station on the map, a pop-up window appears with the following additional information:

1. Station name and air quality index at this station and hour.
2. "View Station" option, which locates the station using Google Maps.

3. "Show details" option with brief information about the station; air quality index and relevant advice on the health of the general population and sensitive population groups; a link to information on air pollution in the country where the station is located and to the web page of the administration responsible for reporting concentrations for that station, and two graphs.

Values displayed when hovering over the horizontal chart show the hourly AQ index, hourly concentrations for NO_2, O_3 , and SO_2 , and the 24-hour running average for PM measured at the station or filled pass for the past 7 days. The pie chart indicates the number of days with a specific air quality level, indicated by the corresponding colored index bar, over the past 365 days.

The user can filter the selection by country and station type. Stations are classified according to the predominant sources of emissions: transport, industry and background (where the level of pollution does not depend on either transport or industry). The user can view all stations, only traffic stations, or only non-congested stations (e.g. industrial and background stations).

Resources used for the development and maintenance of the air quality index calculation system.

The system was developed by the joint resources of the European Environment Agency and the Directorate-General for the Environment of the European Commission to inform citizens and public authorities about the latest state of air quality in Europe.

From a technological point of view, the map is an adaptation of the JavaScript library of the Mapbox service. Other libraries were also used for additional functions. The index does not allow downloading data for analysis and serves only as a communication tool. But it contains links to primary data that can be downloaded from another resource.

In addition, the agency provides detailed information on the mechanisms and tools of the monitoring system, and it also pays attention to communication with key stakeholders (interested parties).

The European Environment Agency also publishes a range of information on air quality:

- EU air pollution webpage: https://www.eea.europa.eu/en/topics/in-depth/ air-pollution,
- Air quality in real time: the latest air quality measurements: https://www.eea.europa.eu/data-and-maps/explore-interactive-maps/up-to-date-air-quality-data,
- Key air quality statistics for major air pollutants: map view: https://www.eea.europa.eu/data-and-maps/dashboards/air-quality-statistics.

1.3. Measurement of AIR in Ukraine and Ivano-Frankivsk

1.3.1. LUN City AIR

In Ukraine and in Ivano-Frankivsk, in particular, AIR measurementsare conducted by the Ukrainian public air quality monitoring system **LUN City AIR.** LUN City AIR is a Ukrainian public air quality monitoring system, created with the aim of improving the environmental situation in the country. The project was developed by the teams of the Ukrainian IT company LUN and Kyiv National University named after Shevchenko, Faculty of Radiophysics, Electronics and Computer Systems.

The stations are located around the city and monitor the air quality outside the window every second. The devices measure pollutants that are particularly harmful to health - the concentration of PM_1, $PM_{2.5}$, PM_{10}. These ultra-fine particles are not visible to the naked eye, their source is primarily combustion processes - car exhaust, pipe smoke, fires.

Indicators in real time are displayed on a map, in Telegram and Viber bots, in a widget for iOS. LUN City AIR services are available from a phone and a computer.

Familiarization with the Ukrainian real-time air quality monitoring system from the public network LUN City AIR:

- https://misto.lun.ua/air-about_en#rec282628357,
- https://misto.lun.ua/air/ivano-frankivsk.

The stations are handed over to the city free of charge, and maintenance is also free.

1.3.2. SaveEcoBot

The SaveEcoBot project is the only public environmental system in Ukraine that combines data on the current state of the environment, pollution, pollutants and environmental protection tools. This is a volunteer project of the Save Dnipro initiative group.

On the website https://www.saveecobot.com/ you can find:

• interactive map of the radiation background.

• detailed information on the state of the radiation background in regions and settlements.

• air quality map with wind direction and speed.

• information on air quality from each monitoring station and data on populated areas.

• analysis and map of fires in Ukraine with details for each of the regions.

• analysis of environmental taxes.

• statistics of the results of the eco inspection.

The chatbot will easily help you find the following information:

• monitoring of the EIA register (environmental impact assessment), which displays the stages of the environmental assessment procedure for the planned activities of enterprises.

• data on permits for emissions of harmful substances into atmospheric air by stationary sources of polluting enterprises of groups 1, 2 and 3.

• data on special permits for subsoil use.

• data on permits for special water use.

• data on licenses for hazardous waste management.

• information about business entities that have a tax debt.

• data on licenses for the production of particularly dangerous chemicals.

• data on waste declarations.

1.4. Ukrainian air quality index

At its meeting in May 2024, the Cabinet of Ministers adopted changes to the procedure for monitoring atmospheric air. This decision is important in the context of the implementation in Ukraine of European air quality standards and the implementation of Law No. 2973 of March 20, 2023 on the reform of the environmental monitoring system. The corresponding working group under the Ministry of Environment, which includes more than 30 experts in the field of air monitoring, worked on the changes to the order.

Based on the results of the discussions, a decision was made to gradually implement complex and systematic data collection, which will allow for appropriate analysis. One of the novelties of the resolution is the introduction in Ukraine of an air quality index similar to the European one. In order for this index to start working as soon as possible, the Ministry of Environment team is already working on the preparation of approaches and criteria for its implementation.

To implement at the state level the definition of an air quality index indicator similar to the European one, the principles and methods of calculating the Ukrainian air quality index UAQI , which are used in practice by the All-Ukrainian network of public air quality monitoring EcoCity, can be used as a basis. These developments are based on the experience and practice of the participants and partners of the international program "Clean Air for Ukraine", as well as on the international experience of the EPA USA and EEA5 EU in calculating air quality indices and the practice of their application in order to promptly inform the population about air pollution and health risks. i population

1.4.1 Structure and list of parameters

Ukrainian index of air quality (Ukrainian Air Quality Index, UAQI) is a scale of qualitative and quantitative assessment of atmospheric air quality. UAQI as a

communication tool allows interested parties to:

- better understand air quality where they live, work or travel;
- make an informed decision about actions for safety in case of deterioration of air quality;
- conduct a current and retrospective analysis of air quality and substantiate the relevant decision of air quality management in Ukraine, in individual zones, agglomerations or locations;
- disseminate current information about air quality in graphic and digital form, adapted for perception by citizens without special professional training.

UAQI consists of four groups of the main pollutants, as well as physical parameters that affect air quality and safety:

- group (A) Content of aerosols and other finely dispersed solid particles in the air;
- group (B) Air content of gaseous pollutants of the priority list defined by the WHO (WHO -2021);
- group (C) Air content of other pollutants from the priority list, which is used in the practice of protecting atmospheric air from pollution in Ukraine (List A and List B of Appendix 2 PCMU 827, List of substances PCMU 1598);
- group (D) Parameters of physical factors that affect the quality and safety of air (in particular, parameters of radioactivity of atmospheric air, etc.).

1.4.2 Categories of air quality

Ukrainian index of air quality (Ukrainian Air Quality Index, UAQI) establishes 10 categories of air quality – six main, two additional and two special.

Six main categories provide the user with information on the quality and safety of ambient air according to EEA practice EU 9. Two additional categories are used to indicate cases where air quality is unknown for various reasons. Special categories of air quality indicate special cases of abnormal monitoring results with a low degree of confidence, or special conditions of use. These categories are not used for public notification, but are taken into account during detailed analysis of retrospective monitoring results.

To clearly and unambiguously indicate each category of air quality, use:

- numerical designation of the category, Roman numerals from I to X ,
- the name of the quality category, which characterizes the level of risk and danger (key message),
- color marking, which intuitively helps to understand the level of risk and danger,
- range of values (scale) for each monitoring parameter.

Determining the category of air quality (both for each individual monitoring

parameter and in general for a specific location or territory) is done by a simple comparison of the monitoring result with the value ranges (scale) of each air quality parameter. Table 1.2 shows the value ranges (scale) of air quality categories for parameters used in the practice of the Ukrainian network of public monitoring of air quality Eco City.

The scale of the Ukrainian air quality index simultaneously determines:

a) a list of monitoring parameters that are taken into account to assess air quality and safety;

b) established designations, names and units of measurement of monitoring parameters;

c) ranges (from... to inclusive) that determine the air quality category of each monitoring parameter;

d) established color designations of air quality categories for each range.

Parameters H_2S, Cl_2, PH_3 and NH_3 are chemical air safety alert parameters. Therefore, not all air quality categories are set for these parameters. This is due to the sensitivity of the monitoring tools and the tasks that these tools perform.

For additional categories of air quality (VII and VIII) no ranges of values have been established. This is due to the nature of the key message for these categories – "Air quality unknown" for various reasons. Accordingly, the very fact of the absence of monitoring results for one or another parameter will determine these categories of air quality.

For the purpose of prompt notification (or informing) of the population, key messages and recommendations of actions for the population are established for each category (except for special categories IX and X).

If the monitoring result exceeds the upper set limit of category VI, then category VI is used for public notification purposes, but air quality category X is used for detailed analysis and information purposes.

For the purposes of quantitative and qualitative assessment of atmospheric air, additional parameters are set for each category, which allow to calculate the numerical value of UAQI or qualitatively determine the level of risk and danger.

It is important to note that these guidelines do not contain recommendations and algorithms for quantitative assessment of AQI.

Quantitative assessment of AQI is an important tool for informing the population about air quality, detailed analysis of medium and long-term changes in air quality, identifying trends and evaluating the effectiveness of the environmental policy of air quality management in the zones and agglomerations of Ukraine.

It is worth paying attention to the fact that the general term "radiation background" in atmospheric air is widely used in practice as the power of the exposure dose (a common non-system unit of measurement is μR/h, the system unit

of measurement is Kl/kg·s.

Monitoring tools used by the Ukrainian network of public air quality monitoring Eco City, evaluate the exposure dose of photon radiation (mainly gamma radiation), when passing through 0.001293 g of air (the mass of 1 cm^3 of dry air under standard IUPAC conditions), as a result of the completion of all ionic processes, ions are formed that carry one electrostatic unit of quantity current of each sign. At the physical level, monitoring instruments (equipped with Mueller-Geiger tubes) estimate the power in A/kg or Cl/kg. The use of system units of equivalent dose measurement (Sv or J/kg) requires taking into account the weighting factors of exposure to various types of radiation (X-rays, γ -radiation, β -particles, muons, neutrons, protons, charged pions, α -particles, nuclear decay fragments, heavy ions) taking into account the selective effect of different types of tissue (bone marrow, colon, lungs, stomach, mammary gland, gonads, bladder, liver, esophagus, thyroid gland, bone surface, brain, salivary gland, skin, other tissues) according to the instructions and recommendations of the International Commission on Radiation Protection. That is why we recommend using the off-system unit μR/h for broad communication.

1.4.3. Color scale

Prompt notification of the population about air quality requires clear principles of visual communication and requirements for air quality notification.

To indicate different categories of air quality, a combined color scale is used, which on an intuitive level provides information both about the air quality at a certain location or territory, and about the quality (availability) of the data of the monitoring results, on the basis of which the air quality is determined. A visual communication strategy should provide the user with intuitive information about air quality.

1.4.4. Key messages about air quality

Ukrainian index of air quality (Ukrainian Air Quality Index, UAQI) allows interested persons to learn about air quality in the area where they live, work or travel. However, the main purpose of UAQI is to help make an informed decision about actions of a general nature in case of deterioration of air quality.

To achieve this goal, the air quality notification should contain not only the name of the category, but also general recommendations for reducing the negative impact of polluted air on health, which, if necessary, can be implemented by the population without additional professional explanations and consultations. This task of the Ukrainian air quality index is implemented by combining the graphic and textual parts of the air quality message, which take into account the guidelines for actions for different categories of the population.

The key message and instructions for additional actions should differentially

take into account the impact of polluted air on different categories of the population. For this purpose, the Ukrainian Air Quality Index establishes two types of notifications:

- messages for the general population and interested users;
- a special message for certain population groups that are (vulnerable, sensitive to air pollution by a certain substance).

UAQI air quality category provides the user with information about the short-term air quality situation in a specific location or area. Long-term assessment of air quality (monthly, quarterly, annual) may differ significantly from short-term and requires special numerical methods of analysis of monitoring results. The UAQI air quality category is not a tool to verify compliance with air quality standards and cannot be used for this purpose. These guidelines do not contain methodologies and approaches to the numerical determination of the Ukrainian air quality index and its application in the practice of analysis and long-term assessment of air quality in a certain location or territory.

2. The procedure for alerting and informing the population about the deterioration of air quality through WEB services or social networks

2.1. Radiation and Smog Alarm chatbot

2.1.1. Basic information about the chatbot in Telegram

To fulfill the notification tasks, the All-Ukrainian network of public air quality monitoring EcoCity uses the **Radiation and Smog Alarm** chatbot. This multi-functional tool provides quick notification of the public about air pollution, chemical and radiation hazards in communities where public air quality monitoring stations of the EcoCity network are installed.

The chatbot in passive or active mode provides users with information about the quality and safety of air in the community according to the criteria of the Ukrainian Air Quality Index UAQI and supports three main scenarios of communication with the user (Pic.5)

1. Scenario of active search and selection of a monitoring station of interest to the user, when receiving information about air quality and safety

2. The scenario of subscription and automatic notification of the user about the deterioration of air quality at the selected monitoring station.

3. The scenario of subscription and automatic informing of the user about the current state of air quality and safety at the selected monitoring station.

Radiation chatbot and smog Alarm provides users with additional advantages compared to known analogues in Ukraine:

- warnings about radiation danger and the content of gaseous chemical

compounds;

- a comprehensive approach to air quality assessment in accordance with the guidelines and recommendations of the Ukrainian Air Quality Index UAQI ;
- informing and warning about air pollution by priority and specific gaseous pollutants (nitrogen dioxide, carbon monoxide, ammonia, surface ozone, volatile organic compounds);
- a fair, non-manipulative approach to informing the population of communities where there are no (not installed) online air quality monitoring stations.
- Technical capabilities and limitations:
- each registered user has the opportunity to subscribe to alerts and information for up to 10 public monitoring stations.
- each registered user can independently determine "whether to receive only notifications" or receive "notifications and information", the user defines the list of monitoring stations.
- the system is designed for a load of up to 100 simultaneous active user requests and up to 1000 simultaneous user notifications according to their subscriptions, or up to 2000 simultaneous notifications at the administrator's request.
- the system maintains its own databases (registers) and stores them for up to 1.5 years with the possibility of downloading these registers at the administrator's request.

2.1.2. Data sources

Radiation chatbot and smog Alarm has its own server, dynamic and retrospective databases that keep it running and alerting customers. The chatbot takes primary data from the dynamic database of the Ukrainian network of public air quality monitoring EcoCity, which combines the results of public air quality monitoring of EcoCity users (https://eco-city.org.ua), and (according to the recommendations of scientific and technical advisors of the network «EcoCity») optionally from the open partner databases of the LUN City Air network (https://misto.lun.ua/air) and the open databases of Luftdaten.info (https://maps.sensor.communit). After aggregation and interpretation, these monitoring results undergo initial processing according to the guidelines and principles of the Ukrainian Air Quality Index (UAQI).

Own source of data received directly from the user is:

- database (dynamic register) of registered users (users who contacted the chat bot, user IDs provided by the Telegram system, registered phone number, registered User name, date of active request),

- a database (dynamic register) of the results of the registered user's selection of a location of interest to him/her (level – city/village, region, time of active request) and the type of request by identifier (air quality, radiation and chemical safety, etc.),
- a database of subscriptions of registered users to update information on a certain public air quality monitoring station (notification or information service).

The chatbot does not require and does not store personal data of the user, which are not recognized as public in the Telegram environment (personal data of the name, surname, data of the results of GPS requests – the user's location).

Radiation concept and smog Alarm provides a special administrator function – forced mass mailing of additional information and reference messages to all registered users. This function is set in case of extraordinary circumstances in the Eco City network and important information of public interest to all users.

2.1.3. Criteria for notifying the population about deterioration of air quality

Automated public notification of air quality violations must simultaneously satisfy several requirements:

- timely notify and warn users about deterioration of air quality. This will allow the user to make an informed decision about safety and health risks. This will also create an opportunity for the user to take precautions.
- timely notification of air quality improvement (removal of restrictions and risks associated with temporary and short-term air pollution). This will allow the user to objectively assess the situation and plan activities in new circumstances.
- do not turn messages about deterioration or improvement of air quality into "informational noise". This will protect the user from excessive and redundant information. It also prevents the user from losing interest in information about the state and quality of the air.

Radiation concept **and smog Alarm** uses a risk-based approach to determine the moment (objective circumstances) when it is necessary to notify the public about deterioration of air quality or improvement of air quality. For this, each air quality category is assigned a numerical NAQC risk score , which corresponds to the number of the air quality category and characterizes the overall assessment of the AQC air quality category at a certain location of the installation of the monitoring station in a specified estimated 20-minute period of the day.

2.2. EcoCity map SMOG ALARM – implementation of the Ukrainian air quality index

Currently, citizens of Ukraine in most territories can use air quality monitoring maps on the eco-city.org.ua website and the updated website reborn.eco-city.org with the help of a network of more than 250 automated monitoring stations of the

All-Ukrainian network of public air quality monitoring EcoCity.ua.

EcoCity created the first Ukrainian air monitoring map, on which any user can view the level of air pollution in real time. The team manufactures monitoring stations of its own development. These are devices that can be installed anywhere there is a Wi-Fi network or an Ethernet connection. Stations can measure dozens of different pollutants using different variations of sensors for different conditions and monitoring tasks.

The EcoCity project has been in existence for over six years and is constantly developing and growing. It grew from a few simple stations in Ivano-Frankivsk to a large-scale network that covers the whole of Ukraine and monitors more than 20 different atmospheric air pollutants, in particular, NO_2, SO_2, CO, CH_2O, H_2S, NH_3, O_3 , Cl_2, HF. EcoCity was developed and supported by the "Clean Air for Ukraine" program with the support of the Czech NGO "Arnica".

On September 4, 2024, the official presentation of the updated air quality monitoring site EcoCity: Reborn took place.

The site evaluates four groups of pollutants:

- micro dust
- basic gases
- other gases
- radiation background

The largest index will get priority and is displayed in the central part and marked with the corresponding color on the map. Humidity, atmospheric pressure, and air temperature are also measured.

Among the main innovations, there is a convenient search for stations on the map, the ability to view data on the state of the air in different regions and detailed statistics on the level of pollution, which allows users to receive the most accurate information about air quality in real time, a search for cities by name has appeared, which was previously was not, but there was a demand for it.

You can go to the statistics page, which shows a list of areas, and sort them by name, check which of the areas is currently more polluted. It is possible to see the average indicators for a specific area, which are currently fixed there. Here you can also check the recommendations that exist at a certain level of pollution, which can affect health.

Another innovation is the ability to find out the indicators for the last 48 hours at each station. Thanks to this, it is possible to compare the data for the last two days: whether the pollution was as it was, for example, a week ago or a month ago.

3. Ukrainian state information resources designed to display information on monitoring of environmental objects

3.1. "EcoSystem"

"EcoSystem" is the only nationwide automated information and analytical online platform in the field of environmental protection, which was created and implemented in partnership with the Ministry of Environmental Protection and Natural Resources, the Ministry of Digital Transformation with the support of the USAID/UK aid project "Transparency and Accountability in Public Administration and Services /TAPAS".

The single ecological platform "EcoSystem" was created so that every citizen of Ukraine has up-to-date and reliable information about the state of the environment and natural resources, as well as interacts with the state in a transparent and convenient way.

The project includes:

- monitoring data on the state of air, water, and soil in populated areas;
- all registers maintained by the Ministry of Environment and central authorities that we coordinate;
- a full range of online services for citizens and businesses with topical updates, reporting calendars, newsletters.
- EcoSystem developers wanted to provide the following advantages for platform users :
- "so that when searching for the necessary information, you do not go to a bunch of sites, write requests and wait for an answer. And then try to figure out " where is the truth? " ,
- "so that our dialogue with you is transparent, constructive and convenient - without unnecessary bureaucracy",
- "so that you receive services quickly and conveniently, and officials do their work honestly".
- The following services for monitoring environmental objects are available, in particular:
- e-Environment. All information from institutions that monitor the environment in various areas - air, water, soil, etc. is collected here. You can check data in state registers and get information conveniently, simply and without unnecessary hassles.
- e-Air. This is an electronic service for convenient access to information about permitted emissions into atmospheric air with the function of obtaining such a permit. Here you can check information about whether the enterprise has a permit to emit pollutants; who is an environmental auditor and much more. With the help of the

service, you can submit documents for obtaining a permit; to register a report on the inventory of pollutant emission sources; issue an environmental auditor's certificate and use other administrative services.

- e-Water. This is an electronic system of accounting for water users and water pollution. Here you can find information about the biggest polluters of water bodies, about issued permits for dredging, as well as work on the lands of the water fund within the coastal protection strips along the seas, sea bays and estuaries, in inland sea waters, estuaries and the territorial sea. Obtain an online permit for special water use and submit an annual report.
- e-Waste. This is an electronic waste accounting and monitoring system in Ukraine. Here you can find registers of waste disposal sites, reports on waste disposal and information about enterprises that have the right to work with hazardous waste and enterprises that can produce particularly dangerous chemicals. In addition, administrative services such as submitting a waste declaration, processing documents for cross-border transportation of waste, obtaining licenses for conducting economic activities for the management of hazardous waste or licenses for the production of particularly hazardous chemicals are available online.
- e-Ecocontrol. This is an electronic environmental control system. With the help of the service, you can notify relevant authorities about illegal activity, find information about scheduled and unscheduled inspections conducted by the State Inspection and their results.
- e-Environmental Impact Assessment. Electronic system of environmental impact assessment. Users can access information from the Environmental Impact Assessment Register, the information-analytical system for calculating environmental risks, and relevant administrative services.

3.2. Open data portal

On website https://diia.data.gov.ua/about you can get information about various aspects of the life of the state. This data is very valuable, and much of it should be available and open to businesses, startups, government officials, journalists, and the public. Open data helps to monitor the work of state bodies, improve state services and create new services.

The issue of environmental pollution is important for 93% of Ukrainians. Thanks to the Resolution No. 835, state bodies have opened dozens of registers in the field of ecology: data on the quality of surface water, licenses for hazardous waste management, permits for air emissions, subsoil use and special water use, and many others.

Publishing state data on the Unified State Open Data Portal in free access is the first step. Data should be easy to understand even for non-specialists. Therefore, on

the basis of this data, developers create user-friendly services that make it easier for citizens to find information about the state of the environment, the presence of pollutants and potentially dangerous objects that can affect their health, the choice of a place of residence, and other areas of life.

The creation of this web resource became possible thanks to the support of the American people, provided through the United States Agency for International Development (USAID) and with the financial support of the government of Great Britain (UK aid).

The portal works in experimental operation mode.

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Lecture 12. European water monitoring in Ukraine: legislative framework, methodical and technical support for practical implementation.

Plan.

1. Introduction: water management and water protection policy of the EU.
2. Framework water directive, EU legislation.
3. State water monitoring in Ukraine, its approach to European standards.
4. Water strategy of Ukraine for the period until 2050.

1. Introduction: water management and water protection policy of the EU

A certain limitation in water resources in Ukraine requires the implementation of such principles of management, integrated use and protection of water that would meet the modern requirements facing the countries of Europe. Special attention is paid to issues of water resource quality management of river basins based on comprehensive ecological assessments of physical properties, chemical and hydrobiological composition of waters. In Ukraine, a movement in this direction began from the end of the 1990s to the beginning of 2000 with the development of "Methodology for ecological assessment of the quality of surface water according to the relevant categories" (1998), the implementation of a number of international scientific projects under the auspices of the UN and the European Union (EU) on the Dnipro, Tysa, Western Bug. The results of this work are implemented in the practice of state water monitoring, are reflected in the water management department, and are also covered in the educational and methodological literature of the ecological direction. The policy of the European Union and the strategy for the management of the environment, in particular natural waters, strives to achieve sustainability in the water sector in the territory of the member states. For this purpose, the Water Framework Directive (2000/60/EC) was adopted in 2000. At the same time, the system of management and protection of water resources is part of state management. In each European country, it has national characteristics, which is related to the specifics of the historical path of the formation of state administration, the level of economic and social development, the ecological situation and geographical characteristics of the country's territory, the availability and state of water resources, the culture and way of life of the population. The main requirement of the Water Framework Directive (WFD) is comprehensive water management planning based on the basin approach, which provides for:

- monitoring of water quality and quantity;
- assessment of society's water needs and the impact of human activity on water basins;
- setting goals;
- development of programs aimed at achieving goals;

- openness, consultations with the public for decision-making;
- monitoring and reporting on the implementation of the Directive.

Benefits of implementing the Water Framework Directive:

- a coordinated approach achieved through the combination of surface water management and groundwater management;
- avoiding shortages and environmental losses due to excessive water consumption. It is achieved by bringing water quality to the appropriate requirements;
- rational and sustainable use of water resources without pollution using economic mechanisms;
- prevention of management based on compliance with administrative boundaries.

Management is based on river basins and catchments (basin principle).

Although the EU plays a leading role, the responsibility for the effective implementation of the WFD rests with the Member States. National governments are responsible for the implementation of EU water policy at the national level. This is a very important link in the system, because the most advanced EU legislation cannot be implemented effectively if it is not correctly applied by the member states and translated into their national legislation. According to Art. 13 of the Water Code of Ukraine (1995), state management in the field of water use and protection and reproduction of water resources should be carried out according to the basin principle on the basis of interstate, state and regional programs for the use and protection of water and reproduction of water resources. Currently, methodological and methodical foundations of this approach are being formed in the country, programs for ecological improvement of individual river basins are being developed, and public advisory and consultative basin councils are being created. In world practice, a fairly wide range of basic principles have been established, which should become the basis for the formation of a modern management system for the use, protection and reproduction of water resources. If we group these guidelines according to their functional features in relation to environmental management at the regional level, then at least three main groups can be distinguished:

- Using the main provisions of the concept of sustainable development when forming a strategy for water use and water protection;
- Basin approach to planning and management of water resources;
- The ecosystem principle of regulating the use, protection and reproduction of water resources and regulation of anthropogenic load on the environment.

2. Framework water directive, EU legislation

European integration of Ukraine is more than a goal or visa-free. These are also practical "everyday" benefits that every citizen of Ukraine receives from the fact that the country begins to live according to European standards. Preservation of water ecosystems, access to reliable monitoring data of water resources, improvement of water quality for Ukrainians are also part of this great European integration movement. The date of the start of the implementation of the Directives by Ukraine is November 1, 2014. The implementation plan of the EU WFD was approved by the Decree of the Cabinet of Ministers of Ukraine dated April 15, 2015 No. 371 "On the approval of the implementation plans of some acts of EU legislation developed by the Ministry of Ecology and Natural Resources" http://www.kmu.gov.ua/document/248102954 /Dir_2000_60.pdf

EU legislative acts establishing requirements for surface water quality:

– Directive 2000/60/EU, (Water Framework Directive), which establishes the basis for actions in the field of water policy;

– Directive 2006/11/EC "On pollution caused by certain hazardous substances discharged into the aquatic environment of the Community";

– Directive 2008/105/EC establishing environmental quality standards (EQS) in the field of water policy for substances whose pollution control requires priority measures;

– Directive 96/61/EU On integrated prevention and control of pollution (Directive of Pollution Prevention and Control);

– Directive 2006/7/EU "On water quality management in bathing areas (beach areas)"; - Directive 98/83/EU on drinking water;

– Directive 91/271/EU concerning the treatment of municipal wastewater.

The Ukraine-EU association agreement takes into account six directives on water quality and water resources management, and should ensure their implementation in Ukraine.

The Water Framework Directive establishes the principles of management of all water resources in order to prevent water deterioration. It requires approval of river basin management plans and programs of measures aimed at achieving "good state" of waters (which includes good chemical and good ecological state), definition of protection zones. It also contains a list of priority substances, water pollution with which requires special measures (for such substances, the established environmental quality standards must be achieved in order to achieve a good chemical state). In 2022, the European Commission came out with a proposal to add 24 new substances as priority substances. The Framework Water Directive contains requirements for monitoring the state of surface, underground and other waters. For such priority substances (as well as some others), environmental quality standards (maximum

concentrations) are established in Directive 2008/105/EU.

2. Directive 2006/118/EU on the protection of groundwater against pollution and depletion establishes requirements for the quality of groundwater.

3. Directive 2007/60/EU on flood risk assessment and management is a systemic tool that is also based on integrated water resources management. Its main objective is to reduce and manage flooding risks by assessing, mapping and developing risk management plans.

4. Directive 2006/7/EU on the management of the quality of bathing waters requires monitoring, assessment of the state of bathing waters and informing citizens. By a separate implementing decision 2011/321/EU, the European Commission established requirements for information signs that must be posted to inform the public about the state of bathing water, by decision (EU) 2017/1583 – standards of equivalence of microbiological methods.

The practical tasks arising from the implementation of acts in this area are complex and require considerable time, human and material resources, and the capacity of authorities. Among such tasks, it is possible to highlight the establishment (definition) of river basins and sea waters, the development of appropriate management plans for water basins, flooding risks, monitoring the state of water resources, establishing water resource quality standards and discharge standards, reporting, etc. The Water Framework Directive establishes the principles of management of all water resources in order to prevent water deterioration. Thus, it requires approval of river basin management plans and programs of measures aimed at achieving "good state" of waters (which includes good chemical and good ecological state), definition of protection zones. It also contains a list of priority substances, water pollution with which requires special measures (for such substances, the established environmental quality standards must be achieved in order to achieve a good chemical state).

In recent years, Ukraine has adopted a number of normative legal acts for the implementation of EU directives in this area. In particular, in 2018, the Government approved the Procedure for State Water Monitoring, and at the end of 2020, the Ministry of Environmental Protection and Natural Resources approved the first modern surface and sea water monitoring programs that meet European requirements. These are the Program of State Diagnostic and Operational Monitoring of Surface Waters and the State Monitoring Program of Coastal and Marine Waters of the Black and Azov Seas. These data are the basis for the development of specific measures for the management of the river basin to improve or maintain the state of water bodies.

3. State water monitoring in Ukraine, its approach to European standards

Harmonization of the relationship between man and nature, protection of the natural environment, rational use of water resources - these issues are among the most relevant at the moment, because they affect every inhabitant of the planet, and the future of all humanity depends on their solution. At the same time, providing the world's population with water is one of the priorities of sustainable development defined by the UN. Every year, Ukraine increasingly experiences both the problem of water shortage and the accumulation of environmental problems directly related to water resources. As a result, the need to create an effective national water resources management system capable of ensuring the achievement of a good ecological state of water, the rationality of its use, and the introduction of effective incentives for sustainable development is necessary today. Obtaining detailed objective information about the state of river basins is possible only on the basis of their systematic state monitoring of waters, which is an integral part of the state system of environmental monitoring of Ukraine and is carried out in accordance with the procedure determined by the Cabinet of Ministers of Ukraine [3], based on international and national legislation.

The purpose of state water monitoring is to ensure the collection, processing, preservation, generalization and analysis of information on the state of water bodies, forecasting its changes and the development of scientifically based recommendations for decision-making in the field of use, protection of water and reproduction of water resources [11].

Surface water quality monitoring in Ukraine is carried out according to the basin principle, according to the Surface Water Monitoring Program, by specialists of 27 laboratories on 436 reaches of 170 rivers, 29 irrigation systems, 1 estuary, 11 channels of complex purpose. More than 3,000 samples of surface water are taken annually, and about 100,000 measurements of parameters characterizing the hydrochemical and physicochemical state of water bodies are performed [5].

The organization and conduct of state monitoring of surface water resources of Ukraine is ensured by state legislative documents:

- Constitution of Ukraine;
- Law of Ukraine "On Environmental Protection";
- The Water Code of Ukraine, the Law of Ukraine "On Amendments to Some Legislative Acts of Ukraine Regarding the Implementation of Integrated Approaches to Water Resources Management According to the Basin Principle";
- Resolution of the Cabinet of Ministers of Ukraine No. 391 dated 30.03.1998 "On approval of the Regulation on the state environmental monitoring system";
- Order of the Ministry of Ecology and Natural Resources of Ukraine dated February 6, 2017 No. 45 "List of pollutants for determining the chemical state of

surface and underground water bodies and the ecological potential of artificial or significantly altered surface water bodies".

➢ Resolution of the Cabinet of Ministers of Ukraine dated September 19, 2018 No. 758 "On approval of the Procedure for state monitoring of water" and others.

The highest regulatory document is the Constitution of Ukraine, which guarantees the rights to a sufficient standard of living and environmental safety by providing drinking water in the necessary volumes and in accordance with established standards. Article 50 states: "Everyone has the right to an environment safe for life and health and to compensation for damage caused by the violation of this right" [8]. The practical implementation of relations in the mentioned sphere is regulated by lower-level legal acts: the Water Code of Ukraine, laws of Ukraine, decrees of the President of Ukraine, resolutions of the Cabinet of Ministers of Ukraine, acts of ministries and agencies, territorial bodies, etc.

The main legislative act in the field of water management in Ukraine is the Water Code of Ukraine, which, together with other measures of organizational, legal, economic and educational influence, contributes to the formation of the water and ecological legal order and ensuring the ecological safety of the population of Ukraine, as well as more effective, scientifically based use of water and their protection from pollution, clogging and depletion [2]. Article 21 of the Water Code of Ukraine defines the concept of state water monitoring. It states that "in order to ensure the collection, processing, preservation and analysis of information on the state of water, forecasting its changes and the development of scientifically based recommendations for making management decisions in the field of water use and protection and reproduction of water resources, state water monitoring is carried out. The components of state water monitoring are monitoring indicators:

- biological,
- hydromorphological,
- chemical,
- physical and chemical.

In order to implement the Water Directive and Ukraine's obligations under the Association Agreement between Ukraine and the European Union, on October 4, 2016, the Law of Ukraine "On Amendments to Certain Legislative Acts of Ukraine Regarding the Implementation of Integrated Approaches to Water Resources Management According to the Basin Principle" was adopted [6]. The law made significant changes to the Water Code of Ukraine. In particular, the hydrographic and water management zoning of the territory of Ukraine was implemented, the basin principle of water resources management was implemented, the methodology and classification of the ecological and chemical state of the surface water body, the ecological potential of the artificial or significantly changed surface water body, as

well as the quantitative and chemical state of the underground water body was implemented. These changes also provided for the definition of the "List of pollutants for determining the chemical state of surface and underground water bodies and the ecological potential of artificial or significantly altered surface water bodies", which was implemented through the order of the Ministry of Ecology and Natural Resources of Ukraine dated 02.02.2017 No. 45 [9].

Monitoring of water resources is embedded in the structure of the main environmental law of Ukraine, the Law of Ukraine "On Environmental Protection", which, among other things, in Art. 20 states the authority regarding "the organization of monitoring of the natural environment, the creation and maintenance of the network of the nationwide ecological automated information and analytical system for providing access to environmental information" [7]. Article 22 of the mentioned Law specifies that "in order to ensure the collection, processing, preservation and analysis of information on the state of the environment, forecasting its changes and the development of scientifically based recommendations for making effective management decisions in Ukraine, a system of state monitoring of the environment is being created".

The results of monitoring and evaluation of the implementation of the state environmental policy strategy are highlighted in the National Report on the Implementation of the State Environmental Policy of Ukraine, which is submitted by the Cabinet of Ministers of Ukraine to the Verkhovna Rada of Ukraine every five years, in regional and sectoral environmental annual reports, which are submitted to the central executive body.

After the ratification of the Water Framework Directive and the signing of the Association Agreement between Ukraine and the EU in 2014, our state undertook a number of obligations to adapt its own regulatory framework, standards, procedures and monitoring methods. The basic document was Resolution No. 758 of the Cabinet of Ministers of Ukraine dated September 19, 2018 "Procedure for state water monitoring" [12], which entered into force on January 1, 2019. This document complies with EU directives and will help to obtain more information about the state of water in Ukraine. According to the new document, monitoring is carried out according to the basin principle of river management. The assessment of the condition is carried out for the entire river basin, and not for a part within the administrative division (integrated management of water resources according to the basin principle at the legislative level was introduced back in 2016). This principle of water resources management also guarantees a direct connection between the water usage fee and the financing of priority water protection measures within the basin.

Previously, monitoring results obtained in some part of the river were attributed to the entire river, but according to the new "Procedure", monitoring will be carried

out for each water body separately. And another principle of comparison of rivers will be applied - not between themselves or with a mountain river where the water is very clean, but the same river basin with itself in different periods of observation, in dynamics. An extended list of biological, hydromorphological, chemical and physico-chemical indicators for monitoring is also provided - a total of 45 priority pollutant substances. Different indicators are used for different waters: surface, underground and sea. There are 5 classes of ecological status: "excellent", "good", "satisfactory", "bad" and "very bad" and 2 classes of chemical status: "good" and "not achieving good". The practical implementation of the resolution was the order of the Ministry of Environmental Protection and Natural Resources of Ukraine dated December 31, 2020 No. 410 "On the approval of state water monitoring programs" [10], which for the first time defined the systematic diagnostic and operational monitoring of surface waters with the recording of biological, physico-chemical, chemical (priority), chemical (basin specific), hydromorphological indicators. The monitoring plan also states: names and codes of monitoring points, geographic coordinates (longitude, latitude), river basin district, sub-basin, surface water category, surface water body type. The periodicity, subjects and performers of monitoring have been determined. Subjects of state water monitoring are:

- ❑ Ministry of Environment and Natural Resources of Ukraine (Ministry of Natural Resources);
- ❑ State Water Agency of Ukraine (State Water Agency);
- ❑ State Geology and Subsoil Service of Ukraine (State Geonadra);
- ❑ State Emergency Service of Ukraine;
- ❑ The State Agency of Ukraine for the Management of the Exclusion Zone (in the exclusion zone and the zone without conditional (compulsory) resettlement of the territory that suffered radioactive contamination as a result of the Chernobyl disaster).

The objects of state water monitoring are:

- ✓ massifs of surface waters, including surface coastal waters and zones that should be protected;
- ✓ underground water;
- ✓ marine waters within the territorial sea and the exclusive maritime and economic zone, including zones that should be protected.

The overall coordination and organization of monitoring is entrusted to the Ministry of Natural Resources. This document defines a clear division of responsibilities between monitoring subjects without duplication of powers, and introduces new monitoring indicators that have not been measured in Ukraine until now – prioritized, hydromorphological and biological [12]. According to the new monitoring system for surface, underground and sea water, a clear division of responsibilities between organizations that measure indicators is provided, without

duplication of powers, a six-year monitoring cycle has been introduced, and the number of water monitoring points has increased from hundreds to several thousand.

The Ministry of Environmental Protection and Natural Resources of Ukraine has been designated as responsible for the development and approval of the state monitoring program. The regulatory act specifies that such a program must contain: information about the state water monitoring facility (code, facility name, location, and other characteristics); biological, physico-chemical, chemical and hydromorphological indicators, frequency of monitoring, information about the subject and performer of water monitoring.

There are also categories of procedures carried out in accordance with the goals and tasks of monitoring, namely the procedure:

- ✓ diagnostic monitoring,
- ✓ operational monitoring,
- ✓ research monitoring of surface water bodies,
- ✓ seawater monitoring procedure.

Diagnostic, operational and research monitoring will be carried out on biological, physico-chemical, chemical and hydromorphological indicators according to the basin principle. For this purpose, appropriate state monitoring programs for water in river basins are being prepared. Diagnostic monitoring of surface water masses is one of the most important stages in the development of the River Basin Management Plan. The implementation of European standards for water management through the implementation of the River Basin Management Plan aims to achieve a "good" ecological state of water bodies [1]. Diagnostic monitoring is carried out for surface waters during the first year of state monitoring, for groundwater – during the first two years of state monitoring. It will help to know how human activity influenced the quantitative and qualitative state of water. On its basis, measures will be developed to achieve a "good ecological state" and a "good chemical state" of waters. Operational monitoring is carried out for water bodies where there is a risk of not achieving a good ecological state of the waters, or water is taken annually for drinking and domestic needs. Operational monitoring data are the basis for the development of specific measures in terms of river basin management to improve or maintain the condition of water bodies. Research monitoring is carried out by the subjects of state monitoring of waters, which independently determine the points, the list of indicators and the frequency of their measurement. Based on the data and information obtained as a result of monitoring of water masses, the ecological and chemical state of surface/ground water masses, the ecological potential of artificial or significantly modified surface and sea water masses are determined [4, 12].

In accordance with the State Water Monitoring Program, approved by the Order of the Ministry of Environmental Protection and Natural Resources of Ukraine "On

Approval of State Water Monitoring Programs" dated December 31, 2020 No. 410 [10], diagnostic monitoring is carried out according to the following indicators and with the following frequency:

- ✓ biological (once a year),
- ✓ physical and chemical (12 times a year),
- ✓ chemical (prioritized) (12 times a year),
- ✓ chemical (pool specific) (12 times a year),
- ✓ hydromorphological (once every 6 years).

Taking into account the collected data on bodies of water, they develop management plans for river basins and assess the level of achievement of ecological goals; regarding marine waters, they are developing a marine strategy for achieving a "good" ecological state [12].

4. Water strategy of Ukraine for the period until 2050

The Decree of the Cabinet of Ministers of Ukraine dated December 9, 2022 No. 1134 approved the Water Strategy of Ukraine for the period until 2050.

The strategy is designed to solve the main water problems of the country, namely:

- ❑ ensuring equal access to high-quality drinking water that is safe for health;
- ❑ achieving a "good" ecological state of waters;
- ❑ prevention of droughts, floods and other harmful effects of water;
- ❑ sustainable management of water resources according to the basin principle.

Among the expected results of the Strategy:

- ➢ by 2024 – 100% of the legislative framework in the water sector meets EU requirements;
- ➢ by 2024 – 9 river basin management plans have been created;
- ➢ from 2025 – annual restoration of at least 5 km of small river beds;
- ➢ by 2027 – 100% of washing powder contains permitted concentrations of phosphates and other phosphorus compounds;
- ➢ by 2032 – up to 20% reduction in the annual amount of damage caused by floods and high water levels, compared to 2020;
- ➢ by 2030 – 100% of the urban population has high-quality water supply and drainage;
- ➢ by 2050 – 95% of the rural population has high-quality water supply and drainage;
- ➢ 2043-2050 years – 100% implementation of indicators of river basin management plans and flood risk management plans.

The monitoring system of surface water resources in Ukraine has acquired a legislative justification. Since 2019, European approaches to water monitoring have

been implemented in Ukraine in accordance with the requirements of the Water Framework Directive, according to which monitoring is an integral part of the reform of environmental control and responsibility and the basis for making any management decisions. The main task is a real assessment of the state of water resources and the possibility of making effective decisions based on reliable data, providing the public with access to information about the state of water bodies. In accordance with the requirements of integration with the EU, all received data will be classified according to European standards and in full compliance with EU water directives.

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Lecture 13. Quality of underground and surface water and assessment of suitability for use (experience of EU countries).

Plan.

1. Effectiveness of the implementation of the requirements of the Water Framework Directive.
2. Basin water resources management system.
3. Improvement of monitoring of the quality of land surface waters
4. Management of water resources in certain European countries.

1. Effectiveness of the implementation of the requirements of the Water Framework Directive

River Basin Management Plans are a key tool linking the Water Framework Directive and the Urban Waste Water Directive. Ukraine's obtaining the status of a candidate for EU membership requires wider and stricter implementation of norms, standards and obligations, including in the field of water resources. In particular, in accordance with the Ukraine-EU Association Agreement, Ukraine undertook to implement the requirements of 6 water Directives, including the key Water Framework Directive and the Urban Wastewater Directive.

The effectiveness of the implementation of the requirements of the EU Water Framework Directive is closely related to and depends on the implementation of the requirements of the Urban Wastewater Directive. The list of plans for the river basin area will contain measures aimed at reducing water pollution by organic, biogenic and hazardous substances, will include planned infrastructure projects and measures aimed at reducing their impact on the state of surface waters. Up to 60 % of the effectiveness of river basin management plans in reducing water pollution is the construction, reconstruction, and modernization of water treatment facilities and drainage networks. At this stage, 9 RBMP projects have been developed for all river basins, which will be supplemented by a program of measures to achieve good water condition. The management plans are measures for the recovery of the water sector and are included in the Recovery and Reconstruction Plan of Ukraine in the post-war period. Reconstruction must be carried out in accordance with the requirements of EU Directives.

The state of surface waters is determined by ecological and chemical status. Ecological status is determined, first of all, by the state of biological elements (fish, benthic invertebrates, aquatic flora), evaluated according to five classes:

- excellent;
- kind;
- satisfactory;
- bad;

➢ very bad.

Chemical status is assessed by only two classes:

➢ kind;

➢ unable to achieve good.

Within the borders of Ukraine, 9 regions of river basins have been allocated:

- ❑ Vistula (Western Bug, Syan);
- ❑ Danube;
- ❑ Dniester;
- ❑ Southern Bug;
- ❑ Dnipro;
- ❑ Don;
- ❑ rivers of the Black Sea region;
- ❑ rivers of the Azov region;
- ❑ rivers of Crimea.

The Water Framework Directive (Directive 2000/60/EC) provides a legislative framework for achieving good status for water bodies, both surface and groundwater, and provides for the following key principles regarding water quality:

➢ five classes of ecological status of surface water bodies are provided: "high", "good", "moderate", "low", "bad";

➢ the general goal of WFD is to achieve "good status" of all waters (surface and ground);

➢ states should develop their own indicators of the ecological state from "high" to "poor", since the initial (natural background) conditions for surface waters are different in different countries;

➢ good state of surface water – such a state of a surface water body, for which its ecological and chemical state can be called at least "good";

➢ good chemical status is the status of surface waters, in which the concentrations of pollutants do not exceed the European quality standards for all types of chemicals.

➢ The good condition of a water body implies that

➢ biological indicators of the state deviate from the reference ones only to a small extent;

➢ the main physical and chemical indicators ensure the normal functioning of the ecosystem and all types of water use;

➢ the content of priority polluting substances corresponds to HYANO.

Physico-chemical parameters in the classification of the state of surface waters:

general: temperature conditions, oxygen regime, content of basic ions, mineralization, pH, content of consumer substances (total nitrogen, nitrites, nitrates, total phosphorus, phosphates;)

specific: 33 substances according to Annex X to the WFD, which have the highest priority for taking joint actions to reduce or eliminate their entry into natural waters (priority substances);

other substances that are found in this water body in significant quantities.

When classifying the state of surface waters, there is a clear difference between the role of general physicochemical elements of quality and specific pollutants:

➢ with a good ecological condition, the content of general physico-chemical quality elements should not exceed the limits established to ensure the functioning of the ecosystem and achieve the values determined for biological quality elements;

➢ the content of priority pollutants must comply with the Environmental Quality Standards (EQS) (Order of the Ministry of Ecology and Natural Resources of Ukraine dated 20.02.2017 No. 235/30103 "On approval of the List of pollutants for determining the chemical state of surface and underground water bodies and the ecological potential of artificial or significantly changed massif of surface waters").

EU Directive 2009/90/EU regulates the requirements for measurement methods. This Directive establishes the technical characteristics for chemical analysis and control of the water condition in accordance with Article 8 (3) of the WFD:

✓ the methods used to control environmental indicators and parameters must comply with international ISO standards and European EN standards. It is also allowed to use national standards that guarantee obtaining data of the same degree of accuracy and comparability as ISO and EN;

✓ methods of analysis should provide the ability to determine the concentration of a pollutant in water at the level of 30% of the EQS with an uncertainty of not less than 50%. If the EQS is absent, or there is no method for defining, control using the best available methods that do not lead to dramatic costs is made;

✓ quality control: member states must ensure that laboratories participating in water quality assessment meet the requirements of ISO 17025 "General requirements for the competence of testing calibration laboratories" (in the national standardization of SSU ISO 17025:2005); laboratories must confirm competence through participation in professional testing programs; using in practice the production of standard samples that ensure control of the content of contaminated substances in accordance with the requirements of Article 4.

The main areas of harmonization of domestic physical and chemical research of water bodies with EU approaches:

✓ classify surface water bodies by establishing quality standards characterizing their reference and good condition according to basic physical and chemical indicators;

✓ justify the list of particularly dangerous pollutants (prioritized substances) that cannot be discharged into water bodies and develop standards for their content in

water and other components of water ecosystems;

✓ provide an economically justified program for monitoring the physical and chemical indicators of the quality of surface water and compliance of discharged wastewater;

✓ maintain at the appropriate level and develop the technical and personnel potential for monitoring and analytical control, continue the implementation of international standards in the activity of the laboratory;

✓ develop rules for assessing the quality of surface base waters and the state of water ecosystems, provided by physical and chemical indicators.

2. Basin water resources management system

The main principles of water resource management in most developed countries are as follows:

➢ management is carried out by the river basin, and not by the administrative territory, since the basin management principle is based on the actual interrelationships and unity of surface and underground waters within the river basin. Water resources are managed not as a once-measured volume or physical body, but as a complex water exchange system, with its main characteristics, including a multi-sectoral structure of water use, water composition, environment, ecological condition;

➢ management of water resources of the river basin at the final stage is carried out collectively. Different countries do it differently, but the idea is the same – to create two levels of government: legislative and executive. The first is implemented by the creation of the Basin Council, the second by the creation of the Water Agency.

Basin Councils and Water Agencies are the main structures in the system of collective management of water resources of the rivers of the basin (perhaps several small basins).

The basin council is the legislator for all water problems of the basin and constitutes a small real "parliament of water". This "parliament" consists of representatives of water management organizations, water users, local administration and representatives of the population. Council members are appointed by the administration, elected by the population or recommended by organizations. In different countries, the process of forming the Council is different. The Basin Council carries out water management policy within the framework of national programs with the aim of protecting the water resources of the basin from depletion and pollution, ensuring the functioning of the economy and the natural environment; it also approves the action program of the Water Agency and cost estimates.

National ministries and departments, local administration should not interfere in the actions of the Council and the Agency, but on the contrary, should create conditions for the implementation of their plans. The Water Agency is the executor of

the decisions of the Basin Council. It is obliged to monitor the state of the river, all water consumers and ensure coordination of water consumption and drainage with the problems of water source protection. The main activity of the Water Agency is production and financial assistance in the execution of certain types of work, individual projects by the agency's organizations, lending on preferential terms to other contracting organizations that perform water management works.

Management of water resources is carried out with the help of economic levers, in particular, payment for the use of water and its pollution. All funds must go to the agency and be used to improve the water quality and ecological condition of the rivers of the basin, improve the water supply of the population and implement other measures. For each basin, a scientifically based program for preserving and improving the water-ecological condition is developed for the future (5-10 years) and approved by the Basin Council. This program is then implemented by the Water Agency. Funds received for water are taxed as income and are not spent on other purposes, except for water management problems in the basin. During 2004–2006, the international project "Management of the Bug, Latoritsa and Uzh River Basins" was implemented under the European Union program for Ukraine on cross-border cooperation. The cross-border cooperation project was aimed at implementing the provisions of the Helsinki Convention (1992) and the EU Water Framework Directive (2000) on integrated and balanced water resources management. The project was implemented in three main directions:

- cross-border cooperation;
- implementation of the organizational structure of river basin management;
- complex monitoring and management of water resources.

Within the basins, in order to carry out the functions of management, planning and control over the use, protection and reproduction of river waters, implementation of international programs and agreements on these issues, ecological improvement of the basin, development of international cooperation on issues of monitoring and information provision, coordination of actions to prevent emergency situations, a new water resources management system for Ukraine is being implemented, which is based on the principle of basin planning, declared in the EU Water Framework Directive.

3. Improvement of monitoring of the quality of land surface waters

Monitoring is a system of observing anthropogenic changes in the natural environment, assessing and forecasting its condition against the background of natural changes. Monitoring solves the following tasks:

1) observation of changes in the state of the biosphere, determination of changes caused by human activity and generalization of the results of observations;

2) identification of trends and forecast of possible changes in the state of the biosphere by comparison with the criteria (maximum permissible concentration – MPC and maximum permissible load – MPL), which set the limits of possible environmental damage.

The complexity of monitoring sea pollution requires the determination of a number of hydrometeorological parameters: water temperature, current speed and direction, wind speed and direction, amount and quality of precipitation, atmospheric pressure, etc.

The monitoring and control system is based on the formation of a network of local points (stations), the placement of which makes it possible to determine pollution fields. At marine water pollution monitoring stations, work is carried out according to two programs - abbreviated and full.

The scientific basis of monitoring sea pollution has the following main principles of organization: 1) the complexity of conducting chemical analysis (water, suspended substances, bottom sediments) and meteorological observations, especially at stations of the I category – in the places of discharge of polluting substances and of the II category – in the polluted areas of the seas and oceans; 2) determining the dynamics of seawater pollution by conducting long-term systematic observations of the background concentrations of pollutants in the areas furthest from the sources of pollution at category III base stations; 3) analysis of pollutant transport processes through observations on oceanographic sections and the main circulation systems of the World Ocean; 4) consistency of ocean pollution monitoring as a subsystem of environmental monitoring with monitoring of the impact of pollutants on marine organisms.

Monitoring of pollution sources. This is a system of observation, assessment and forecasting of the volume and level of pollution of wastewater, which is discharged by the source of pollution into water bodies. The observation system can be stationary or mobile. The obtained information on the composition and volume of wastewater, the further development of the source of pollution makes it possible to predict changes due to the impact of the source of pollution on the water body and to establish maximum permissible emissions (MPEs), which limit the volume and amount of harmful substances discharged into water objects.

Monitoring of land surface water pollution. This is a system of observation, assessment and forecast of the state of surface waters of the land to obtain information about their quality, necessary for the rational use of water resources and the implementation of measures to protect them from pollution and depletion. In this regard, the monitoring of land surface water pollution solves the following main problems:

- observation and control of the level of pollution of surface waters of land

based on physical, chemical and hydrobiological indicators;

- studying the dynamics of polluting substances and identifying the conditions under which sharp fluctuations in the level of pollution are observed, in order to provide forecasts of the level of pollution of water bodies;
- study of the patterns of self-cleaning processes and accumulation of pollutants in bottom sediments;
- study of patterns of entry and exit of substances through estuaries of rivers to draw up the balance of chemical substances of water bodies.

Systematic monitoring and control of the level of surface water pollution both in places exposed to the influence of human economic activity and in areas of minimal pollution (background creation) are carried out by the organization:

- a stationary network of observation points for the natural state and pollution of surface waters by physical, chemical and hydrobiological indicators;
- a specialized network and points of observation and control on polluted water bodies to solve a number of scientific and research tasks;
- a temporary expeditionary network of observation and control points on water bodies not covered by the above-mentioned observations.

At fixed network points, the list of water quality components is determined primarily by the composition and volume of wastewater discharged into the water body, its toxicity, and the requirements of water consumers. These include: water temperature, suspended solids, mineralization, color, pH, dissolved oxygen, ChOC, BOC, odor, major ions, biogenic substances, as well as very common pollutants such as petroleum products, volatile phenols, biogenic substances, heavy metals.

The approach to the organization of the system of observations for biological indicators is generally the same as for physical and chemical ones, that is, it involves conducting observations and control at established points in the agreed terms and according to a single unified methodology. In order to determine the program of hydrobiological observations, it is necessary to accumulate hydrobiological information for various species over a period of time: macrophytes, phyto-, bacterio-isoplankton, zoobenthos, neuston, periphyton.

The monitoring system of land surface water pollution includes observation and control of the level of pollution of the bottom sediments of the water body. At the current rates of pollution of water bodies, many harmful pollutants accumulate in significant quantities in bottom sediments, which are a source of secondary pollution. Points of observation and control must be combined with hydrological posts or areas that are provided with hydrological data.

In the monitoring system of the State Water Agency of Ukraine, in order to forecast the water supply of sectors of the economy and the population with water of appropriate quality, observations are carried out on 125 rivers, 34 reservoirs, 6 canals,

32 irrigation systems, the waters of which are used for intensive technical and drinking water supply (1995).

The improvement of the system of observation and control of surface waters of land is developing in the following main directions:

- ✓ optimization of the observation system (in particular, placement of control points), clarification of observation programs (terms, frequency);
- ✓ improvement of chemical-analytical and biological support of the control system (new methods of water analysis, their unification);
- ✓ development and widespread implementation of automated and remote methods of obtaining, processing and transmitting hydrochemical information;
- ✓ creation of electronic banks of hydrochemical information;
- ✓ creation of new and improvement of existing water quality forecasting methods.

In general, the automation of analysis methods, along with the use of new highly sensitive methods, are the most important directions in hydrochemistry. In a number of countries, automatic water quality control stations have appeared, which determine such indicators as temperature, dissolved oxygen, specific electrical conductivity, pH, sodium content, chlorine - up to 20 indicators in total. Several stations located on water bodies according to a certain scheme, in the presence of an information processing center and communication channels, create a system. The advantage of such systems is the continuity of observations. It is advisable to create automated systems in areas with a stressed water balance, where they will become part of water quality management in the future. In Ukraine today, automatic water quality control stations are widely used in the Transcarpathian region in the basin of the Black Tisza River. Automated systems include: an information processing center, which consists of a control room, a computer complex, and stationary hydrochemical and hydrobiological laboratories; automatic water pollution control stations, which determine indicators of the chemical composition of water; mobile hydrochemical and hydrobiological laboratories.

Promising methods of observing and monitoring the state of water bodies are remote, including aerospace, methods, which are extremely effective in studying large water areas and need improvement. The conducted studies revealed a connection between the parameters of electromagnetic radiation and some indicators of water bodies: the concentration of phytoplankton chlorophyll, mineral suspended and dissolved organic substances, mineralization, water temperature, and the intensity of wave processes.

The first systems of remote monitoring of water bodies are being created. They include: spacecraft; data reception and processing centers; aerial observation stations; automatic buoy stations. The upper level of the operational monitoring system is a

spacecraft with remote sensing equipment. Multi-zone video information is transmitted to data reception and processing centers. Here, information is processed and maps of optically active ingredients are created, by which variability in time and space of hydrochemical and hydrobiological fields is determined, as well as to detect sudden changes in the state of aquatic ecosystems. This information is transmitted to the territorial hydrometeorological offices.

If anomalies are detected on the maps based on space data, which indicate changes in the water in the ecosystem, its middle link - the aerial observation station - is connected to the monitoring. These stations (e.g. airplanes) are equipped with remote measuring devices for electromagnetic radiation in the visible, infrared, and ultrahigh-frequency wave ranges. The information received at the air observation station is sent to the on-board information and measurement complex, which is used to visualize these data and pre-process them. The remote monitoring link can include a mobile hydrochemical and hydrobiological laboratory, which is placed on board a ship or on a car, automatic buoy stations. Means for emergency measurements of concentrations of some ingredients are placed at automatic buoyancy stations. The information received from the buoys is transmitted to the air observation station, and from it through the spacecraft to the data reception and processing center.

In the monitoring system of the Hydrometeorological Service of Ukraine, regular observations are made of physical, chemical and biological indicators of water quality. Water quality control points are combined with hydrological stations and areas provided with hydrological data. The identified ingredients include:

- ionic composition,
- mineralization,
- suspended substances,
- dissolved oxygen,
- biogenic compounds,
- oil products,
- phenols,
- pesticides,
- heavy metals.

Radiation monitoring of surface waters in connection with the accident at the Chernobyl NPP is carried out in the Dnipro basin - on reservoirs, main tributaries (Pripyat, Uzh, Teteriv, Desna) and some small rivers. In recent years, monitoring networks have been optimized, expanding the list of ingredients to be determined and specifying the placement of observation points.

Surface water chemical analysis laboratories operate in structural units of the Hydrometeorological Service of Ukraine. The network of observations of the hydrometeorological service includes 231 stationary points, these points are located

on 134 rivers, 15 reservoirs and 1 estuary and cover the following main river basins of Ukraine: Dnipro, Danube, Dniester, Southern Bug, Western Bug, Siversky Dinets, Priazovya rivers. The choice of observation points is determined by the physical and geographical conditions of the region, and for conducting research on polluted objects, the placement of observation points should provide the most complete description of the extent and types of pollution.

As a rule, most of the points include several cross-sections (above and below the site of wastewater discharge), vertical (on a rod at a distance of 3–5 m from the shore) and horizontal (surface, deep) sampling. In total, taking into account cross-sections, verticals and horizontals, samples are taken at almost 500 points. The highest density of observation points is in industrial areas, especially on the Dnipro and its reservoirs. On average, each river, except for the Dnipro, has 1–2 observation points, which provides fairly complete information about their ecological state. Special attention is paid to water quality control of the Dnipro and its reservoirs, the average water flow of which is 60% of the total water flow of the rivers of Ukraine.

In the monitoring system of the State Water Agency of Ukraine, in order to forecast the water supply of sectors of the economy and the population with water of appropriate quality, observations are carried out on 125 rivers, 34 reservoirs, 6 canals, 32 irrigation systems, the waters of which are used for intensive technical and drinking water supply (1995).

4. Management of water resources in European countries

4.1. Basic principles of water resources management in France

In accordance with the water law in France in 1964, a highly efficient water management system was organized, which is now recognized as one of the best in the world. Thanks to this system, the ecological condition of French rivers improved significantly in the 1980s. The modern water policy of France is built in accordance with the new water legislation of the country, which is based on the following principles of natural water management:

✓ decentralization - they manage not water as a physical body, but a water exchange system, the unit of which is the river basin. The basin rather than the administrative-territorial principle of management, which is based on the actual unity of surface and underground waters within a single water exchange area and considers the river as a complex, simultaneously hydrological, physical, chemical, biological and social system, allows the most complete resolution of all water and related environmental problems;

✓ fee for water and pollution - any water user pays for it, and every polluter pays much more;

✓ organization of institutes of collective water management, the task of which includes regulation and elimination of actually existing contradictions between consumers and water polluters, ensuring rational water withdrawal from a specific water system;

✓ ensuring the legal right of any resident or organization to water without violating the rights of other consumers;

✓ preservation of the water environment as the main regulator of the state of the entire environment, the basis for ensuring the improvement of people's living standards and the development of the economy;

✓ conducting continuous studies of the state of the water environment.

4.2. Basic principles of water management in Great Britain

Since 1973, after the adoption of the law on water resources in Great Britain, the Water Resources Authority was established, the powers of which included the regulation of water management activities in specific water basins. According to this law, the engineering and environmental policy for the operation of river basins included:

✓ development of surface water quality standards;

✓ preparation and implementation of technical projects for relevant river tributaries, discharge points and water intake;

✓ ensuring the ecological well-being of water ecosystems.

Until 1989, water management in England and Wales was in the hands of the state. At the same time, there was a conflict of interests, because the same state administration bodies were responsible both for taking water from water bodies and supplying it to water consumers, and for discharging return water and preventing pollution. In 1989, in order to improve water management, the British government implemented measures to privatize the water supply service. Ten private public water companies currently provide water and sewerage services to consumers in England and Wales. Withdrawal of water from water bodies is regulated by the National River Administration (NRA), and discharge of return water is regulated by Her Majesty's Pollution Control Board (PCB) and the NRA. Unlike the bodies of the French basin management, the NRA performs the functions of administrative regulation of water use, but does not have the rights of its financial regulation. To implement the national policy in the field of water resources use and protection, long-term programs are being developed in Great Britain, which define the main directions of water management activities. The greatest attention is paid to the following issues:

✓ rational water use and drainage;

✓ prevention of degradation and restoration of water bodies;

✓ hydroecological control;

✓ creation of technical means of water quality control and management.

A water protection program until 2030 has been developed.

4.3. Basic principles of water resources management in Spain

In Spain, the Law on Water Resources, which entered into force in 1986, reflects the general tendency of the EU to expand the concept of rational use of water resources. Legal provisions that regulate administrative activities contribute to the gradual implementation of integrated water resources management. The leading state bodies in this area are the River Basin Management and the National Water Resources Council. The Council is the main consultative body in which autonomous regions and river basin management are represented. The main principles of the law on water resources are also included in the instructions of the river basin authorities, which are responsible for the development of hydrological plans. Under the Water Resources Act, the National Water Board is required to report on plans and projects of a general nature that may cause long-term impacts on water resources.

4.4. Basic principles of water resources management in Germany

In Germany, the declared goal of water management policy is to restore and maintain the ecological balance of the country's water bodies. Such an environmental policy is a necessary condition for long-term and guaranteed supply of good quality water to the population and other consumers. In 1986, the general legislation was significantly revised. The need to expand the concept of water resources management was emphasized and amendments were made to federal laws: on water resources, detergents, and waste disposal. These laws aim to implement preventive measures and support the use of levers such as "polluter pays" and "best available technology". Positive results were achieved when the law on detergents was adopted: in 10 years, the amount of phosphorus in detergents was reduced by approximately 50%. As a result of anti-pollution measures adopted by municipalities and industries, the number of polluted water bodies has decreased.

4.5. Basic principles of water resources management in Norway

In Norway, to support an integrated approach to water management at the government level, an advisory committee on coordination of water management was established in 1978, which included representatives of six ministries. An important role is assigned to the new law on planning and construction. If in the previous law (adopted in 1985), the main attention was paid to land use planning, then in the new law, significant importance is given to the issue of the use of lakes, rivers, and coastal waters. An important role in the implementation of laws and compliance with the norms of water use and land use is played by the Department of Environmental

Protection, whose 18 branches have created a strong system of regional-level promotion of long-term use and protection of natural resources, including water. Local authorities are primarily responsible for proper water supply. In 1985, the parliament adopted a plan for the development of drinking water supply. High quality standards are supported by the legally proposed norms for the protection of reservoirs and water intakes from activities or works that may cause pollution.

4.6. Basic principles of water resources management in Finland

Finland's centralized water management system, together with widely developed legislation, forms the basis for integrated water management and planning. In 1983, the Ministry of Environmental Protection was established in the country, which is responsible for all the main areas of environmental protection. In 1987, amendments to the Water Resources Act (1962) emphasized the need for ecological approaches to surface water management. A national targeted program for combating pollution of water bodies was adopted, and a government committee was established to develop a comprehensive system of financing environmental protection activities.

Ukraine's transition to European principles of water monitoring has become a key topic for discussion by representatives of monitoring entities and civil society. This led to the following changes:

✓ new legislation was formed in accordance with the requirements of the Water Framework Directive;

✓ biological, hydromorphological, physico-chemical and chemical (priority and basin-specific) indicators are investigated as part of the measurements;

✓ new types of monitoring were introduced - diagnostic, operational, research and marine water monitoring;

✓ a single program for monitoring subjects was approved;

✓ 4 modern laboratories for water monitoring are equipped;

✓ the assessment of the state of surface water masses according to 5 classes of ecological and 2 chemical states has been introduced.

The introduction of European requirements requires a fundamental restructuring of the functionality of the State Water Agency's laboratories, which is observed at this stage. Water pollution is a significant health hazard. It promotes the spread of diseases such as cholera and dysentery and can cause other long-term illnesses. There can also be negative consequences for the environment and the economy: both the loss of income from tourism and a decrease in agricultural productivity. 28% of Europe's groundwater is contaminated, and most of the drinking water comes from here. The disposal of nitrates and pesticides, caused mainly by modern farming methods, costs utilities billions of euros. Pollution comes from the urban environment, plastic, sewage and cooling water from power plants. Sewage

inevitably enters waterways, as evidenced by another alarming figure: 22% of Europe's streams, rivers, lakes and seas are affected.

The EU Directorate-General for the Environment provides the following statistics:

✓ the total environmental costs associated with nitrogen pollution are estimated in the EU from 70 to 320 billion euros per year.

✓ In 2022, 85.7% of bathing sites were rated as excellent in the EU and minimum water quality standards were met in 95.9 % of sites.

✓ Unsafe water kills more people each year than war and all other forms of violence combined.

✓ 81% of sea waters, 31% of coastal waters, 36% of rivers and 32% of lakes in the EU are eutrophic (enriched with biogenic elements, which is accompanied by the destruction of the reservoir's productivity). Too much nitrate in the water leads to excessive growth of seaweed, which has a negative effect on plant and animal life.

✓ 22% of Europe's surface water bodies and 28% of groundwater are significantly affected by diffuse pollution from agriculture with both nutrients and pesticides.

✓ 230,000 tons of plastic enters the Mediterranean every year from land-based sources; 20,000 tons are for shipping activities.

✓ Europeans are concerned about pollution: 69% consider it the main threat to their water supply.

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Lecture 14. Assessment of water quality taking into account European experience and international standards.

Plan.

1. The maximum allowable concentration of pollutants.
2. Proposals for revising the list of priority substances in surface waters.
3. Assessment of water quality: world experience.
4. Methodology of ecological assessment of surface water quality by relevant categories.
5. Overview of EU policy on drinking water quality.

1. Maximum permissible concentrations of pollutants

Maximum permissible concentrations of pollutants and maximum permissible levels of biological and physical effects are used as the main criteria of environmental quality. It should be noted that the scientific basis of this approach was developed in 30s of XX century and subsequent studies were aimed only at their deepening and detailing. But the scale of anthropogenic impact on environmental objects has increased. Its pollution has become global. So in modern conditions, the use of MPC as the only environmental standards is not always effective. Flowering of reservoirs, reduction of the self-cleaning capacity of water ecosystems, reduction of fish productivity of water bodies and other ecological violations take place even in compliance with the established MPC. However, in most cases, MPCs cannot be realistically achieved with the current state of technology and the available financial resources of enterprises, which leads to widespread, and therefore practically irresponsible, violation of norms. Recognizing this position, some hygienists have in recent years considered the MPC as an ideal to strive for. According to experts of the World Health Organization (WHO), "those regulations do not achieve the goal that cannot be implemented." The unsatisfactoriness of the existing state was also highlighted in the development of the system of maximum and temporarily permissible discharges (MPD and TPD) of polluting substances. Since the basis of their calculations is the use of MPC, these standards have some common limitations. The situation is complicated by the fact that for some components of aquatic ecosystems (bottom sediments, biota) MPCs have not been developed at all, and for others (water environment) there are many of them, but only 10% of the total number of established norms are actually controlled. In addition, some forms of substances are often regulated, and in natural objects there are also other forms with other MPCs. For example, aniline and aniline hydrochloride, which are not distinguished by the existing method of determination, differ in MPC by three orders of magnitude (fish farming MPC of aniline -0.0001 mg/dm^3, and aniline hydrochloride – 0.1 mg/dm^3). Researches carried out in recent years show that the system of MPC does not have the

necessary flexibility, and this leads in some cases to excessive strictness of regulations and, accordingly, unjustified costs for their provision. For example, the fishery MPCs of heavy metals for all types of surface waters are the same, despite the fact that the toxicity of these compounds is significantly lower in hard waters. The MPC system does not take into account the synergism and antagonism of the action of various pollutants. The toxicity of polluting impurities depends on the geo- and hydrochemical situation against which it appears.

The forms of transformation of pollutants are insufficiently taken into account when developing MPCs, while the intermediate products of transformation are often more toxic than the original compounds, for example, the formation of mutagenic nitro- and azo compounds during the microbiological degradation of nitro- and azoaromatic compounds, etc. Processes such as the accumulation of pollutants by biological objects that are not used as food products, such as seaweed, and their subsequent release during mass die-off, remain outside the scope of the MPC system. The MPC system does not take into account the biocenotic reactions of ecosystems to anthropogenic influences, the specifics of their functioning in different physical and geographical zones and geochemical provinces, and their different toxic resistance. The development of new MPCs (approximately 50 per year) does not correspond to the rate of entry of new chemical compounds into the environment (approximately 25,000 per year), and requires significant material and financial costs. According to foreign experts, the cost of developing one MPC at the modern methodical level is 500,000 dollars and has a tendency to grow. At the same time, the MPC system does not guarantee full environmental safety, since the norms established in laboratory conditions for individual compounds do not allow for regulation of the real total anthropogenic load on landscapes and their components. There are no approaches to the normalization of the spatial volumetric characteristics of anthropogenic loads in the MPC system. But to preserve the sustainability of ecosystems, such regulations are absolutely necessary. The use of MPC as the only environmental standards is not effective enough not only for management purposes, but also for monitoring and assessing the state of natural objects. When using this approach, the entire variety of quality states of natural components is divided into two categories: satisfactory and unsatisfactory quality, without differentiation within the specified groups. With the help of this approach, it is impossible to analyze the results of biological analysis of the qualitative state of the environment and to assess the ecological well-being of water bodies.

A comparative analysis of the regulatory framework of water protection activities in Ukraine and in other countries shows their significant difference. This is manifested in the difference of the principles underlying in the regulation, in the breadth of the arsenal of standards and rules which are used, their provision by

methods of analytical control, etc. A characteristic feature of the regulation of anthropogenic impacts on the environment abroad is the realism of the approaches used; careful economic analysis of decision-making in this field; in the broad participation of the public in the discussion of issues about the implementation of norms recommended by experts; the presence of their clear differentiation depending on the region, the protected objects, the characteristics of the sources of influence, the state of ecosystems, forms of the presence of pollutants in the environment, zoning of the territory, etc. For example, UK surface water discharge regulations are much stricter in highly polluted areas than in more prosperous ones. In Hungary, the regulation of the composition of wastewater is carried out taking into account the functional zoning of the country's territory. Similarly, in the USA, the principle of creating zones is used, where the quality of surface waters is protected especially strictly. In Japan, regulatory requirements for the composition of wastewater are differentiated for large and small enterprises in order to maintain the competitiveness of the latter. Standards for the permissible content of heavy metals in surface waters, which have been developed in the EU, differ significantly (by 2-10 times or more) depending on the hardness of the water and the type of organisms that are protected. In Germany, permissible levels of anthropogenic load on water bodies are developed for individual lands. It should also be noted that in the water protection practice of other countries, in addition to the MPC, for the purpose of regulating water use, ecological classifications of natural objects, technological restrictions, economic standards, etc. are widely implemented. The realism and flexibility of the regulation system abroad ensures significant efficiency of water protection activities.

2. Proposals for revising the list of priority substances in surface waters

In October 2022, the Commission adopted a proposal to revise the list of priority substances in surface waters. It is proposed to add 25 substances, including a standard for total pesticides. The proposed substances create well-documented risks to nature and human health. These include: PFAS, a large group of "forever chemicals" used in cookware, clothing and furniture, firefighting foams and personal care products; a number of pesticides; bisphenol A, a plasticizer and component of plastic packaging; a number of pharmaceuticals used as pain relievers, anticonvulsants or antibiotics; and silver. The commission also proposed updating the quality standards for a number of substances already on the list, mainly to make the standards more stringent because of evidence indicating a higher risk than originally identified. Among the substances with stricter standards are some metals and industrial chemicals. Four other existing priority substances are proposed to be delisted and one more to be integrated into the new PFAS group, while eight already regulated “other pollutants” have been re-designated as priority substances, bringing the total to 74.

If the proposal is agreed by the Council and the European Parliament, Member States will have to take measures to reduce emissions of all these pollutants where necessary to meet quality standards.

2.1. Better and more cost-effective treatment of urban wastewater

The revised Urban Wastewater Treatment Directive will help Europeans benefit from cleaner rivers, lakes, groundwater and seas, and make wastewater treatment more cost-effective. To make the best use of wastewater as a resource, it is proposed to achieve energy neutrality of the sector by 2040 and to improve the quality of the sludge to enable its reuse, thus contributing to a circular economy.

Several improvements will help to protect health and the environment. These include obligations to recover nutrients from wastewater, new standards for micropollutants and new requirements for monitoring microplastics. The water treatment obligation will be extended to smaller municipalities with 1,000 inhabitants (up from 2,000 inhabitants now). To help cope with the heavy rains that have become more frequent due to climate change, there is a demand for integrated water management plans in large cities. Finally, based on the experience of Covid-19, the Commission proposes to systematically monitor wastewater for the presence of several viruses, including CoV-SARS-19, and antimicrobial resistance.

EU countries will have to ensure access to sanitation for all, including vulnerable and marginalized groups. As 92% of toxic micro pollutants found in EU wastewater come from pharmaceuticals and cosmetics, the new extended producer responsibility scheme will require producers to pay for their removal. This is in line with the «polluter pays» principle and will stimulate research and innovation in non-toxic products and make the financing of wastewater treatment more equitable.

The wastewater sector has significant untapped potential for renewable energy production, for example, from biogas. EU countries will have to track industrial pollution at the source to increase opportunities for reuse of sludge and treated wastewater, by avoiding waste of resources. Rules for the recovery of phosphorus from sludge will facilitate its use in the manufacture of fertilizers, which will benefit the production of food products. The changes are estimated to increase costs by 3.8% (up to €3.8 billion per year in 2040), bringing benefits of more than €6.6 billion per year with a positive cost-benefit ratio in each Member State.

2.2. Protection of surface and underground waters from new pollutants

Based on modern scientific data, the Commission proposes to update the lists of water pollutants that are subject to stricter control in surface and underground waters. 25 substances with well-documented problematic effects on nature and human health will be added to the lists. They include:

✓ PFAS, a large group of “forever chemicals” used in cookware, clothing and furniture, firefighting foam, and personal care products, among others;

✓ a range of pesticides and pesticide degradation products, such as glyphosate;

✓ Bisphenol A, plasticizer and component of plastic packaging;

✓ some pharmaceutical drugs used as pain relievers and anti-inflammatory agents, as well as antibiotics.

The substances and their standards have been selected through a transparent and scientifically controlled process. The new rules recognize the cumulative or combined effects of mixtures, broadening the current focus on single substances alone. In addition, standards for 16 pollutants already covered by the rules, including heavy metals and industrial chemicals, will be updated, and four pollutants that no longer pose an EU-wide threat will be removed. The proposals will now be considered by the European Parliament and the Council under the normal legislative procedure. Once adopted, they will come into force gradually, with different targets for 2030, 2040 and 2050, giving industry and government time to adapt and invest.

3. Assessment of water quality: world experience

Water quality assessment is a rather time-consuming task, as it is based on the comparison of the average concentrations observed at the water quality control point with the established MPC standards for each ingredient. Particular difficulties arise if it is necessary to show the tendency of water quality over several years. If the concentrations of some ingredients decrease and others increase in the area of the water body, it is very difficult to comprehensively assess the water quality and identify the tendency. This leads to the need to develop a methodology for comprehensive assessment of water quality. Therefore, in operational work, preference is given to determining the WPI (water pollution indices). Evaluation according to the WPI indicator makes it possible to compare the water quality of different water bodies with each other, regardless of the presence of various pollutants, to identify the trend of water quality over time.

The pollution index for surface water is calculated based on only a certain number of indicators. According to the results of the analysis of each of the indicators, the arithmetic average value is derived. The number of analysis for determining the average value should be at least 4. If when calculating the arithmetic average value, those outside the normal range of observations were used (as a result of the accidental discharge of pollutants), there should be a corresponding note in the text. The calculation of WPI is carried out according to the formula:

$$WPI = \frac{C}{MPC}/n$$

where MPC is the maximum permissible concentration (value) of the indicator.

C is the actual concentration (value) of the indicator; n is the number of indicators.

For surface waters, the number of indicators taken into account while calculating the WPI must be at least 5, regardless of whether the waters exceed the MPC or not, but must include dissolved oxygen and BOC_5. For sea waters, the number of indicators must be at least 4 and necessarily include dissolved oxygen. In general, indicators are selected regardless of the limiting sign of harmfulness, for equal concentrations of indicators, preference is given to substances that have a toxicological sign of harmfulness. Taking into account the fact that the amount of biochemical oxygen consumption (BOC_5) is an integral indicator of the presence of easily oxidizable organic substances (the MPC for complete BOC is 3 mg/dm^3 relative to O_2), as well as the fact that with an increase in the content of easily oxidizable organic substances and a decrease in the content of dissolved oxygen, the quality of water decreases disproportionately sharply. Norms for these indicators when calculating WPI are taken slightly different than MPC (tables 2-5). Moreover, in contrast to other indicators for dissolved oxygen, the standard/real concentration ratio is used in the calculations of WPI.

Modern surface water quality management in most European countries is carried out on the basis of water quality requirements consisting of quality criteria (standards) and water quality targets. The interrelationship of these elements forms the basis for applying a systemic approach to water resources and water quality management.

Table 1.

Water quality assessment criteria according to WPI (excluding water content)

Water quality class	Description	WPI	Water quality class	Description	WPI
For surface waters			For sea waters		
I	Very clean	<0,3	I	Very clean	<0,25
II	Clean	0,3-0,1	II	Clean	0,25-0,75
III	Moderate pollution	1,0-2,5	III	Moderate pollution	0,75-1,25
IV	Pollution	2,5 – 4,5	IV	Pollution	1,25-1,75
V	Dirty	4,6-6,0	V	Dirty	1,75-3,00
VI	Very dirty	6,0-10	VI	Very dirty	3,00-5,00
VII	Extremely dirty	>10	VII	Extremely dirty	>5,0

In order to provide further methodological guidance for the development of

water quality requirements, the Economic Commission of the United Nations (UNECE) published "UNECE Recommendations to Governments on Water Quality Criteria and Target Indicators" (1993).

Water quality criteria are established for a number of traditional parameters. Nowadays, increased attention is paid to water quality criteria for hazardous substances that, due to their toxicity, persistence, ability to bioaccumulate and/or their carcinogenic, teratogenic or mutagenic effects, impose a threat to water use and the functioning of aquatic ecosystems. Target indicators of water quality take into account not only the impact of individual discharges, but also the cumulative effect of a whole range of different discharges into a water body. This makes it possible to set the general limit level of the content of pollutants in accordance with the requirements for the use of the water body. The development and establishment of water quality target indicators can be carried out in different ways, they can be grouped:

- ❑ establishing target indicators of water quality according to water classification schemes;
- ❑ establishing target indicators of water quality for a specific water object.

Most EEC countries have established quality targets for surface water based on classification schemes. A number of these countries consider it a strategic goal to achieve I or II water quality class within a certain period of time, which correspond to excellent or good water quality in the four- and five-point schemes. It should be noted that classifications of the quality of surface water used in different countries differ in a number of features, in particular in terms of objects of classification. Some of them apply to any types of natural waters, others only to reservoirs or watercourses. For example, Germany uses a single water classification, while Japan has developed separate classifications for rivers, lakes, and coastal sea waters. The classifications differ according to the principles underlying their construction, the number of selected classes, the set of indicators used, their normative values, the methods of selecting the appropriate gradations of water quality, means of data aggregation, and other characteristics. So, for example, five classes of water quality are allocated in Finland, in the classification of Great Britain – four with the division of the first into two subclasses, in Germany – four classes with allocation of three intermediate gradations between classes, etc.

It should also be noted that the developed classifications of water bodies differ significantly both in terms of the amount of necessary information and the possibility of automating data collection and processing. UNECE prepared "Standard Statistical Classification of the Quality of Surface Freshwater for the Support of Aquatic Life" (1994). Class boundaries are defined primarily for ecotoxicological considerations based on research by the US Environmental Protection Agency. Concentrations of

hazardous substances in classes I and II must be lower than the current detection limits. In class III, anthropogenic loads are present, but the concentrations are below the values of chronic and acute toxicity. For class IV, violations of constant concentration levels are possible, but there are no conditions for stable toxicity in relation to concentration levels, their duration and frequency. We can cite only a few examples of transboundary waters for which water quality targets have been established. These include the Great Lakes, some transboundary rivers in North America, and the Rhine River in Europe. Based on the terms of the UNECE Agreement, water quality targets are being developed for some other transboundary surface waters in Europe, including the Danube, Elbe, Oder and their tributaries. When determining ecosystem targets, an attempt is made to describe the desired conditions for a given ecosystem through a set of parameters, taking into account ecological characteristics and the category of water use. Ecosystem target indicators can determine the level or condition of some biological properties, which could be an indicator of the general condition or "health" of the aquatic ecosystem. They are used in combination with target indicators of water quality.

Among the ecological classifications of surface waters in Europe, the classification of the member states of the Council for Mutual Economic Assistance (1982) gained the greatest recognition. This classification was one of the first international systems of surface water typification from an ecological point of view. It took into account the specifics of the functioning of water ecosystems of watercourses and reservoirs and was aimed at using the assessment of the quality of border waters of member states the Council for Mutual Economic Assistance. The European Union (EU) has issued a number of directives that address water quality issues. The most important of them is Directive 77/795/EEC of 1977 as amended in 1989, which establishes a general procedure for the exchange of information on the quality of surface water in the EU for such purposes as:

- ✓ determining the level of river pollution;
- ✓ approval of guidelines for pollution control;
- ✓ exchange of information on long-term trends and improvement of the environment as a result of the application of current national and EU regulations;
- ✓ giving the maximum possible value to the comparison of the results obtained by the monitoring stations of the member states;
- ✓ establishing the basis for the surface water pollution control system at the EU level as a component of the global environmental control system envisaged by the UN Environment Program.

4. Methodology of ecological assessment of surface water quality by relevant categories

Specialists of Ukraine have developed several options for the classification of surface waters, however, only the officially approved classification specified in the normative document "Methodology of ecological assessment of the quality of surface waters by relevant categories" can be used as ecological target indicators. This classification is based on the ecosystem principle. The necessary completeness and objectivity of surface water quality characteristics are achieved by a sufficiently wide set of indicators that reflect the features of the abiotic and biotic components of water ecosystems. The complex of indicators of ecological classification of surface water quality includes general and specific indicators. General indicators, which include indicators of the salt composition of water and trophosaprobiological (ecological and sanitary) indicators, characterize the usual characteristics of aquatic ecosystems, the concentration of which can change under the influence of economic activity. Specific indicators characterize the content of toxic and radioactive pollutants in the water. The system of ecological classification of surface water quality of Ukraine includes three groups of specialized classifications according to:

✓ criteria for the saline composition of waters (tables 2–5);

✓ trophosaprobiological (ecological and sanitary) criteria;

✓ criteria for the content of specific substances of toxic and radiation effect, as well as by the level of toxicity (tables 6).

The group of classifications based on the criteria of the salt composition of water includes four specialized classifications, each of which has significant environmental significance:

✓ classification of the quality of surface waters of land and estuaries according to the criterion of mineralization (table 2);

✓ classification of the quality of surface waters, land and estuaries according to the criteria of ionic composition (table 3);

✓ classification of the quality of fresh hypo- and oligohaline waters according to the criteria of pollution by the components of the sale composition (table 4);

✓ classification of the quality of brackish ß-mesogaline waters according to the criteria of pollution by the components of the salt composition (table 5).

Of the mentioned classifications of water quality, the first two differ from each other and from the rest in terms of their structure. The classification of surface water quality according to the mineralization criterion has three classes and seven categories of water quality subordinate to them:

✓ fresh water class (I) with two categories – hypohaline (1) and oligohaline waters (2);

✓ brackish water class (II) with three categories – ß-mesogaline (3), α-

mesogaline (4) and polyhaline (5) waters;

- ✓ class of salty waters (III) with two categories - ß-branch, ultra-branch waters.
- ✓

Table 2.

Classification of land surface water quality according to the mineralization criterion

Quality class	Fresh water -1		Brackish waters -II			Salt water - III	
Water quality category	hypo-branch-1	oligo-branch -2	ß-meso-branch -3	α-meso-branch - 4	multi-branch	EU-branch-6	Ultra – branch -7
The amount of mineralization, g/dm^3	Less 0,5	0,51-1,00	1,01-5,0	5,01-18,0	18,01-30,0	30,01-40,0	40,00

Table 3.

Classification of surface waters according to the criteria of ionic composition

Class	Hydrocarbonate (C)			Sulfate (S)			Chloride (Cl)		
Group	Ca	Mg	Na	Ca	Mg	Na	Ca	Mg	Na
Type	I	I	I	II	II	I	II	II	I
	II	II	II	III	III	II	III	III	II
	III	III	III	IV	IV	III	IV	IV	III

Table 4.

Classification of the quality of fresh hypo- and oligohaline waters according to the criteria of pollution by the components of the saline composition

The amount of mineralization, g/dm^3	Quality class						
	I	II		III		IV	V
	Quality category						
	1	**2**	**3**	**4**	**5**	**6**	**7**
sum of ions	≤500	501-750	751-1000	1001-1250	1251-1500	1501-2000	>2000
sulfate	≤20	21-30	31-75	76-150	151-200	201-300	>300
chloride	≤50	51-75	76-100	101-150	151-200	201-300	>300

Table 5.

Classification of the quality of brackish ß-mesogaline waters according to the criteria of pollution by the components of the salt composition

The amount of	Quality class

mineralization, g/dm^3	I	II		III		IV	V
	Quality category						
	1	**2**	**3**	**4**	**5**	**6**	**7**
sum of ions	1000-1500	5001-2000	2000-2500	2501-3000	3001-3500	3501-4000	>4000
sulfate	≤200	201-400	401-600	601-800	801-1000	1001-1200	>1200
сульфати	≤400	401-800	801-900	901-1000	1001-1100	1101-1200	>1200

Table 6.

Ecological classification of the quality of surface waters according to the criterion of the content of specific substances of toxic action

The amount of mineralization, mg/dm^3	Quality class						
	I	II		III		IV	V
	Quality category						
	1	**2**	**3**	**4**	**5**	**6**	**7**
1	2	3	4	5	6	7	8
Mercury	<0,02	0,02-0,05	0,06-0,2	0,21-0,50	0,51-1,00	1,01-2,5	>2,5
Cadmium	<0,1	0,1	0,2	0,30-0,50	0,6-1,5	1,6-5,0	>5,0
Copper	<1,0	1,0	2,0	3-10	11-25	26-50	>50
Zinc	<10	10-15	16-20	21-50	51-100	101-200	>200
Lead	<2,0	2-5	6-10	11-20	21-50	51-100	>100
Chromium (common)	<2,0	2-3	4-5	6-10	11-25	26-50	>50
Nickel	<1,0	1-5	6-10	11-20	21-50	51-100	>100
Arsenic	<1,0	1-3	4-5	6-15	16-25	26-35	>35
Iron (total)	<50	50-70	76-100	101-500	501-1000	1001-2500	>2500
Manganese	<10	10-25	26-50	51-100	101-500	501-1250	>1250
Fluorides	<100	100-125	126-150	151-200	201-500	501-1000	>1000
Cyanides	0	1-5	6-10	10-25	26-50	51-100	>100
Oil products	<10	10-25	26-50	51-100	101-200	201-300	>300
Phenols (volatile)	0	<1	1	2	3-5	6-20	>20
SS	0	<10	10-20	21-50	51-100	101-250	>250

The classification of the quality of surface waters according to the criteria of ionic composition divides them into three classes (hydrocarbonate, sulfate, chloride), each of which in turn is differentiated into three groups (calcium, magnesium and sodium), which means there are nine categories according to ionic composition. In addition, certain categories of water according to the ionic composition are also divided into four types according to the quantitative ratio of ions. Ecological classification of surface water quality according to trophosaprobiological (ecological and sanitary) criteria includes the following groups of indicators:

✓ hydrophysical - suspended substances, transparency;

✓ hydrochemical - concentration of hydrogen ions, ammonium nitrogen, nitrite nitrogen, nitrate nitrogen, phosphorus phosphates, dissolved oxygen; permanganate and bichromate oxidation, biochemical oxygen consumption;

✓ hydrobiological - phytoplankton biomass, self-cleaning index - self-pollution;

✓ bacteriological - the number of bacterioplankton and saprophytic bacteria;

✓ bioindication of saprobity – saprobity indices according to Pantle–Bukka and Goodnight–Whitley systems.

The group of classifications of surface water quality of land and estuary based on the criteria of the content and biological action of specific substances includes three specialized classifications:

❑ ecological classification of the water quality of land and estuaries according to the criteria of the content of specific toxic substances;

❑ ecological classification of the quality of surface hypo- and oligohaline and brackish ß-mesohaline waters according to the level of toxicity;

❑ ecological classification of surface waters of land and estuaries according to the criteria of specific indicators of radiation action.

All systems of ecological classification of the quality of surface waters of Ukraine are built according to the same principle: five classes and seven categories of waters subordinate to them are distinguished. Specific hydrophysical, hydrochemical, hydrobiological and specific quantitative indicators are elementary signs of water quality. Complex quantitative characteristics determined by the integration of elementary characteristics are generalized characteristics of water quality. The classes and categories of water quality determined by these characteristics reflect the natural state, as well as the degree of anthropogenic pollution of surface waters of land and estuaries of Ukraine. According to the state, the following characteristics are given to the classes and categories of water quality:

I class with one category (1) – excellent;

II class – good, with two categories: very good (2) and good (3);

III class – satisfactory, with two categories: satisfactory (4) and mediocre (5);

IV class with one category (6) – bad;

V class with one category (7) – very bad.

According to the degree of purity (pollution), the classes and categories of water quality are given the following characteristics:

Class I – with one category (1) – very clean;

Class II – clean, with two categories: clean (2) and fairly clean (3);

Class III – polluted, with two categories: lightly polluted (4), moderately polluted (5);

Class IV – with one category (6) – dirty;

Class V – with one category (7) – very dirty.

Environmental assessment of the quality of surface waters of Ukraine must necessarily include all three blocks of indicators;

- ✓ block of salt composition of water,
- ✓ block of trophosaprobiological (ecological and sanitary) indicators of water,
- ✓ block of indicators of the content and biological action of specific substances.

The result is a single environmental assessment, which is based on the final conclusions for the three blocks. The procedure for environmental assessment of surface water quality consists of four consecutive stages, namely:

- ❑ stage of grouping and processing of initial data;
- ❑ the stage of determining the classes and categories of water quality according to individual indicators;
- ❑ the stage of generalization of water quality assessments by individual indicators (expressed in classes and categories) by individual blocks with determination of integral values of classes and categories of water quality;
- ❑ the stage of determining the combined assessment of water quality (with the definition of classes and categories) for a certain water body in general or its individual sections for a certain observation period.

The initial data for the ecological assessment of water quality are, first of all, aggregated and separated results of systematic monitoring of water quality in water bodies of Ukraine, collected and processed by a network of observation points and laboratories of the systems of the Ministry of Ecology and Natural Resources, the Hydrometeorological Service of Ukraine, the State Water Agency of Ukraine. The materials of systematic observations of water quality obtained by scientific institutions of ecological profile are also taken into account.

The raw data on water quality by individual indicators are grouped within three blocks. The raw data (samples) grouped by blocks for each available water quality indicator are subject to certain processing: arithmetic mean values are calculated, minimum and maximum (worst) values are determined, which together characterize the variability of the values of each of the water quality indicators in real conditions of performance and analysis of observation results.

The stage of generalization of water quality assessments by individual indicators with determination of integral values of classes and categories of water quality is performed only on the basis of the analysis of indicators within the relevant blocks. This generalization consists in determining the average and worst values for three block indices of water quality, namely: for the index of pollution by the components of the salt composition of water (I_1), for the trophosaprobiological (ecological and sanitary) index (I_2), for the index of specific indicators of toxic and radiation action

(I_3). Thus, six block index values should be determined, namely: I_1avg. and I_1max.; I_2avg. and I_2max.; I_3avg. and I_3max.

Having the values of block indices of water quality, it is possible to determine their belonging to a certain class and category using the ecological classification system. Average values for three block indices of water quality are determined by calculating the average category number for all indicators of a given block; while category 1 has number 1, category 2 number – 2, etc.

Table 7.

Definition of water quality subcategories

The average value of the block indices	Designation of the relevant subcategories of water quality
1,0-1,2	1
1,3-1,4	1(2)
1,5-1,6	1-2
1,7-1,8	2(1)
1,9-2,2	2
2,3-2,4	2 (3)
etc. for categories 3-7	

The stage of determining the combined assessment of water quality for a certain water body in general or for individual areas is the calculation of the integral (ecological) index (IE). The use of the ecological index of water quality is advisable in those cases when it is more convenient to use an unambiguous assessment: for planning water protection activities, developing water protection measures, carrying out ecological and ecological-economic zoning, ecological mapping, etc. The value of the ecological index of water quality is determined by the formula:

$$I_E = \frac{(I_1 + I_2 + I_3)}{3},$$

where I_1 is the index of contamination by the components of the salt composition of water; I_2 – index of trophosaprobiological (ecological and sanitary) indicators of water; I_3 – index of specific substances of toxic and radiation effect.

The salt composition of the surface waters of Ukraine is estimated by the sum of ions and individual ingredients. When grouping data in space and time, the assessment is given according to the average and maximum (worst) values of the indicators. The class of water is determined by the predominant anions, groups – by the predominant cations. Types of water are determined by the ratio between ions (in equivalents):

I - $HCO_3^- > Ca^{2+} + Mg^{2+}$,

II - $HCO_3^- < Ca^{2+} + Mg^{2+} < HCO_3^- + SO_4^{2-}$,

III - $HCO_3^- SO_4^{2-} < Ca^{2+} + Mg^{2+}$,

IV - $HCO_3^- = 3$.

During the ecological assessment, it is necessary to predict the comparison of the obtained results with the values of the ecological standards established for this water body. This is necessary for the analysis of compliance (or non-compliance) of water quality with the values of all those indicators that are established as a result of ecological regulation of water quality for a specific water body.

The ecological classification of surface waters of Ukraine fully complies with the recommendations of the EU Water Framework Directive. Based on the method of ecological assessment of the quality of surface waters of Ukraine, the "Methodology of mapping the ecological state of surface waters of Ukraine by water quality" was developed.

5. Overview of EU policy on drinking water quality

High-quality, safe and sufficient drinking water is essential for public health and well-being. Apart from consumption, we also use it for many other purposes such as washing, cleaning, hygiene or watering our plants.

Most people living in the EU already have good access to high-quality drinking water, thanks in part to 30 years of EU drinking water quality policy. This policy ensures that water intended for human consumption can be consumed safely, providing a high level of health protection. The main principles of EU drinking water policy are:

✓ protect human health by ensuring the quality of water intended for human consumption,

✓ ensure that the quality of drinking water is monitored using standards based on the latest scientific evidence,

✓ ensure real and effective monitoring, assessment and quality assurance of drinking water,

✓ provide Europeans with adequate, timely and appropriate information,

✓ improve access to water intended for human consumption.

The recast Drinking Water Directive (DWD) is the main EU law on drinking water. This concerns the access to and quality of water intended for human consumption to protect human health. The new edition is the Commission's response to the first ever successful European citizens' initiative Right to Water (Right2Water), which gathered 1.6 million signatures in support of improving access to safe drinking water for all Europeans. The Commission analyzed the Drinking Water Directive by launching a pan-European public consultation on drinking water quality to assess the

need for improvements and ways to achieve them. Following these consultations and in line with the principles of the new European framework of social rights, the proposal contains an obligation for EU countries to improve access to safe drinking water for all social groups. Member States must transpose the Directive into national law and implement its provisions by January 12, 2023.

The revised Drinking Water Directive will further protect human health through updated water quality standards, tackle problematic pollutants such as endocrine disruptors and microplastics, and ensure even cleaner tap water for all. The directive applies to:

- all water, in its original state or after treatment, intended for drinking, cooking or other domestic purposes in both public and private premises, regardless of its origin and whether it is supplied from a distribution network, from a tank or bottled or in containers, including spring water;
- all water used in any food business for the production, processing, preservation or sale of products or substances intended for human consumption.

The key features of the revised Directive are:

✓ enhanced water quality standards that meet or, in some cases, are even stricter than World Health Organization (WHO) recommendations,

✓ combating new pollutants such as endocrine disruptors and PFAs, as well as microplastics,

✓ a preventive approach that prioritizes actions to reduce pollution at the source by introducing a risk-based approach,

✓ measures to ensure better access to water, especially for vulnerable and marginalized groups,

✓ measures to popularize tap water, including in public places and restaurants, to reduce the consumption of (plastic) bottles,

✓ harmonization of quality standards for materials and products in contact with water,

✓ measures to reduce water leakages and increase transparency of the sector.

On January 19, 2022, the first checklist was adopted. This means that drinking water in the EU will need to be more closely monitored for the potential presence of two endocrine-disrupting compounds (beta-estradiol and nonylphenol) throughout the water supply chain. Endocrine disruptors are a mixed group of chemical substances of different structures that can affect physiological and biochemical processes in the human body.

5.1. Minimum hygienic requirements for materials in contact with water intended for human consumption (revised Article 11 DWD)

On January 23, 2024, the European Commission adopted new minimum hygiene

standards for materials and products that come into contact with drinking water. They will apply from 31/12/2026 to materials and products intended for use in new installations for the intake, treatment, storage or distribution of water, or for renovation work, including supply pipes, valves, pumps, water meters, fittings and taps. These standards will prevent or reduce microbial growth and the risk of harmful substances leaching into drinking water. This will make the water safer to drink and reduce the administrative burden for companies producing the relevant materials and products, as well as for national authorities and conformity assessment bodies.

Commission acts on minimum hygiene standards for materials and products in contact with drinking water were published in the Official Journal on 23 April 2024 by means of three implementing decisions and three delegated regulations. Products that meet these EU standards will receive an EU declaration of conformity and a special EU label. Thus, the product can be sold throughout the EU without any restrictions related to possible problems for public health or the environment.

5.2. Methodology for measuring microplastics

On 16 May 2024, the Commission notified Member States of the Delegated Decision on the methodology for measuring microplastics in water intended for human consumption. This methodology will allow Member States to measure microplastics in drinking water in a harmonized way. Until now, many different methods have been used to measure microplastics in drinking water, making it difficult to compare and interpret monitoring results. The establishment of the Commission's harmonized EU methodology will help member states gain knowledge about the presence of microplastics in their water supply chain. This methodology was developed to include microplastics in the revised DWD checklist.

5.3. EU legislation on improving the quality of the drinking water system, which should be implemented in the system of Ukrainian legislation

Directive 98/83/EU of the Council of the European Union on the quality of water intended for human consumption, as amended by Regulation (EU) 1882/2003 and Regulation (EU) 596/2009, which was to be implemented in accordance with the Association Agreement, was significantly changed several times. In 2020, the revised Directive (EU) 2020/2184 (DWD) of the European Parliament and the Council of December 16, 2020 on the quality of water intended for human consumption (revised) [2] (hereinafter referred to as Directive 2020/2184) was adopted, which regulates water quality, intended for consumption in the European Union, and is the main legal act of the EU on drinking water.

The revised Directive guarantees safer access to water for all Europeans and ensures the highest drinking water standards in the world, in line with the zero

pollution ambitions announced in the European Green Deal. According to Article 13(8) of Directive 2020/2184, the first implementing act was adopted in January 2022 to establish a checklist of substances or compounds of concern in water intended for human consumption that may pose a potential risk to human health.

In the process of harmonizing national legislation with EU law, it should also be taken into account that the drinking water quality system is part of the EU water policy as a whole, since the protection of drinking water resources is defined as an integral component of the plans and measures provided for by the Water Framework Directive 4, and is closely related with the European Green Deal, circular economy and zero pollution action plans, as well as with other documents adopted to implement Directive 2020/2184, namely:

✓ Resolution of the European Parliament of October 5, 2022 regarding access to water as a human right - external dimension (2021/2187) [5],

✓ Resolution of the European Parliament of April 5, 2022 on measures against nitrate water pollution, including the improvement of various nitrate measurement systems in the member states (2021/3003(RSP) [6].

Another 6 documents for the implementation of Directive 2020/2184, including implementation.

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Lecture 15. European soil monitoring in Ukraine: legislative framework, methodical and technical support for practical implementation.

Plan.

1. Peculiarities of soil monitoring organization.
2. Soil monitoring in Ukraine and the principle of organizing observations.
3. Technical and economic justification of soil monitoring.
4. Sources and types of soil degradation.
5. A modern approach to the soil monitoring system (SMS).

1. Peculiarities of soil monitoring organization

Soil monitoring is conditionally divided into

4. soil pollution monitoring;
5. soil erosion monitoring;
6. soil salinity monitoring.

All mentioned types of soil monitoring make it possible to assess both the possibility of using soils for certain types of their purpose, and to determine their market value. In 1982, the International Food Organization (FAO) adopted the World Soil Charter, in which it called on the governments of all countries to consider the soil cover as a universal asset of mankind, and in 1983, UNEP approved the Principles of World Soil Policy.

Soil monitoring in Europe exists, on the one hand, within the framework of several programs (International Cooperative Program for the Assessment and Monitoring of Aerial Pollution of Forests, the International Integrated Monitoring Program covering 31 European countries, the European Geological Forum), and on the other hand, as independent networks points in individual countries.

The development of soil monitoring networks in Europe has been largely influenced by various directives of the European Union, in particular the Nitrate Directive 91/676/EEC, the Directive on the Sustainable Use of Pesticides (Directive 2009/128/EU), the Directive 86/278/EEC on Environmental Protection and, in particular, soil in cases of agricultural use of sewage sludge, Regulation on fertilizers (EU Regulation 2019/1009), Regulation on mercury (EU Regulation 2017/852) and Regulation on plant protection products (EU Regulation 1107/2009), on permissible concentrations of heavy metals, control of enterprise emissions, use of effluents and production waste on agricultural land, etc. The final documents focus on the need to solve (harmonize and standardize) a number of methodological issues: soil indicators, formation of EuroSoilMonitoringNet networks, selection and description of objects (sampling technique, depth and time intervals of sampling), study methods, databases and information systems. Legislation on environmental impact assessment can also be attributed to important aspects of soil pollution regulation. To determine the

amount of compensation for environmental damage, it is important to take into account the provisions of Directive EU and CE dated April 21, 2004 No. 2004/35/EU on environmental liability for the prevention and elimination of the consequences of environmental damage.

In recent years, many countries of the European Union have revitalized the work on soil monitoring in connection with the adoption by the EU on November 17, 2021 of a new soil strategy until 2030, which announces the creation of a global soil monitoring network. Such a system involves the use of various sensors (working in real time) to monitor soil pollution.

The UN Convention to Combat Desertification in Countries Suffering from Severe Drought and/or Desertification, especially in Africa (Ukraine acceded to it on July 4, 2002) encourages parties of the Convention to strengthen assessment and monitoring capabilities, including hydrological and meteorological services. The national action programs of the parties of the Convention should provide for measures to monitor and assess the consequences of drought, including monitoring and assessment of ecological degradation to provide reliable, timely information on the processes and dynamics of resource degradation in order to inform and facilitate the development of more effective policies and appropriate measures.

In the EU, land and soil monitoring is carried out by:

4. The European Environmental Agency, in particular, its organization European Topic Center on Urban Land and Soil Systems (ETC/ULS), which is part of the Eionet network;

5. European Statistical Service (Eurostat);

6. within the framework of the Eionet network's functioning - thematic groups of experts, known as National Reference Centers Soil, or NRC Soil. In particular, Eurostat organized the LUCAS soil monitoring platform and supports the LUCAS topsoil database of the same name.

Scientific and technical support of these works is provided by the Joint Research Center at the European Commission. All organizations and institutions cooperate closely with each other in coordinating efforts and exchanging information. The methodological basis of LUCAS land and soil monitoring is that monitoring is carried out through point statistical observations, at more than 250,000 points throughout the EU. Observations cover different types of land use and land cover types. Observations are repeated every few years, which makes it possible to detect changes in land use.

The methodological principles of EU soil cover identification are described in the technical report "LUCAS Topsoil Survey: methodology, data and results". Every three years, the methodology is reviewed and updated, and the network of observation points is expanded. Three groups of target parameters for soil condition

monitoring have been defined:

- their physical degradation (as a result of erosion, burial, compaction);
- chemical degradation (pollution, acidification, eutrophication);
- biological soil degradation, soil loss of organic matter and their multifunctional properties (their ecosystem functions).

In general, the organizational and methodological foundations of land monitoring in the EU are well developed. In 2021, the European Topic Center on Urban Land and Soil Systems (ETC/ULS) prepared and published a technical report "Soil monitoring in Europe: Indicators and thresholds for soil quality assessments" (2021). At the same time, questions still remain in the system of soil monitoring in the EU, in particular, regarding target parameters, sampling schemes and their analysis, criteria of spatio-temporal representativeness, requirements for statistical processing to assess uncertainties and trends, levels of intensity (detailing) measurements, integration with other types of environmental monitoring (climate, air, biodiversity, water quality) [1].

2. Soil monitoring in Ukraine and the principle of organizing observations

Soil is a special organo-mineral natural formation that arose as a result of the impact of living organisms on the mineral substrate and the decomposition of dead organisms, as well as due to the impact of natural waters and atmospheric air on the surface horizons of rocks in different climate and relief conditions in the Earth's gravitational field. On the other hand, soil is the most immobile natural medium compared to, for example, the atmosphere or surface waters. The migration of pollutants in the soil is relatively slow. Therefore, high levels of soil contamination by some substances are localized in the places of their release into the environment. In addition, a gradual change in the chemical composition of soils, disruption of the unity of the geochemical environment and living organisms is possible. The most intensive way of transfer of pollutants that enter the soil can be transfer with atmospheric air in the case of pollution from the soil entering the atmosphere through evaporation or together with dust. Another relatively quick way of dispersal of pollutants is their washing by sewage. But not all of these transfer mechanisms play a significant role in soil pollution. Under the influence of physico-chemical factors and, mainly, as a result of the activity of microorganisms, decomposition of pollutants of organic composition occurs. In a number of cases (contamination of soil with benzo(a)pyrene, pesticides and other substances) it is even possible to establish a balance between entering the soil and their decomposition in the soil.

Monitoring of the condition of lands and soils and the content of pollutants in them is carried out by 6 monitoring entities:

– Ministry of Emergency Situations (State Hydrometeorological Service),

– Ministry of Nature (State Environmental Inspection),
– Ministry of Health (sanitary and epidemiological service),
– Ministry of Agrarian Policy,
– State Forestry Committee,
– State Committee on Land Resources of Ukraine.

The State Hydrometeorological Service observes and monitors soil contamination of agricultural land with pesticides at 35 sites in 18 regions and heavy metals in 20 settlements. Samples are taken once every five years, samples for heavy metals are taken every year in some cities.

The State Environmental Inspection carries out sampling at more than 600 industrial sites and determines pollution according to 27 indicators. The sanitary-epidemiological service carries out control and monitoring of the condition of the soil in the territories where the consequences of negative impact on the health of the population are possible. The areas where agricultural products are grown, areas where pesticides are used, soils in the area of residential areas, playgrounds and institutions are mostly covered. Soil samples are studied in places where toxic waste is stored on the territory of enterprises and outside it in places where they are stored or buried. The Ministry of Agrarian Policy monitors agricultural land. The network on which soil observations and monitoring are carried out by units of the State Technological Center for Soil Fertility Protection consists of 1,003 sites. Radiological, agrochemical and toxicological determinations, residual amounts of pesticides, agrochemicals and heavy metals are carried out.

The State Committee for Forestry and Agriculture monitors the soils of forest areas and the impact on them of adjacent industrial zones, including the presence of heavy metals in the soil and vegetation. State Committee on Land Resources of Ukraine monitors manifestations of erosive and other exogenous processes, spatial pollution of land by objects of industrial and agricultural production, irrigated and drained lands, as well as the dynamics of changes in land resources along the shorelines of water bodies.

2.1. Principles of organizing observations on the level of soil contamination

Standards for the content of chemicals in the soil, taking into account the harmful effects of these substances on human health, are complicated by the fact that the main amount of chemicals from the soil enters the human body not directly, but through food chains: soil-plant-human, soil-plant-animal-man, soil-water-man, soil-atmospheric air-man. Chemical elements that are not captured by spectral analysis can be determined by the atomic absorption method. Mobile forms of metals are also determined by this method. The atomic absorption method allows determination of up to 70 elements in concentrations at the level of 0.1-0.01 μg/ml, which allows

analysis without prior concentration. Using the atomic absorption method, you can determine Ca, Mg, Fe, Mn, Cu, Zn, Cr, Ni, Pb, Cd, Hg, As, Se. The negative consequences of anthropogenic soil pollution are already being felt at the regional and even global levels. Therefore, the development of programs for monitoring the level of chemical contamination of soils, a system of monitoring and assessing the condition of soils due to anthropogenic pollution, is relevant.

Soil condition monitoring includes:

5. registration of the current level of chemical contamination of soils, identification of geographical patterns and dynamics of temporary changes of contamination of soils depending on the location and technological parameters of pollution sources;

6. assessment of the possible consequences of soil contamination and prediction of trends in the chemical composition of soils in the near future;

7. justification of the composition and nature of measures to regulate possible negative consequences as a result of soil contamination and measures aimed at fundamental improving of the condition of already contaminated soils;

8. providing interested organizations with information on the level of soil contamination.

The following types of observations can be distinguished:

- routine or systematic observations;
- complex observations, which include the study of the migration processes of organic matter in the systems: air-soil, soil-plant, soil-water, soil-bottom sediments;
- study of the vertical migration of pollutants;
- observation of the level of pollutants in certain points.

The main tasks of soil monitoring:

- timely detection of adverse changes in the properties of the soil cover during various types of its use;
- seasonal control of the state of the soil cover (dynamics of changes) under agricultural crops to issue timely recommendations;
- assessment of average annual soil loss (rate of soil cover loss as a result of rain, wind, irrigation erosion);
- identification of areas with a deficient balance of biogenic elements, identification and assessment of the rate of loss of humus, nitrogen and phosphorus;
- control over changes in soil acidity and alkalinity, especially in areas with high doses of mineral fertilizers and near large industrial centers - sources of acidification of atmospheric precipitation;
- control over the saline regime of the processes of irrigation of fertilized soils;
- control of soil contamination by heavy metals;

- control over local soil pollution of the heavy metals in the zone of influence of industrial enterprises and transport highways, as well as pollution by pesticides in the areas of their permanent use;
- long-term and seasonal (according to the phases of plant development) control of humidity, temperature, structural condition, water-physical properties of soils and their content of plant nutrients;
- assessment of probable changes in soil properties during the design of hydraulic engineering, land reclamation, implementation of new farming systems, fertilizers, etc.;
- control over the size and correctness of alienation of usable land for industrial and communal purposes.

In Ukraine, soil monitoring is regulated by the resolutions of the Cabinet of Ministers of Ukraine dated August 20, 1993 No. 661 "Regulations on Land Monitoring" and dated March 30, 1998 No. 391 "Regulations on Environmental Monitoring". General requirements for soil sampling. Sampling is carried out (in accordance with State standard 28168-89 Soils. Selection of samples. Such methods of soil sampling are used for general and local pollution, near polluting enterprises, near highways, etc. In the case of general soil contamination, the studied areas for the selection of soil samples are selected according to the coordinate grid, indicating the number and coordinates. In the case of local soil contamination, a system of concentric circles located at differentiated distances from the source of contamination is used to determine the investigated areas, indicating the numbers of the circles and the azimuth of the sampling site. When studying soil contamination, samples are taken layer by layer from depths of 0–5, 10–20, 21–40, 41–60 cm depending on the purpose of the study. In addition, the size of the studied area, the number and type of samples are determined. The maximum allowable size of plots: in the Polissia – 8 hectares, in the forest-steppe zone – 25 hectares, in the steppe – 40 hectares. The average plot size is 25 hectares.

To determine chemical substances in the soil, as well as their toxicity and mutagenicity, the size of the plot varies from 1 to 5 ha, where at least one combined sample is taken, the weight of which must be at least 400 g. [2]

3. Technical and economic justification of soil monitoring

In the National Scientific Center "Institute of Soil Science and Agrochemistry named after O. M. Sokolovskyi" of the National Academy of Sciences of Ukraine (Kharkiv) under the leadership of academician of the National Academy of Sciences of Ukraine V. V. Medvedev, the concept and technical and economic justification of soil monitoring in Ukraine was developed. Its necessity is determined by four main factors:

✓ the exceptional importance of maintaining soils in a state in which they retain the ability to regulate the cycles of biophilic elements;

✓ the importance of control and prevention of disturbance of soil formation processes manifested in dehumification, over-compaction, erosion, acidification, flooding, salinization, etc.

✓ the importance of significantly increasing soil fertility, increasing returns from land reclamation and chemical treatment, improving the quality of agricultural products;

✓ the impossibility of adequately assessing the current state of the soil cover based on the available information due to outdated data, focus only on a narrow consumer and inconsistency of methods.

Elements of soil monitoring existed in Ukraine before. Thus, the State Institute for Land Management "Ukrzemleproekt" conducted a systematic survey of the soils of Ukraine in the period 1956-1961 as part of the 1st round of a large-scale soil survey. In the period 1975-1990, the 2nd round of a large-scale soil survey of the soils of Ukraine was conducted (which was not completed - 80% of the areas were surveyed). A comparison of the results of these two rounds made it possible to identify undesirable trends in soil cover change:

– the impact of erosion processes on the soil cover is increasing, during the 20-23-year period between rounds, the area of eroded arable soils increased by 25%;

– processes of soil dehumification are ongoing, the humus content in the soil has decreased by 0.3% on average across Ukraine;

– there was a significant compaction of the soil due to the systematic loss of humus and the constant impact on the soil of running systems and tillage machines;

– decalcification of soils, the appearance and increase of hydrolytic acidity on typical and ordinary chernozems (black soil), the cause of which was the application of high doses of mineral fertilizers;

– the flooding of large areas of floodplains as a result of the construction of a cascade of reservoirs on the Dnipro, which also led to the rise of groundwater and flooding of territories far from the reservoirs.

By 2000, divisions of «Agricultural Chemistry» conducted four rounds of agrochemical surveys, which made it possible to identify trends in changes in the humus state of soils, the reaction of the soil environment, the supply of soils with available phosphates and exchangeable potassium in individual farms, regions and in Ukraine as a whole. Elements of soil monitoring were also carried out by the hydrological and reclamation expeditions of the Ministry of Agriculture and Forestry, and now by the relevant services of the Ministry of Agrarian Policy (monitoring of soils of the ameliorating background, irrigation erosion), hydrometeorological stations, Ukrgeology, and now the State Geoservice, institutions of the academies of

sciences of Ukraine, the National Space Agency of Ukraine (remote sensing), etc. However, these works are still performed unsystematically. Currently, in Ukraine, the soil monitoring service is being formed within the framework of the state environmental monitoring system. Its tasks include periodic control of the dynamics of the main soil-forming processes - physical, chemical, biological and others under natural conditions and when anthropogenic load is imposed.

The objects of soil monitoring are the main types, subtypes, backgrounds, types and varieties of soils, which are selected within the soil province and maximally reflect the diversity of the soil cover, all levels of anthropogenic load. Natural objects (forests, nature reserves), reference objects of a high level of agricultural land use (state variety plots, variants of stationary experiments, fields of farms where the soil protection contour-ameliorative farming system is implemented), ordinary farms were selected as permanent control points.

The state of the soil is reliably diagnosed with information on changes in the structure of the soil cover, land transformation, assessment of the rate of change of the main indicators (humus, pH, air and nutrient regimes, capacity for cation exchange, physical, water, pollution, biological activity), assessment of the intensity of erosion, indicators of the reclamation state (quality of irrigation water, level of mineralization of groundwater, salinity of soils in the aeration zone, secondary salinization, evaluation of the rates of activation of drained peatlands, transformation of organic matter, secondary fertilization) and, finally, evaluation of the effectiveness of soil fertility.

Observations are conducted by ground (standard methods and devices) and remote means (remote sensing). The development of correlations between ground and remote methods is carried out at special test sites. A program of special studies aimed at methodical support of remote ground monitoring has been developed at National Scientific Center «Institute of soil science and agrochemistry». In accordance with this program, methods of remote determination of soil characteristics are created and tested, as well as appropriate filming equipment and means of operational decoding of information. [2]

4. Sources and types of soil degradation

If under the influence of natural factors the balance and course of usual geological processes are not disturbed, then under the influence of anthropogenic factors negative processes occur that lead to degradation and exhaustion of soils, their withdrawal from agricultural use.

Soil degradation is a set of processes caused by human activity that reduce their fertility. There are physical, chemical, and biological types of degradation. Causes of soil degradation: erosion, violation of agricultural technology rules, destruction of

forests, excessive use of chemicals, acid precipitation, etc. Desertification is a process of deterioration and decrease in the productivity of territories, which occurs in any climatic conditions, and its intensity depends on the decrease in water and increase in the thermal regime. An important cause of desertification is anthropogenic influence without taking into account the interrelationship of natural components (relief, soil, plant and animal life), which form the biological productivity of the territory, resistance to the influence of external factors.

Salinity causes complete or partial removal of soils from active agricultural use, reducing their productivity. The main reason is excessive, unsystematic watering in the absence of drainage. Repeated salinization: shallow mineralized groundwater, rising through the capillaries of the soil and evaporating, leaves salts near the surface; with excessive watering, groundwater rises, water logging and salinization of the soil with salts dissolved in these waters.

According to FAO, at least 50% of all irrigated land in the world is saline. Land is being expropriated for the construction of roads, industrial enterprises, housing, communications, and the expansion of cities (over 60 million hectares).

Annually, the humus content in the soils of Ukraine decreases (by 1.5-1.8 t/ha per year), which increases soil compaction and reduces their water capacity by 15-20 times. Dehumification is associated with a decrease in the amount and deterioration of the quality of organic matter entering the soil. To prevent dehumification, it is necessary to apply 8-12 t/ha of humus per year, plow the harvest residues into the soil, apply mulching of the surface with straw, use mineral fertilizers, etc. The optimal content of humus in the upper horizons of chernozems is 5-7 %. [2]

Soil erosion affects society through its on-site and off-site effects. One of the negative impacts is a decrease in the flow of various ecosystem services. Losses of nutrients, in particular losses in N, P and K, are determined, which directly causes changes in the productivity of agricultural crops, in particular cereals. [7]

4.1. Indicators of technogenic disturbance and pollution of the soil layer

According to the degree of danger, chemical substances that pollute the soil cover are divided into 3 classes (State standard 17.4.1.02-83): 1 – highly dangerous, 2 – moderately dangerous, 3 – slightly dangerous (table 1).

The marked indicators are considered as criteria for evaluating soil and rock contamination by inorganic and organic substances. A general assessment of the degree of contamination of the soil cover can be carried out according to the criteria that distinguish lightly, moderately and heavily contaminated soils.

Table 1.

Criteria for the hazard classes of chemical substances in soils

№	Indicators	Norm indicators for hazard classes		
		I class	II class	III class
1.	Toxicity, DL_{50}, mg/kg	<200	200-1000	>1000
2.	Persistence in soil, months	>12	6-12	<6
3.	MAC in soil, mg/kg	<0,2	0,2-9,5	>0,5
4.	Migration	They migrate	They migrate little	They do not migrate
5.	Persistence in plants, month	>3	1-3	<1
6.	The impact on the nutritional value of agricultural products	strong	moderate	none

In mildly polluted soils, the content of organic matter does not exceed the MPC or the background value. In moderately polluted areas, the exceeding of the MPC (background) is insignificant and does not lead to significant changes in soil properties. In highly polluted soils, the content of pollutants is several times higher than the MPC (background), which significantly affects both soil properties and the quality of agricultural products. Sometimes assessments are carried out according to the degree of contamination by individual pollutants (heavy metals, oil and petroleum products, benz(a)pyrene, etc.). To extract the man-made component, data from unpolluted areas or areas with fossil soils that have not undergone anthropogenic influence are used. Soils are considered polluted when the concentration of oil products (OP) in them reaches such a value that negative ecological changes in the surrounding natural environment begin: the ecological balance in the soil is disturbed, soil biota dies, productivity falls or plant death occurs, changes in morphology, water-physical properties of soils occur, their fertility decreases, there is a danger of contamination of underground and surface waters. A dangerous level of soil pollution is considered to be a level that exceeds the limit of self-cleaning potential.

In some countries, it is accepted that the upper safe level (N) is the content of oil product in the soil of 1-3 g/kg; the beginning of serious environmental damage (K) - at a content of 20 g/kg and above. In view of the physical and geographical conditions of Ukraine (as well as the nature of land use), which affect the processes of self-cleaning in case of pollution of the natural environment of oil product, for the practice of carrying out work on detoxification of oil product in the soil, it is

advisable to adopt the following degrees of gradation of soil contamination of oil product (taking into account Clark):

- uncontaminated soils – up to 1.5 g/kg;
- weak pollution – from 1.5 to 5 g/kg;
- average pollution – from 5 to 13 g/kg;
- severe pollution – from 13 to 25 g/kg;
- very strong pollution – more than 25 g/kg.

Weak pollution can be eliminated in the process of self-cleaning of the soil in the next 2-3 years, average - within 4-5 years. The beginning of serious ecological damage is soil contamination with oil products in concentrations exceeding 13 g/kg, at these concentrations, oil products migration into groundwater begins, and the ecological balance in the soil biocenosis is significantly disturbed. It is considered that concentrations less than 5 g/kg correspond to the zone of ecological norm (N), 5-13 g/kg - risk (R), 13-15 g/kg – crisis (K) and more than 25 g/kg – zone calamity (C).

I should be noted that the degree of contamination of the soil cover by oil products does not always affect their translocation (and accordingly, the quality of agricultural products), which is obviously connected with the hydrophobicity of most carbohydrate and non-carbohydrate fractions. It is necessary to differentiate pollutants soils by hazard class (according to State standard 17.4.1.02-83) (Table 4.2).

Table 2.

General assessment of the degree of pollution of the lithosphere with the selection of classes of ecological status

Indicator	Classes (zones) of ecological state			
	N	R	K	C
Concentration of all elements and compounds	Background or <1 MPC	Components of 2 and 3 hazard classes within 1-5 MPC; 1 class – at the level of 1 MPC	Components of 2 and 3 hazard classes within 5-10 MPC; 1 class – 1-5 MPC	Components of 2 and 3 hazard classes >10 MPC; 1 class >5 MPC

One of the methods of assessing technogenic «integrity» of soils and rocks of the aeration zone is the character of ^{137}Cs distribution. This cesium isotope is absorbed by the soil in the upper layer (up to 5 cm), if this soil is "virgin"; if the soil

was cultivated, the distribution of ^{137}Cs throughout the whole area will be almost uniform.

5. A modern approach to the soil monitoring system (SMS)

A modern approach to the soil monitoring system requires a clear understanding of the main functions of the soil. The assessments of threats to soil functions leads to a need to formally identify the functions that the soil performs. The proposed Soil Framework Directive (CEC, 2006) of the European Union recognizes seven soil functions that are vulnerable to soil threats:

- biomass production, including agriculture and forestry;
- storing, filtering and transforming nutrients, substances and water;
- biodiversity pool, such as habitats, species and genes;
- physical and cultural environment for humans and human activities;
- source of raw materials;
- acting as a carbon pool;
- archive of geological and archaeological heritage.

The EU Soil Thematic Strategy was developed at the same time as the Millennium Ecosystem Assessment (MEA, 2005) initiated by the United Nations in 2000. The goal of the MEA was to assess the consequences of ecosystem change for human well-being and to lay the scientific basis for actions that would promote conservation and sustainable use of ecosystems. The MEA was built on the framework for ecosystem services developed by Daily, Matson and Vitousek (1997) and Costanza et al. (1997).

The categories of ecosystem services were formalized by the Millennium Ecosystem Assessment into four broad classes: provisioning, regulating, supporting, and cultural services. The range of major ecosystem services provided by soil, and the specific soil functions that enable those services. [5]

Considering the ecosystem services of the soil, it is important to know what is happening with the soil at the moment, what is the condition of the soil. The soil monitoring system provides the answer to these questions.

The following main areas of activity are favorable for the promotion of the SMS soil monitoring system:

✓ Creation or strengthening of inclusive agricultural/environmental policies that support SMS.

✓ If necessary, the inclusive policy of SMS promotion should be linked with agricultural and environmental policies in such a way that their implementation provides multiple benefits. If such a policy already exists, it can be revised to take into account SMS issues, if necessary.

✓ Increasing the volume of responsible investment and positive incentives

designed to promote the rational use of land resources.

✓ As necessary, the volume of responsible investment in SMS should be increased in accordance with the Principles of responsible investment in agri-food systems. Positive incentives can be envisaged that recognize the value of ecosystem services to those stakeholders who implement SMS principles.

✓ Helping to ensure the rights of ownership and use of land resources. SMS depends on the presence or absence of guaranteed rights of ownership and use of land resources. Access to land and the right to own and use land is an important factor for proper use of SMS by land users and ensuring long-term planning.

✓ Stimulation and development of targeted scientific research in the field of soil science.

✓ It is critical to increase investment in soil research to enable national research programs and their partners to work with land users to identify and address the challenges they face in enhancing ecosystem services provided by soils (e.g. soil productivity).

✓ Prevention or minimization of soil degradation and restoration / reclamation of degraded soils (including long-degraded soils). Soil degradation is minimized with the use of SMS, especially with the use of proven soil-saving tillage methods or minimal tillage methods. Soil reclamation and/or restoration that restore soil productivity should also be a priority, especially in historically established agricultural or other production systems that are currently under threat.

✓ Promotion of effective educational programs. Soil science education (formal or informal) should be strengthened as necessary. Capacity building in the field of SMS is necessary so that a greater number of professionals master modern methods and tools.

✓ Ensuring the proper inclusion of SMS in the work of services for the dissemination of agricultural knowledge. Agricultural extension services should promote the principles and methods of SMS.

✓ Creation / improvement of basic information systems.

Basic principles of sustainable management of soil resources:

✓ Minimization of soil erosion;

✓ Increasing the content of organic substances in the soil;

✓ Ensuring the balance and cycles of nutrients in the soil;

✓ Prevention, minimization and mitigation of soil salinization and salinization;

✓ Prevention and minimization of soil pollution.

✓ Prevention and minimization of soil acidification;

✓ Preservation and increase of soil biodiversity;

✓ Minimization of soil walling;

- ✓ Prevention and minimization of soil compaction;
- ✓ Improvement of soil moisture management.

A new EU soil quality strategy is currently being developed and is due to be published in the second quarter of 2021 – a public consultation on the strategy started on 2 February. The goal of the new strategy is to comprehensively solve problems and stop the spread of soil degradation by 2030. Soil health is extremely important not only for the health of ecosystems, but also for sustainable economic development. Soils provide important ecosystem services such as food, energy and raw materials, carbon sequestration, water purification and filtration, nutrient cycling, pest control, and more. Because of these properties, soils are crucial for combating climate change, protecting human health, protecting biodiversity and ecosystems, and ensuring food security. [8]

Healthy soils are a key contributing factor to achieving the goals of the European Green Deal, such as climate neutrality, biodiversity restoration, zero pollution, healthy and sustainable food systems, and a sustainable environment. The European Environment Agency concludes that the lack of a comprehensive and coherent policy framework for land and soil protection is a key shortcoming that reduces the effectiveness of existing incentives and measures and may limit Europe's ability to meet the EWC targets. A new political framework is needed, as the EU soil quality strategy from 2006 no longer corresponds to today's political context and improved scientific knowledge base.

The problem of soil degradation in the EU is quite significant: up to 12.7% of all soils in the EU suffer from erosion, which causes significant losses. [1, 5, 7]

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