NATIONAL UNIVERSITY OF LIFE
AND ENVIROMENTAL SCIENSES OF UKRAINE

Department of General Ecology, Radiobiology and Life Safety

ENVIRONMENTAL MONITORING

TEXTBOOK

Kyiv 2023

УДК 504.06

Rakoid O.O., Bogoliubov V.M., Klepko A.V., Bondar V.I. Environmental monitoring. Textbook. Kyiv: NUBIP, 2023. 332 p.

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У підручнику ґрунтовно викладені теоретичні і практичні аспекти моніторингу, описані особливості організації різних рівнів моніторингу довкілля, розглянуто сучасні методи та засоби моніторингових досліджень, а також розроблено тлумачний словник термінів у сфері екологічного моніторингу. Дане видання є найбільш сучасним підручником в Україні з дисципліни «Моніторинг довкілля» англійською мовою для фахівців освітньо-кваліфікаційного рівня «Бакалавр».

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INTRODUCTION

Our planet is developing an increasing sense of environmental awareness and with it has emerged a new form of assessment – environmental monitoring. It's a bit of a buzzword in the sustainability sphere and is used to describe the various processes, tests and investigations that are carried out in order to monitor the state of the environment, its natural changes and the impact that any human activity could have on its quality. At its core, environmental monitoring is designed to help us understand the natural environment and protect it from any negative outcomes of human activity.

Environmental monitoring is defined as the observation of the presence of harmful factors such as toxins, bacteria, chemicals and other pollutants in a specific location. Environmental monitoring is a tool to assess environmental conditions and trends, support policy development and its implementation, and develop information for reporting to national policymakers, international forums and the public.

The discipline "Environmental monitoring" is a standard professionally-oriented discipline for students of Educational degree "Bachelor" with specialization 101 Ecology. Purposes of discipline are to expand the object, methods and place of the discipline "Environmental monitoring" in the system of environmental knowledge as well as highlight its main principles; to introduce the main sections of the discipline; to promote ecological outlook for future environmentalists.

Objectives of the discipline is formation the theoretical knowledge and practical skills in the field of environmental monitoring, in particular on the modern problems of different components of the environment (surface and ground water, oceans and seas, atmospheric air, soils etc.), estimation of impact of anthropogenic stresses on them, prediction of changes in the state of environment as well as working out the scientifically-grounded recommendations for realization of nature protection measures.

The main tasks of the discipline are:

- to expand the object, methods and place of the discipline "Environmental monitoring" in the system of environmental knowledge as well as highlight its main principles;

- to introduce the main sections of the discipline;

- to promote ecological outlook for future environmentalists.

After mastering the course, students should know: subjects, tasks and scheme of national monitoring system; scientific and methodical basis for monitoring investigation; methods of grounding the net of observation of the components of biosphere; normative basis of environmental monitoring system; program of observation of the pollution sources and level of pollution; methods of analysis and prediction in changes of the environment.

Students should be able: to ground the choice of methods and places of observation for the state of environment; to use modern methods of analysis and prediction the state of environment; to show the dynamics of changes in the state of environment; to develop scientifically-grounded recommendations for supporting of managerial decisions in the field of environmental protection.

This redaction of textbook was created on the basis of [Rakoid O.O., Bogoliubov V.M. “Environmental monitoring. Study guide for students with direction 101 Ecology”. – Kyiv: NUBiP, 2018. – 168 p.].

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LIST OF ABBREVIATIONS

CBD – the Convention on Biological Diversity

CSD − the United Nations Commission on Sustainable Development

DPSIR framework − the Driving Forces-Pressure-State-Impact-Response framework

DWAF – Department of Water Affairs and Forestry of South Africa

EEA – European Environment Agency

EPA – U.S. Environmental Protection Agency

EPE – Environmental Performance Evaluation

ESA – the European Space Agency

FAO – Food and Agricultural Organization of the United Nations

GE – Geological environment

GEMS – the Global Environment Monitoring System

GEO − the Global Environmental Outlook

GMOs – Genetically Modified Organisms

MAC – Maximum allowable concentrations

MPD – Maximum permissible discharge

MPE – Maximum permissible emission

NASA – the National Aeronautics and Space Administration (USA)

NRF – Nature reserve fund

OECD − the Organization for Economic Cooperation and Development

SAUEZM – the State Agency of Ukraine on Exclusion Zone Management

SCOPE – Scientific Committee on Problems of the Environment

SEMS – the State Environmental Monitoring System of Ukraine

SSAU – the State Space Agency of Ukraine

UAV – Unmanned aerial vehicle

UHMC – the Ukrainian Hydrometeorological Center

UkrSCES – the Ukrainian Scientific Center of Ecology of the Sea

UN – the United Nations

UNCCD – the United Nations Convention to Combat Desertification

UNECE – the United Nations Economic Commission for Europe

UNEP – the United Nations Environment Program

UNESCO – the United Nations Educational, Scientific and Cultural Organization

UNFCCC – the United Nations Framework Convention on Climate Change

WHO – the World Health Organization

WMO – the World Meteorological Organization

1. BASIC CONCEPTS OF ENVIRONMENTAL MONITORING

1.1 Rationale for the need of observations of the state of the "Nature-Society" system;

1.2 Development of scientific foundations for modern monitoring;

1.3 Approaches to defining the structure of the monitoring system;

1.4 Objectives and results of environmental monitoring.

1.1 Rationale for the need of observations of the state of the "Nature-Society" system

Violation of the stability of the system "Nature - Society" is caused by a significant destructive impact of society on the environment as a result of the excessive growth of productive forces and the population. All this leads to considerable uncontrollable anthropic pressure on the Earth's ecosystems and often to irreversible changes in the entire biosphere.

The continuous development of scientific and technological progress leads to a number of global environmental problems, each of which can cause the destruction of our civilization. Among these problems the most critical are: pollution of surface water sources, reduction of biological and landscape diversity of the planet, greenhouse effect, ozone holes, acid rains, pollution of the World Ocean, desertification, deforestation etc.

Decreasing the level of anthropic impact on the Earth's ecosystems can be achieved by reorienting the management of socio-economic systems at all levels to the principles of sustainable development.

One of the most important ways of society's transition to sustainable development is the introduction at all organizational levels of a scientifically sound system of environmental and socio-economic management, which is built on objective data obtained from the environmental monitoring system of the appropriate level (Fig. 1.1), that in turn is the information basis of the concept of sustainable development and a kind of initial function of the management cycle.

In terms of information, the monitoring system should ensure the organization of the necessary information flows and improve the observation of the main processes and phenomena in the biosphere.

To make rational management decisions, a prerequisite is the availability of quality information on the dynamics of various indicators characterizing the state of the environment.

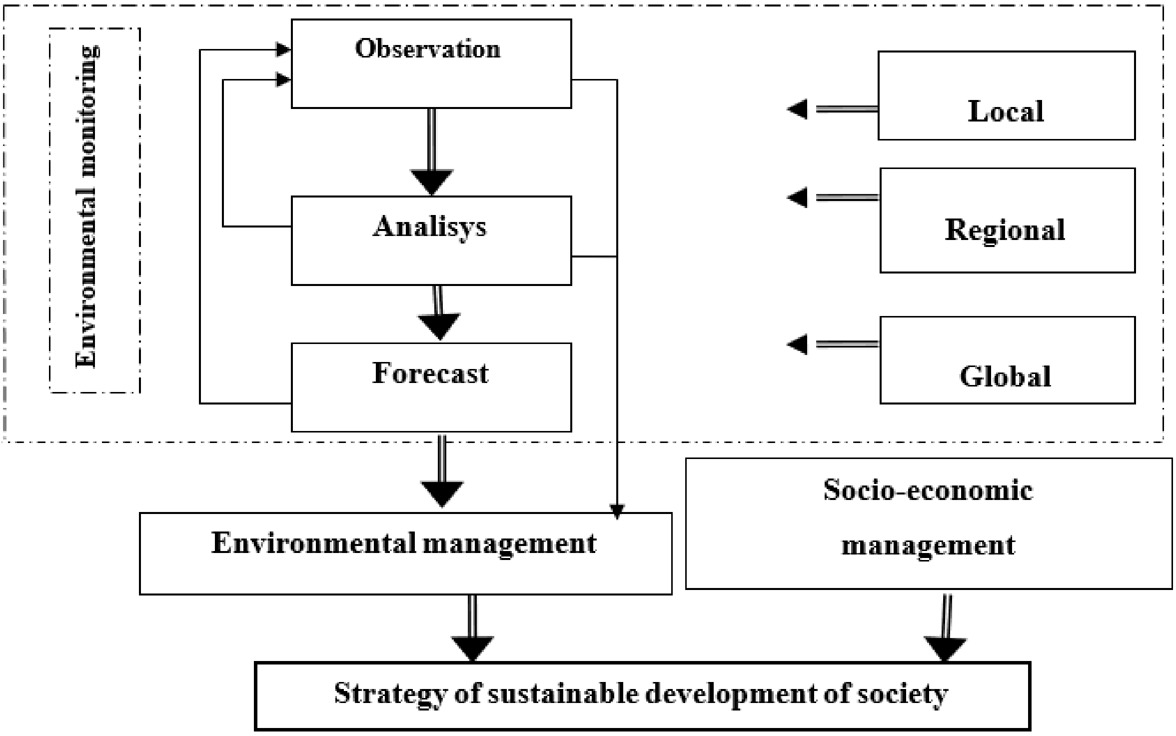


Figure 1.1 – Block diagram of the implementation of the strategy of sustainable development of society

At the same time, all the negative trends occurring in the extremely complex system "Nature-Society" increase the relevance of both environmental and socio-economic monitoring.

Natural changes in the state of the environment are usually studied by existing geophysical services (hydrometeorological, seismic, gravimetric, etc.). And in order to distinguish anthropic changes from natural ones, there was a need to organize special monitoring observations of changes in the state of the biosphere under the influence of human activities.

1.2 Development of scientific foundations for modern monitoring

According to the SCOPE (Scientific Committee on Problems of the Environment) concept, the system of repeated observations of one or more components of the environment in space and time with specific objectives and according to a prearranged program was proposed to be called ***monitoring***.

The term "monitoring" has started up before the United Nations Conference on the Human Environment (Stockholm 1972). The first proposals on the occasion of such a system has been developed by experts of the special commission SCOPE in 1971. The main elements of the monitoring as a system were first described by the R. Munn (1973).

The formation of the scientific foundations of modern environmental monitoring was devoted to the works of Academician I. P. Gerasimov (Gerasimov, 1975, 1976) and Professor Yu. A. Izrael (Izrael, 1984), in which the basic principles of the formation of the environmental monitoring system are developed, and international aspects of the global monitoring system were also partially reflected.

Discussion of the monitoring system intensified before the first intergovernmental meeting on monitoring, convened in Nairobi, Kenya, in February 1974 by the Governing Council of the United Nations Environment Program (UNEP). The materials of the meeting outlined the main provisions and objectives of the program of the global environmental monitoring system, in which special attention was paid to the formation of warnings about changes in the state of the environment related to pollution, and on the other hand – to warning of the threat to human health, the threat of natural disasters, as well as the emergence of other environmental problems.

A detailed discussion of the main tasks of monitoring, as well as various aspects related to the justification and implementation of monitoring systems, took place at the International Symposium on Integrated Global Monitoring of Environmental Pollution in Riga in December 1978.

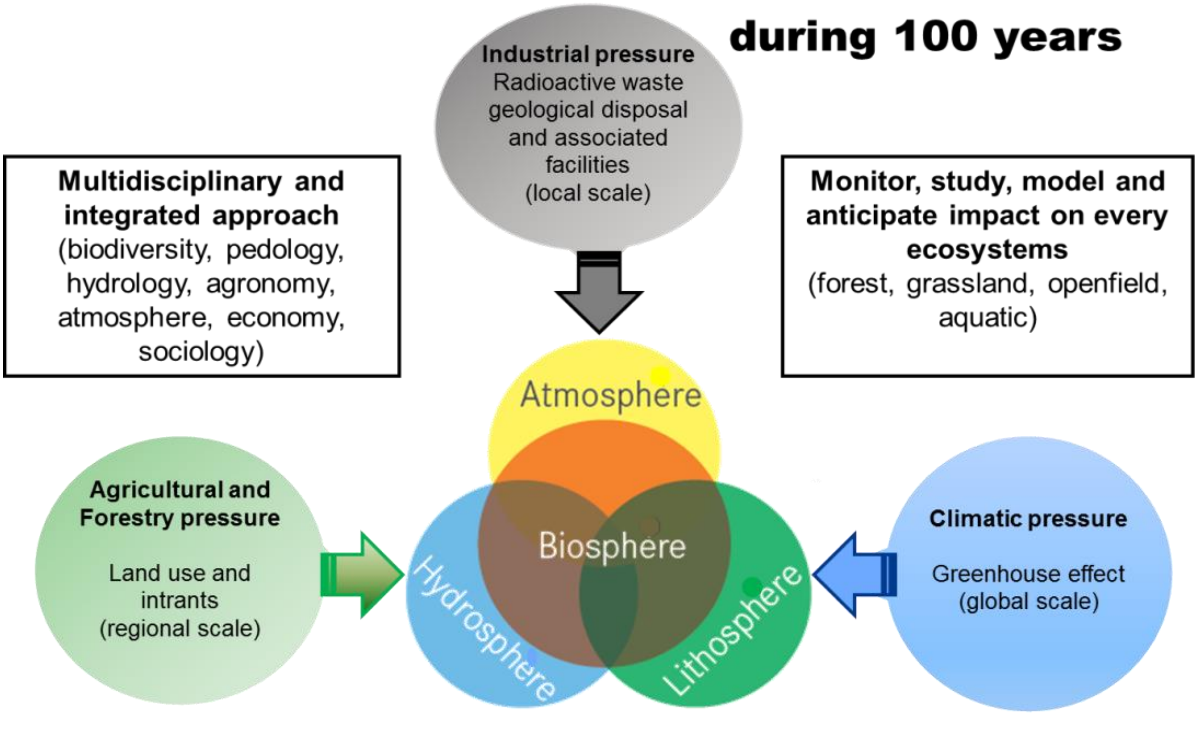


Figure 1.2 Objectives of environmental monitoring

Professor Yu. A. Izrael believed that the term "monitoring" appeared as a counterbalance to the term "control," which included not only observations and obtaining information, but also elements of active action, i.e., elements of management (*control* - in English means both control and management). In our scientific and technical literature, the term "control" provides only for receiving and analyzing information and does not provide for active actions.

A total system for environmental control includes three basic types of activity. The first involves measurements and observations directed towards a description of the state of the environment and its changes. The second activity is the evaluation and analysis of environmental data to determine possible trends and to develop a warning system related to pre-set criteria. This specifically includes functions such as predictions of the environmental consequences of planned actions, descriptions of the budget of contaminants and the analysis of ecosystems, determination of environmental criteria for specific pollutants, and the formulation of recommendations for actions.

The third and final activity in the total system is that of action, designed to avoid environmental deterioration but in the overall context of achieving environmental management in the most beneficial way.

Global environmental monitoring or "monitoring" described as activities of the first type listed above. Accordingly, monitoring is defined as, "a scientifically designed system of continuing measurements and observations."

Environmental monitoring can be defined as the systematic sampling of air, water, soil, and biota in order to observe and study the environment, as well as to derive knowledge from this process (Artiola et al., 2004; Wiersma, 2004).

Monitoring can be conducted for a number of purposes, including to establish environmental “baselines, trends, and cumulative effects” (Mitchell, 2002, pg. 318), to test environmental modeling processes, to educate the public about environmental conditions, to inform policy design and decision-making, to ensure compliance with environmental regulations, to assess the effects of anthropogenic influences, or to conduct an inventory of natural resources (Mitchell, 2002).

Environmental monitoring is defined as "an activity undertaken to provide specific information on the characteristics and functions of environmental and social variables in space and time."

The term environmental monitoring is not used consistently in the environmental field and is often referred to by various terms.

The British Standard EN ISO 14031:1999 defines Environmental Performance Evaluation (EPE) as an internal management process and tool designed to provide environmental management with reliable and verifiable information on an ongoing basis to determine whether an organization's environmental performance is meeting the criteria set by the management of the organisation. EPE can be interpreted as a certain type of environmental monitoring.

Environmental monitoring may be defined according to DWAF's Integrated Environmental Management Framework (IEMF) as "the repetitive and continued observation, measurement and evaluation of environmental data to follow changes over a period of time to assess the efficiency of control measures".

Lastly, according to UNECE (the United Nations Economic Commission for Europe) "environmental monitoring is a tool to assess environmental conditions and trends, support policy development and its implementation, and develop information for reporting to national policymakers, international forums and the public".

1.3 Approaches to defining the structure of the monitoring system

Environmental monitoring in the modern sense can be considered as an analytical and information system, which covers the following main areas:

1) Observations on the state of the environment and on factors that affect certain elements of the environment;

2) Assessment and analysis of the factual state of all components of the environment;

3) Forecasting the state of the environment and assessing this state;

4) Providing scientific and informational support for management decision-making.

A necessary condition for the organization of environmental quality management is the formation of a full-fledged monitoring system.

With the help of the monitoring system, it is possible to identify critical situations, emphasize the critical factors of influence as well as highlight the most sensitive elements of the biosphere. In the process of monitoring, it is important to obtain data on both the abiotic component of the environment and the state of the biota, as well as information on the functioning of ecosystems and responses (i.e., reactions) of ecosystems to possible disturbing influences.

Universal approach for determining the structure of the monitoring system of anthropogenic changes in the environment is its division into basic blocks as it is shown on Fig. 1.3: "Observation", "Assessment of the actual (current) state", "Environmental forecast", "Evaluation of projected state" and "Support decision-making".

In general, the evaluation blocks often include procedures for analyzing and processing observation data, and in the forecasting block - the processes of modeling changes in the state of the environment.

Blocks "Observation", "Assessment of the actual state" and "Forecast of the state of the environment" are closely related to each other, because the forecast of the state of the environment is possible only if there is sufficient information about its actual state (direct link - feedforward).

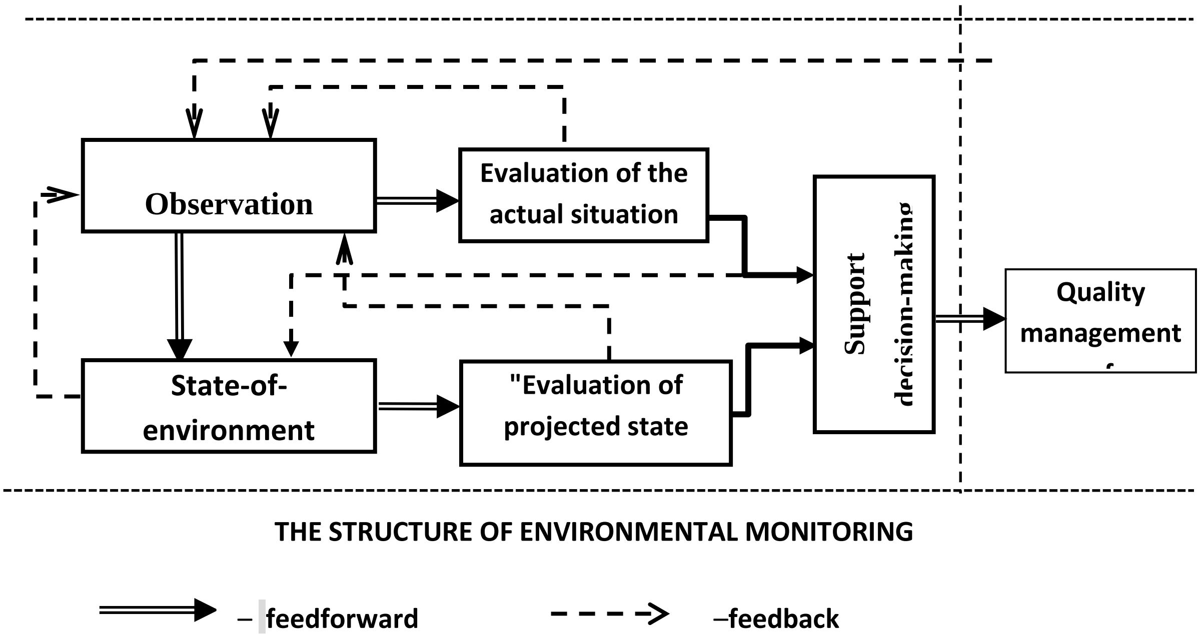


Figure 1.3 The structure of environmental monitoring

The forecast, on the one hand, must take into account observational data and patterns of change in the state of the natural environment, and on the other hand, the focus of the forecast should largely determine the structure and composition of the observation network (feedback).

The data obtained as a result of observations or forecast and characterizing the state of the natural environment should be evaluated depending on the field of human activity in which they are used (through specially selected or developed criteria).

Such an assessment should provide, on the one hand, an estimation of damage from the impact of the relevant activities and, on the other hand, make it possible to optimize human activities, taking into account the existing environmental reserves. In such assessments, it is mandatory to determine the permissible loads on the environment, taking into account the integrated characteristics and indicators.

The direct determination of these indicators is a definite step in the assessment of the state of the environment, because as a result of such measurements it is possible to answer the question about its condition.

When determining the allowable anthropic loads for the ecosystem, it is necessary to proceed from the ecological reserve of this system and the range of allowable fluctuations of its state.

It is important to keep in mind the biological stability of the system and take into account the relationship between disturbances and the effects that occur under the influence of these disturbances. When determining the ecological reserve of an ecosystem, it is necessary to know well and be able to identify critical factors of anthropic disturbances and critical elements of the biosphere, the impact of which can lead to drastic changes in the natural environment.

The occurrence of organized, community-based environmental monitoring has been increasing in the last decade owing to an emerging global emphasis on the importance of sustainable development.

There is a global recognition that “environmental issues are best handled with the participation of all concerned citizens”, a principal first articulated in the United Nation’s Earth Summit Agenda 21 (UN, 1992). This principal was strengthened further in July, 2009, with the formal ratification of the Aarhus Convention which mandates participation by the public in environmental decision-making and access to justice in environmental matters (UNECE, 2008).

There are several global-scale organizations that are responsible for the collection and distribution of environmental data internationally. For example, there are multiple programs operated by the United Nations that participate in global environmental monitoring activities, such as the World Meteorological Organization (WMO), the Global Atmosphere Watch, and the World Conservation Monitoring Centre. The WMO, the World Weather Watch, and the World Health Organization collectively manage the Global Environment Monitoring System (GEMS), which is responsible for monitoring and reporting on the "global state of water, air, climate, atmosphere, and food contamination".

Through the administration of these programs, the United Nations is providing a valuable mechanism for data collection and dissemination on a global scale, making it possible to address global scale issues such as water security and climate change.

1.4 Objectives and results of environmental monitoring

Environmental monitoring is an important tool of effective management of environmental quality, timely warning of negative impacts on the natural environment and population, as well as provision of information to the public and decision-makers about the state of the environment.

The specific aspects of the environment to be studied are determined by environmental objectives and environmental legislation.

The purpose of environmental monitoring is to assess the progress made to achieve given environmental objectives and to help detect new environmental issues.

The results are of fundamental importance to environmental management in general, as the drafting and prioritization of environmental policies is based on the findings of environmental monitoring.

Environmental monitoring is a necessary component of environmental science and policy design. Despite criticisms that environmental monitoring can be ineffective and costly when programs are poorly planned, well-planned monitoring programs cost little in comparison to the resources that can be protected and the policy design that can be informed.

Questions for self-control

1. When and where the term "monitoring" has started up?

2. How many basic types of activity does a total system for environmental control include? Should the environmental monitoring be described as activities of the first type?

3. Name the four main areas of the environmental monitoring.

4. When and where was the 1-st Intergovernmental Meeting on Monitoring held?

5. What is the purpose of environmental monitoring?

6. Why the results of environmental monitoring are so important?

7. Name several global-scale organizations that are responsible for the collection and distribution of environmental data.

2. CLASSIFICATION OF THE MONITORING SYSTEM. ENVIRONMENTAL INDICATORS

2.1 Types and levels of environmental monitoring in Ukraine;

2.2 Approaches to the classification of monitoring systems;

2.3 Introduction to environmental indicators.

2.1 Types and levels of environmental monitoring in Ukraine

Resolution of the Cabinet of Ministers of Ukraine of March 30, 1998 № 391 “Regulations on the State Environmental Monitoring” defined the following types of environmental monitoring that have become generally accepted: general (standard), operational (crisis), background (scientific).

General (standard) monitoring is the optimal for the number of observation parameters at the points combined in the information-technology network, which allow on the basis of assessment and forecast of the state of the environment to regularly develop management decisions at all levels.

Operational (crisis) monitoring is the study of special indicators on a target network of points in real time on selected objects, on sources of high environmental risk in certain regions defined as emergency zones, as well as in areas of accidents with harmful environmental effects to ensure a rapid response to crisis situations and make decisions on their elimination, creating a safe environment for the population.

Background (scientific) monitoring is special high-precision observations of all components of the environment, as well as on the nature, composition, cycling and migration of pollutants, the response of organisms to pollution both at the level of individual populations or ecosystems, and the biosphere as a whole. It is carried out at base stations in nature and biosphere reserves, as well as in other conservation areas.

The system of the state environmental monitoring of Ukraine has three levels:

1) local - territories of selected objects (enterprises, cities, landscape units etc.);

2) regional - within administrative-territorial units, in the territories of economic and natural regions;

3) national - the territory of Ukraine as a whole.

2.2 Approaches to the classification of monitoring systems

There are many other approaches to the classification of monitoring systems according to different criteria.

A generalized classification of possible monitoring systems (subsystems) is given in Table 2.1.

In all systems, the environmental observation block should provide observation of both the sources of anthropogenic influence and the state of elements of the biosphere and changes in their structural and functional indicators (including the responses of living organisms to various influences).

In this regard, it is necessary to first obtain data on the initial (background) state of all components of the biosphere, which is provided by the system of background or baseline monitoring.

Each environmental monitoring system, depending on its purpose, has its own objects of study, but there are several common approaches to defining these objects in general.

There are 5 sections of observations: from local sources and factors influencing the environment to the impact of changes in the state of the environment on the health and well-being of the population.

Table 2.1 Generalized classification scheme of monitoring systems

Principle of classification	Existing or prospective monitoring systems
By universality of the system	Global (including baseline and paleomonitoring). National, "international" (transboundary pollutants transport monitoring), regional
By reaction of the main components of the biosphere	Geophysical monitoring, biological monitoring (which includes genetic monitoring), environmental monitoring (including geophysical and biological monitoring)
By the main components of the biosphere	Monitoring of anthropogenic changes (man-made change of environment) in atmosphere, hydrosphere and lithosphere
By source of influence	Monitoring of sources of pollution, ingredient monitoring (selected pollutants, ionizing radiation, noise, etc.)
By the impact factors	Biotic and abiotic monitoring
By the severity and globality	Monitoring of the ocean, climate monitoring, ozone layer monitoring, etc.
By the methods of observations	Aerospace monitoring (remote sensing methods) Monitoring of physical, chemical and biological parameters
By the systematicity of approach	Biomedical or health-related monitoring, bioenvironmental monitoring, climate monitoring. Options: biomonitoring, geoecological, monitoring of biosphere, monitoring of resources and others.

For example, classification of monitoring systems in the context of observations (Table 2.2).

Observations on local sources of impacts and pollution and on impact factors are allocated in a special section (Section A). Such sources can be natural (volcanic eruptions) and anthropogenic (industrial emissions; agricultural sources - livestock farms and fields after application of chemical fertilizers and pesticides; air, water and motor transport, etc.).

Table 2.2 Classification of reactions of natural systems, sources and impact factors that need to be covered by the monitoring system (by Yu. A. Israel, 1984)

Section of observations	Classification
A. Local sources and impact factors	A.1. Sources of pollution and influence sources A.2. Impact factors (pollutants, radiation etc.)
B. State of the environment	B.1. State of the environment that is characterized by physical and physiographic data B.2. State of the environment that is characterized by geochemical data and pollution data
C. State of biotic component of biosphere	C.1. Challenge response - by biont - in population - in communities and ecosystem
D. Response of a large-scale systems and biosphere	D.1. Response of a large-scale systems (weather and climate) D.2. Response of biosphere in whole
E. Public health and human wellbeing	E.1. Environmental influence on morbidity and public health E.2. Environmental influence on human wellbeing

Section B includes observations of the chemical composition (of natural and anthropogenic origin) of the atmosphere, precipitation, surface and groundwater, ocean and sea waters, soils, bottom sediments, vegetation, animals, as well as observation of the main pathways of contamination.

Section C involves observing the response of biota to various influences and changes in environmental conditions.

Section D - observing the response of large systems (such as weather, climate) and the biosphere as a whole - includes the entire system of observations listed in Sections B and C and requires special generalizations and assessments.

Section E is as important as the others. Because of the great complexity and lack of research on the effects of the environment on humans, a complete comprehensive study is a very complex task and has not yet been fully solved.

Thus, the task of environmental monitoring is to identify anthropogenic changes in ecosystems (against the background of natural fluctuations). This problem can be solved by various methods, in particular by direct measurements of individual characteristics of biota pollution and its reactions to these pollutants, as well as through continuous measurements of integrated indicators in large areas.

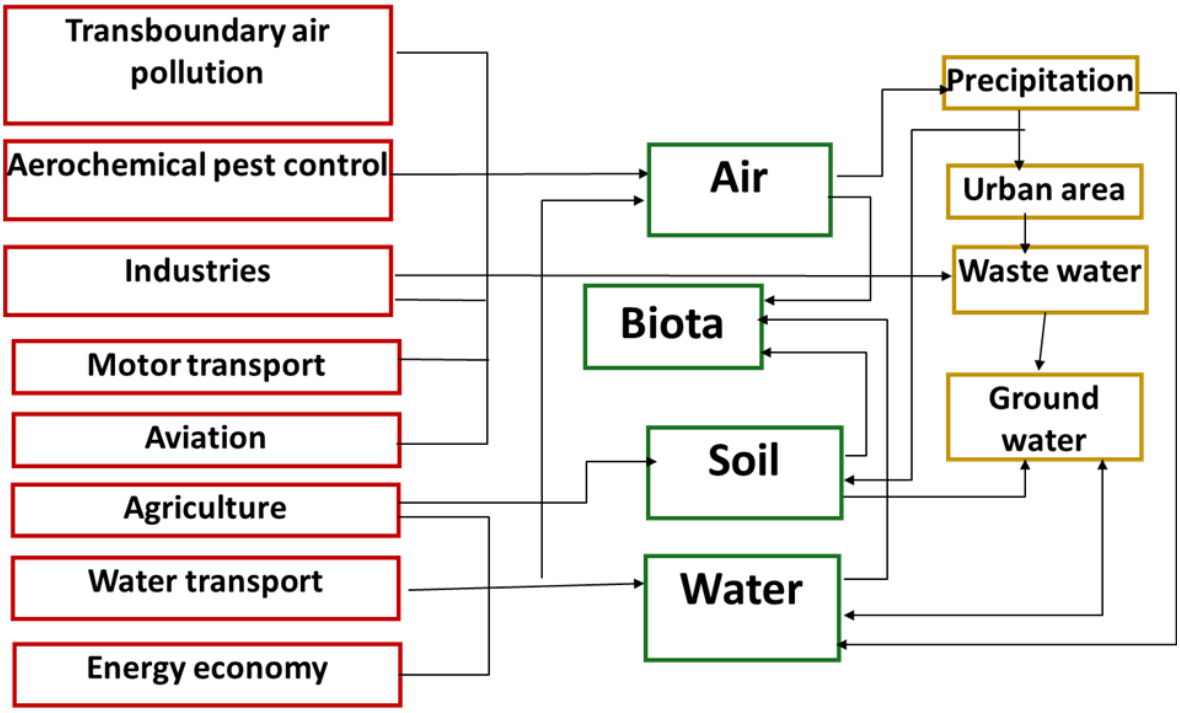


Figure 2.1 Block diagram of the influence of the main sources of pollution on the biosphere

As you know, the complex of anthropic factors (Fig. 2.1) is very diverse: it includes pollution of the natural environment with various substances, physical impacts that disturb the natural coverage of the planet, the abstraction of renewable and non-renewable resources, and so on.

When conducting monitoring of the biosphere it is necessary to organize a sufficiently representative network of observations (measurements) of the most important factors of influence and indicators of the state of the environment. Depending on the specific task of monitoring, these factors and indicators may be different.

The most difficult problems are those associated with significant anthropic disturbances, which are characterized by the magnitude of the identified changes and effects (up to the global scope), as well as the significant inertia and severity of the negative consequences.

When defining indicators and characteristic values, a compromise should be sought between the reliability and availability of information. In this case, the loss of information should be minimal, and the indicator itself should provide informativeness, reality and the possibility of practical implementation, and simplifying information in a way that helps authorized officials make informed decisions and the public to understand the problem.

The indicators simplify a complex reality and are "extracts" of information obtained in the process of observation and analysis of monitoring data. Most environmental indicators should be considered in an inseparable relationship.

2.3 Introduction to environmental indicators

Environmental indicators are simple measures that tell us what is happening in the environment. Environmental indicators have been defined in different ways but common themes exist.

- An environmental indicator is a numerical value that helps provide insight into the state of the environment or human health. Indicators are developed based on quantitative measurements or statistics of environmental condition that are tracked over time. Environmental indicators can be developed and used at a wide variety of geographic scales, from local to regional to national levels (EPA);

- A parameter or a value derived from parameters that describe the state of the environment and its impact on human beings, ecosystems and materials, the pressures on the environment, the driving forces and the responses steering that system. An indicator has gone through a selection and/or aggregation process to enable it to steer action (EEA).

The goal of environmental indicators is to communicate information about the environment − and about human activities that affect it − in ways that highlight emerging problems and draw attention to the effectiveness of current policies.

Environmental indicators are developed in order to:

- assist in the development of optimal environmental policy;
- compare countries and regions;
- ensure understanding of the problem;
- study the causal links between industrial activity and the environment.

The Driving Forces-Pressure-State-Impact-Response Framework (DPSIR framework) focuses on what has gone wrong with the environment and how to fix it. The DPSIR framework is an extension of the Pressure-State-Response (PSR) model, developed by Anthony Friend in the 1970s, and subsequently adopted by the Organization for Economic Cooperation and Development's (OECD) State of the Environment group.

The Global Environmental Outlook (GEO) Indicators by UNEP is a set of selected environmental trends, which are not assumed to be comprehensive. The selected indicators are a mix of environmental pressures, states, impacts and responses. But they do not intend, nor are they able, to capture all aspects of all global and regional environmental problems. The underlying data that are used to compile the indicators come from internationally recognized sources.

GEO is a series of reports on the environment issued periodically by the United Nations Environment Programme (UNEP). The GEO project was initiated in response to the environmental reporting requirements of UN Agenda 21 and to a UNEP Governing Council decision of May 1995 which requested the production of a new comprehensive global state of the environment report.

This infographic depicts the GEO indicators (Fig. 2.2) used from 1990-2005 and charts the progress of the different indicators through the years in that period.

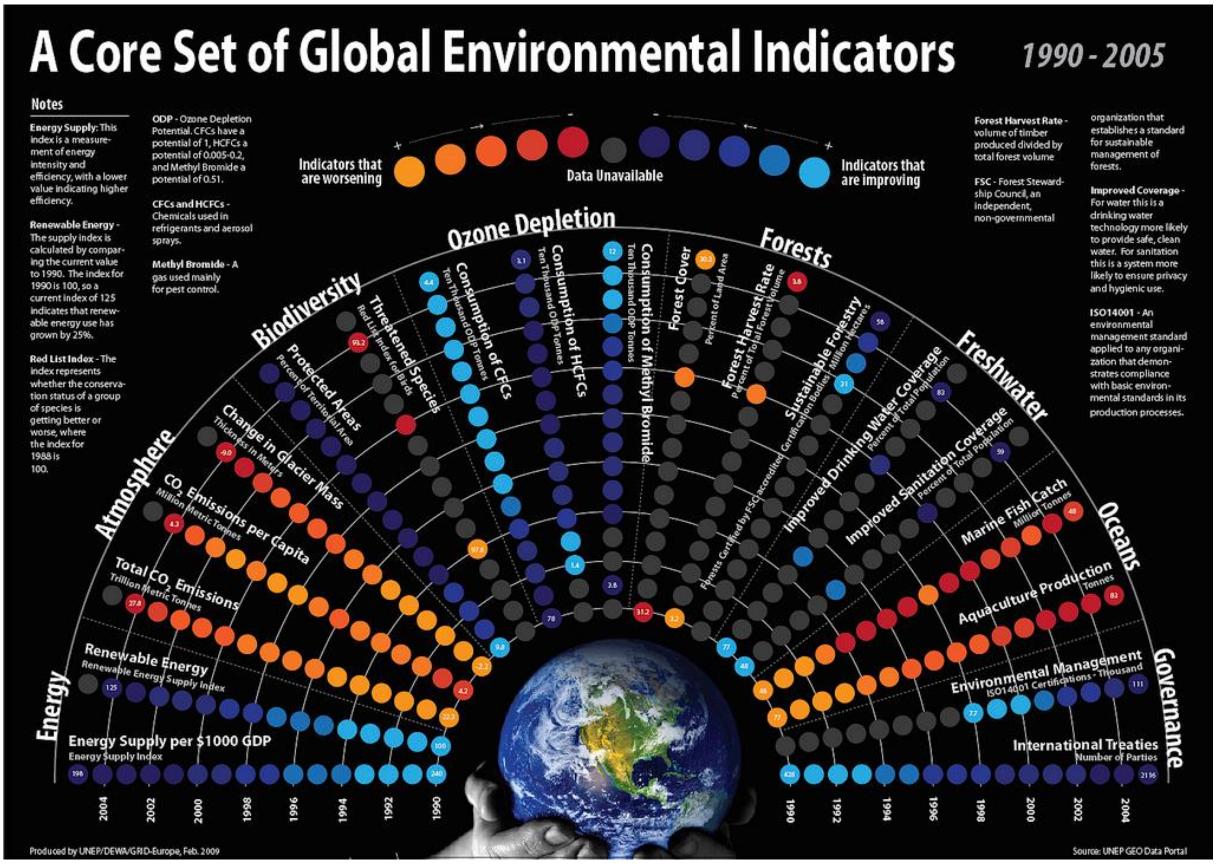


Figure 2.2 A core set of Global Environmental Indicators

For each issue, the single most important, suitable and reliable indicators currently available are presented. Every year, an updated selection of the Core Set of Indicators is included in the GEO Yearbook series as 'GEO Indicators'.

The OECD has developed and published the first international sets of environmental indicators and uses them regularly in its country environmental performance reviews and other policy analysis work.

Central to the OECD work are core environmental indicators to measure environmental progress, complemented with several sets of sectoral environmental indicators to help integrate environmental concerns in sectoral policies.

Indicators are further derived from environmental accounting and work is done on indicators to measure the decoupling of environmental pressure from economic growth.

In 2001 the OECD identified a shortlist of environmental indicators (key indicators). Their selection took into account: their policy relevance with respect to major challenges for the first decade of the 21st century, including pollution issues and issues related to natural resources and assets; their analytical soundness; and their measurability.

The list of indicators hence is neither final, nor exhaustive; it will evolve as knowledge and data availability improve. Ultimately, the list is expected to also include key indicators for issues such as toxic contamination, land and soil resources, and urban environmental quality.

European Environment Agency (EEA) uses five types of integrated indicators. These indicators are designed to answer key policy questions and support all phases of environmental policy making, from designing policy frameworks to setting targets, and from policy monitoring and evaluation to communicating to policy-makers and the public. The indicators are classified as follows:

Descriptive indicators (Type A) responding to the question: What's happening? − For example, the proportion of organic farming to all agricultural lands, %.

Performance indicators (Type B): Does it matter? Are we reaching targets? − They characterize the progress in achieving intended goals such as greenhouse gas emissions.

Efficiency indicators (Type C): Are we improving? There are indicators that characterize the ecological efficiency, for example, the level of emissions per unit of GDP (gross domestic product).

Indicators of political efficiency (Type D): Are the measures working? − are indicators that characterize the relationship between changes in the environment and political measures (response).

Total welfare indicators (Type E): Are we, on the whole, better off? − these indicators are characterizing the development of society, for example, indicators of sustainable development.

Table 2.3 EEA core set of indicators

Theme	CSI	Indicator title
Air pollution and ozone depletion	1	Emissions of acidifying substances
	2	Emissions of ozone precursors
	3	Emissions of primary particulates and secondary particulate precursors
	4	Exceedance of air quality limit values in urban areas
	5	Exposure of ecosystems to acidification, eutrophication and ozone
	6	Consumption of ozone-depleting substances
Biodiversity	7	Threatened and protected species
	8	Designated areas
	9	Species diversity
Climate change	10	Greenhouse gas emissions and removals
	11	Projections of greenhouse gas emissions and removals and policies and measures
	12	Global and European temperature
	13	Atmospheric greenhouse gas concentrations
Terrestrial	14	Land take
	15	Progress in management of contaminated sites
Waste	16	Municipal waste generation
	17	Generation and recycling of packaging waste

Water	18	Use of freshwater resources
	19	Oxygen-consuming substances in rivers
	20	Nutrients in freshwater
	21	Nutrients in transitional, coastal and marine waters
	22	Bathing water quality
	23	Chlorophyll in transitional, coastal and marine waters
	24	Urban wastewater treatment
Agriculture	25	Gross nutrient balance
	26	Area under organic farming
Energy	27	Final energy consumption
	28	Total energy intensity
	29	Total energy consumption
	30	Renewable energy consumption
	31	Renewable electricity
Fisheries	32	Status of marine fish stocks
	33	Aquaculture production
	34	Fishing fleet capacity
Transport	35	Passenger transport demand
	36	Freight transport demand
	37	Use of cleaner and alternative fuels

The establishment and development of the EEA core set of indicators has been guided by the need to identify a small number of policy-relevant indicators that are stable, but not static, and that give answers to selected priority policy questions. They should, however, be considered alongside other information if they are to be fully effective in environmental reporting.

The core set covers six environmental themes (air pollution and ozone depletion, climate change, waste, water, biodiversity and terrestrial environment) and four sectors (agriculture, energy, transport and fisheries).

Some other relevant priorities (chemicals, noise, industry, consumption, material flows) have not yet been included because indicators are insufficiently developed, but this will be the main focus for the future development of the core set (see Table 2.3).

Each indicator in the core set can be positioned in the DPSIR framework, (D = driving forces, P = pressures, S = states, I = impacts, R

= responses) but they are not spread in a balanced and comprehensive way.

The indicators are also classified by type (A = descriptive indicator, B = performance indicator, C = eco-efficiency indicator, D = policy effectiveness indicator, E = total welfare indicator).

Table 2.4 EEA core set of indicators in the DPSIR framework and by type

	D	P	S	I	R	A	B	C	D	E
Air quality and ozone depletion		4		2			6			
Biodiversity			1	1	1	3				
Climate change		2	2			1	3			
Terrestrial			1		1	2				
Waste		1.5			0.5	1.5	0.5			
Water		1	5		1	6	1			
Agriculture					1	2				
Energy	3				2	2	3			
Fishery	2		1			3				
Transport	2				1	2	1			
Total	7	9.5	10.5	3	7	22.5	14.5			

D = Driving force indicator
P = Pressure indicator
S = State indicator
I = Impact indicator
R = Response indicator

A = Descriptive indicator
B = Performance indicator
C = Efficiency indicator
D = Policy effectiveness indicators
E = Total welfare indicator

The United Nations Commission on Sustainable Development (CSD) was created in December 1992 to monitor and report on the implementation of the Earth Summit agreements. The CSD recognized an urgent need for global action to combine national and international information efforts and to promote comparability, accessibility, and quality of that information.

It began a work programme, with the goal of providing national decision-makers with a list of indicators to use in national policies and in reports to the CSD and other international agencies.

The proposed set of environmental indicators are not final or definitive, but can be adjusted to fit national conditions, priorities, and capabilities. Countries are encouraged to adopt and use this set as a starting point for their national indicator programmes. Wide adoption and use of the core set is meant to help improve information consistency at the international level. The CSD's list of issues and associated environmental indicators included such themes as Climate change, Ozon layer depletion, Air quality, Agricultural land, Desertification, Forests, Urban areas, Oceans and marine, Fisheries, Freshwater, Biodiversity, Energy and consamption.

In September 2015, the United Nations Sustainable Development Summit adopted an international framework to guide development efforts, entitled 'Transforming our world: the 2030 Agenda for Sustainable Development'. The SDG framework has a total of 17 goals, 169 targets and 247 indicators – 92 of which are environment related.

The SDGs aim to measure the most pressing issues facing the planet, including the interactions between topics. In terms of the environmental dimension of development, the SDGs cover natural resource management, climate change, water-related issues, marine issues, biodiversity and ecosystems, circular economy, environmentally sound management of chemicals and waste, and many other topics.

It should be noted that since 2021, UNEP has been using the adapted concept of "drivers of change" to track progress in achieving the SDGs and to fill in the sources of information on environment-related indicators.

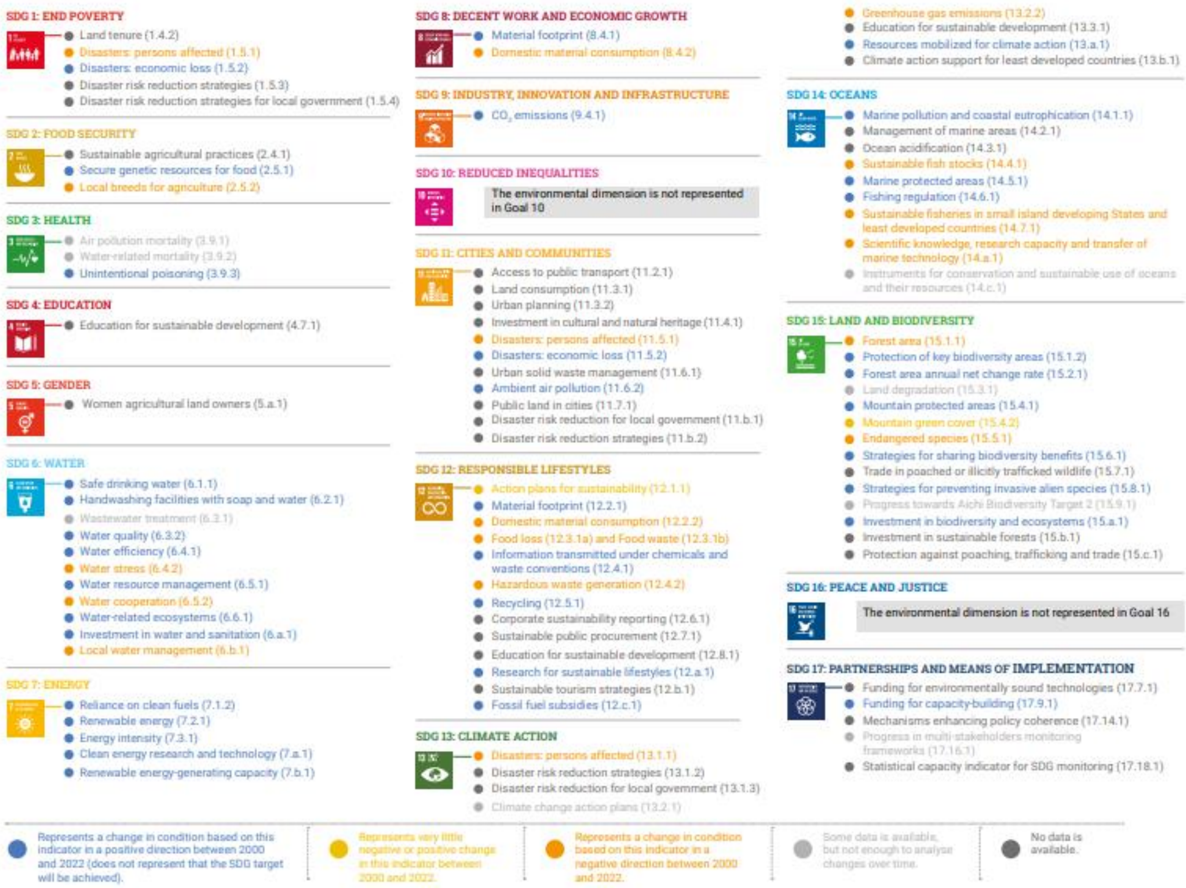


Figure 2.3 Global scorecard on the environmental dimension of the SDGs (according to Report “Measuring Progress: Water-related ecosystems and the SDGs” (UNEP, 2023)

The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) describes this concept as “all those external factors that affect (either positively or negatively) nature, anthropogenic assets, nature’s contributions to people and good quality of life.

They include institutions and governance systems and other indirect drivers, and direct drivers (both natural and anthropogenic)”. The IPBES concept of ‘drivers of change’ sits within a wider causal framework for describing the interactions between society and the environment called the DPSIR (driver, pressure, state, impact and response) framework, which the UNEP has used as the theoretical framework for its work on integrated environmental assessments (Fig. 2.4). This broad definition was adopted in order to include a wide range of actions that impact the environment.

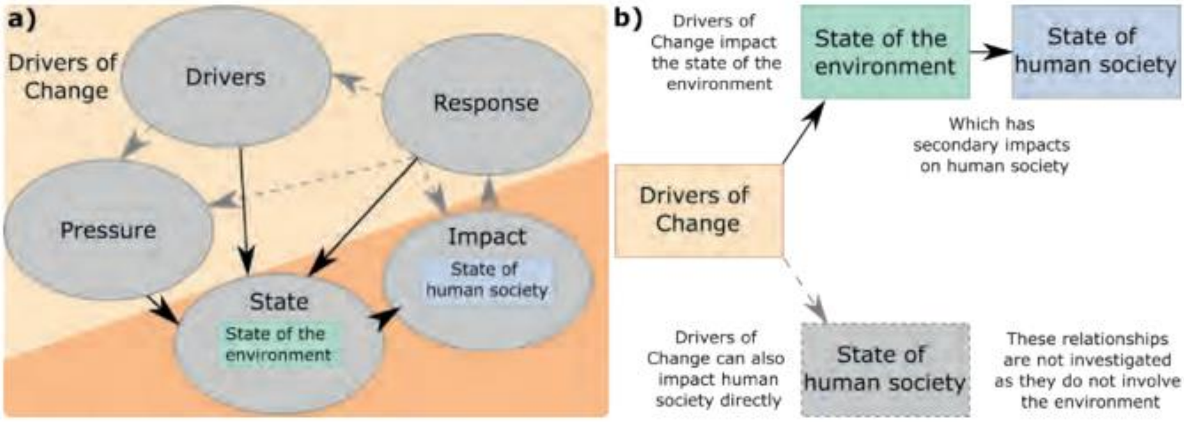


Figure 2.4 Concept of drivers of change and relationships between drivers of change, the state of the environment and the state of society (according to Report "Measuring Progress: Water-related ecosystems and the SDGs" (UNEP, 2023)

Drivers of change relate to the drivers, response and pressure components of the DPSIR framework. Drivers of change that tend to impact the environment negatively, such as current patterns of economic development, inequalities in access to resources and institutional power and tourism, are typically associated with the driver and pressure components of the framework, whereas drivers of change that tend to impact the environment positively, such as protection and sustainable environmental management policies, are typically associated with its response component.

The state of the environment is associated with the state component of the framework and is linked directly to the response component and indirectly to the drivers component via the pressure component. The state of society is associated with the impact component of the framework and is impacted directly by the state component.

Questions for self-control

1. What types of environmental monitoring (according to the Resolution of the Cabinet of Ministers of Ukraine) do you know?

2. What does background (scientific) monitoring deal with?

3. How many levels have the system of environmental monitoring of Ukraine? Name them in ascending order.

4. What is the task of environmental monitoring?

5. Why can the factors of influence and indicators of the state of the environment be different?

6. When defining indicators and characteristic values, a compromise should be sought between the reliability and … of information. (fill in omitted word)

7. What is the goal of environmental indicators?

8. Expand the abbreviation DPSIR. What does this framework focus on?

3. THE GLOBAL ENVIRONMENTAL MONITORING SYSTEM

3.1 Basics of establishing global environmental monitoring;

3.2 Specific programs of monitoring networks;

3.3 Biosphere reserves as integral part of GEMS.

3.1 Basics of establishing global environmental monitoring

The Global Environment Monitoring System (GEMS), currently involving the collaboration of 140 countries across the world, was conceived during the late 1960s within the wider context of growing environmental consciousness − and the availability of instruments and programs that could provide a truly global data set.

Under the aegis of the United Nations Environment Programme (UNEP), its mission is to collect and process data from transnational monitoring systems observing the effects of human activities on the environment and health. GEMS is based on the expertise and infrastructure of specialized United Nations (UN) agencies, and encompasses a number of scientific and professional communities.

In the second half of the 20th century growing appreciation of the global nature of earth systems led to a matching appreciation for pollution and environmental contamination as global issues. Pollution was no longer local but could now be understood as affecting the entire planet. The consequences were not only immediate; they could be felt decades after exposure or contamination, and over several generations.

Transnational approaches to environmental issues were increasingly discussed, including reflections on how the combined scientific, political, and administrative character of the challenges required regulatory and institutional reconfigurations. Nor was awareness of environmental threats always matched by practical knowledge of how to address them.

The 1971 SCOPE (Scientific Committee on Problems in the Environment) report on the planned global monitoring system formed the basis for discussion at the Stockholm conference of the following year. The report outlined the state of the art on environmental monitoring and assessment along with 18 recommendations.

These included how to organize the overall monitoring system, including an analysis of how many and what type of observation stations would be needed and where they ought to be placed, plus what type of data ought to be collected in the first instance − prioritizing the study of pollutants such as carbon dioxide, lead, mercury and cadmium.

Finally, the report stressed the importance of promoting research and pilot studies for the development of new and more efficient monitoring systems. The SCOPE experts called for the integration of these data into a global system and proposed the creation of a new infrastructure for global environmental data collection, under the aegis of the UN.

The Stockholm conference ratified the SCOPE recommendations effectively setting the goals of what would become GEMS, while also laying the groundwork for what would become the UN Environment Programme (UNEP).

The overarching project within which GEMS was located – Earthwatch − was outlined in 1972 and established at the first extraordinary meeting of the UNEP held in Geneva (1973). Earthwatch aimed to provide an efficient environmental assessment mechanism through monitoring, research, evaluation, and information exchange.

The specific idea for GEMS emerged during an intergovernmental meeting on monitoring that took in Nairobi in 1974 as the monitoring component in the Earthwatch program. GEMS would this aim to make assessments on a variety of environmental issues including atmospheric pollution and its impact on climate, contaminants in the food chain and agriculture, ocean pollution, and forecasting disasters such as earthquakes.

GEMS monitoring operations begun after substantial planning discussions. Drawing on the SCOPE report, UNEP established five monitoring programs closely interrelated programmes which have built-in provision for training and for rendering technical assistance to ensure the participation of countries that are inadequately provided with personnel and equipment. The five are:

1. Climate-related monitoring;
2. Monitoring of long-range transport of pollutants;
3. Health-related monitoring (concerned with pollutional effects);
4. Ocean monitoring; and
5. Terrestrial renewable-resource monitoring.

The above-mentioned UNEP Meeting in Nairobi (1974) further refined these goals, also listing the pollutants to be monitored in a specific "*order of priority*." But this was an order of priority that did not align with the SCOPE study in prioritizing, for instance, the monitoring of rapidly rising carbon dioxide levels and their effect on climate, doubtless recognizing the consequences of any action to reduce its levels globally for industrialized nations.

3.2 Specific programs of monitoring networks

From 1976, more specific programs were set up concerning the collection of data on the air (GEMS/Air), water (GEMS/Water), and the food chain (GEMS/Food). The data collected were processed under the responsibility of one or several organizations, depending on the program concerned.

Each of these broad areas contains at least five distinct world-wide monitoring networks. Examples of these latter are the World Glacier Inventory, Background Air Pollution Monitoring Network, Urban Air

Pollution Monitoring Network, Global Water Quality Monitoring Network, Tropical Forest Monitoring Network, Species Conservation Monitoring Network, etc. Monitored data are gathered at suitable coordinating centres for each network at which appropriate data-bases have been, or are being, established. Data are analyzed to produce periodic regional and global assessments which are reported at intervals that are appropriate to the variable which is being considered.

The Global Environment Monitoring System for Air (GEMS Air) of the UN Environment Programme, supports countries to provide quality assured data to keep the state of the world's air quality under continuous review, develops capacity of member states, provides information and services across the science-policy-public interface and fosters transformation by leveraging the collective knowledge of a global network of partners.

At the present time, partnerships include Google, IQAir, NASA, Code for Africa, International Association of Athletics Federations (IAAF), Formula-E (host electric car races around the world), UN-Habitat, World Meteorological Organization (WMO), World Health Organization (WHO), and so on. At the center of the GEMS Air strategy is data science that leverages satellite technology, modelling and analysis capabilities, and ground observations to support services to countries.

The Global Environment Monitoring System for freshwater (GEMS/Water) provides the community with sound data on fresh water quality to support scientific assessments and decision-making on the subject. Surface and ground water quality monitoring data collected from the global GEMS/Water monitoring network is shared through the GEMStat information system. At present, the growing database contains more than 7 million entries for rivers, lakes, reservoirs, wetlands and groundwater systems from 75 countries and approximately 5700 stations. Overall, data is available for the time period from 1965 to 2019 and about 300 parameters.

Since 1976, the Global Environment Monitoring System - Food Contamination Monitoring and Assessment Programme, which is commonly known as GEMS/Food, has informed governments, the Codex Alimentarius Commission (the Codex Alimentarius is international food standards, guidelines and codes of practice contribute to the safety, quality and fairness of this international food trade) and other relevant institutions, as well as the public, on levels and trends of contaminants in food, their contribution to total human exposure, and significance with regard to public health and trade.

The Programme is implemented by the WHO in cooperation with a network of more than 30 WHO Collaborating Centres and recognized national institutions located all around the world.

Since the implementation in 2011 of a new webbased interface the GEMS Food collected more than 2,600,000 analytical results on the occurrence of about 300 chemicals in food.

Priorities of GEMS/Food are following areas:

- Pesticide residues (Aldrin/dieldrin, DDT, Endosulfan, Endrin, Hexachlorcylohexane, Hexachlorobenzene, Heptachlor, Diazinon, Fenitrothion, Malathion, Parathion, Methyl parathion, DTC);
- Heavy metals (Cadmium, Lead, Methylmercury, Inorganic Arsenic);
- Industrial pollutants (Polychlorinated Biphenyls, Dioxins, Dibenzofurans);
- Naturally occurring toxicants (Aflatoxins, Patulin, Fumonisin B1, Ochratoxin A, Acrylamide).

GEMS would primarily be collecting information from existing UN and non-UN monitoring agencies rather than creating new ones.

In particular, GEMS would routinely interact and exchange information and data with the International Atomic Energy Agency, World Health Organization (WHO), WMO (the World Meteorological Organization), UNESCO (United Nations Educational, Scientific and Cultural Organization), and FAO (the Food and Agriculture Organization of the United Nations). Through the Information Referral System, GEMS could also examine data available to ICSU's (the International Council for Science − ICSU, after its former name, International Council of Scientific Unions) World Data centers.

Existing US monitoring and science-policy organizations played prominent roles in the GEMS activities. For instance, the chief source of data on pollution in the GEMS climate-related monitoring program was the WMO Background Air Pollution Monitoring Network (BAPMoN) housed in the US EPA (Environmental Protection Agency). This brought the US National Oceanic and Atmospheric Organization (NOAA) into the project, aside from UNEP.

Once the GEMS was made operational, it exemplified a science-based approach to environmental problems that drew heavily on preexisting monitoring systems laid out in the early 60s and 70s.

The implementation of GEMS was a further step in the development of the technical systems for environmental monitoring that constructed the entire earth as a subject of research and investigation. In nearly 50 years of functioning, the system has collected an impressive volume of data on the state of the earth's atmosphere, water, air, and forests.

3.3 Biosphere reserves as integral part of GEMS

The global environmental monitoring system is organically intertwined with national systems - it largely integrates the background stations of national systems. Biosphere reserves are considered an integral part of GEMS.

Background (baseline) monitoring is for the general purpose of comprehensive assessment and prediction of environmental states and processes.

In particular, the objectives may include:

a) The description of present environmental conditions;

b) The detection of variability and trends;

c) The determination of significant changes caused by man;

d) The modelling and prediction of future environmental states and processes.

Observation programs are formed on the principle of selecting priority pollutants and integral characteristics. Defining priorities in the organization of monitoring systems depends on the purpose and specific tasks: at the territorial level, preference is given to industrial cities, drinking water sources, and fish spawning grounds; as for the environment of observation, priority is given to atmospheric air and water of fresh water bodies and streams.

Monitoring is carried out at such stations as:

1) baseline stations (for global monitoring of very low background concentrations, the most important constituents of the atmosphere;)

2) regional stations (for monitoring long-term changes in atmospheric air composition caused by human activity);

3) regional stations with extended programs.

Observations are carried out according to minimum and extended programs. The minimum program at the baseline stations contains measurements of atmospheric turbidity, air conductivity, CO_2 content in the air and precipitation chemistry.

At regional stations, this program contains observations of atmospheric turbidity and precipitation chemistry.

The extended program contains additional observations for sulfur dioxide, hydrogen sulfide, total ozone, carbon monoxide and all nitrogen compounds, heavy metals.

The main task of background monitoring is to record and establish indicators that characterize the natural background, as well as its global and regional changes in the development of the biosphere. The most difficult task at present is to study ecological changes and organize ecological monitoring at the background level, which includes observation in areas that are far away from any local sources.

Background monitoring may be appropriately conducted in any major biome and at any site representative of a major ecosystem important to man, either aquatic and oceanic (e.g., lake, estuarine, open ocean and coastal waters) or terrestrial (e.g., tundra, forest, grassland).

The background global state of the biosphere is studied at baseline stations, which are based in biosphere reserves (226 biosphere reserves in 62 countries). In Ukraine these are Askania Nova (area - 33307.6 ha), the Black Sea Biosphere Reserve (area - 100 809 ha), the Carpathian Reserve (area - 57880 ha), the Danube Reserve (area - 46402.9 ha).

The background state of the environment in the past, before human impact, can be investigated by analyzing the rings of dead or old trees, samples of glaciers, bottom sediments (historical monitoring).

The program of background environmental monitoring on the basis of biosphere reserves contains the following sections.

1. Monitoring of pollution and other factors of impact on the environment.

2. Monitoring of biota responses to anthropic influences, primarily background levels of pollution.

3. Observation of changes in the functional and structural characteristics of reference natural ecosystems and their anthropogenic modifications.

Observation programs are formed on the basis of the selection of priority pollutants and integral characteristics according to a certain system of criteria. The process of prioritization of pollutants for background monitoring was carried out by the method of expert evaluations (Delphi method) in the 70s.

The selection criteria were considered at the Intergovernmental Meeting on Monitoring in 1974. They included various characteristics of pollutants such as: abundance, persistence, toxicity, transformation into more harmful compounds (products), transport along food chains, and accumulation in organisms. The priority of various pollutants was also determined (Table 3.1).

The found priorities were divided into eight classes (the higher the class, that is, the lower its ordinal number, the higher the priority) with the definition of the environment and the type of measurement program (("I" - impact, "R" - regional, "B" - basic and "G" - global).

Table 3.1 Classification of Priority Pollutants by Priority Classes (by Izrael, 1984)

Class	Pollutant	Environment	Type of program
1	Sulfur dioxide, particulate matters Radionuclides (^{90}Sr + ^{137}Cs)	Air Food	I, R, B I, R
2	Ozone DDT and other chlororganic compounds Cadmium and its compounds	- troposphere - stratosphere Biota Food, Water	I B I, R I
3	Nitrates, nitrites Nitrogen oxides	Drinking water, Food Air	I I
4	Mercury and its compounds Lead Carbon dioxide	Food, Water Air, Food Air	I, R I B
5	Carbon monoxide Petroleum hydrocarbons	Air Sea water	I R, B
6	Fluorides	Fresh water	I
7	Asbestos Arsenic	Air Drinking water	I I
8	Microtoxins Microbiological contaminations Reactive pollutants	Food Food Air	I, R I, R I

Impact monitoring is required to detect and prevent local problems. For instance, urban air pollution monitoring systems are meant to protect human health and to prevent possible damage to various materials and constructions, including historical and cultural monuments. Other systems belonging to this type are surface and drinking water monitoring systems.

As a rule, impact monitoring deals with a relatively limited though variable range of sources and impact factors, with environmental quality assessment based on common criteria, such as maximum permissible concentrations or quality standards established for man. Environmental state prediction and quality management are rather simple and closely connected with sources in a given area (city, industrial complex, etc.).

Regional monitoring, though having the same task, is related to more complicated processes and involves much larger territories. The variety of impact factors decreases while the number of sources increases and the relationship between these factors and environmental quality becomes more complex. This fact considerably complicates the development of predictions and recommendations concerning environmental quality management.

The situation becomes still more complicated when the region considered includes several countries and, hence, there is a need for coordinated efforts at the international level. Usually the most difficult task of regional monitoring (within the framework of one or several states) is the development of criteria of environmental quality, since in this case it is necessary to standardize the impact on natural complexes and not only the impact on man.

Global monitoring is required to detect and prevent negative effects on the biosphere on a planetary or hemispheric scale. In this case the number of impact factors can be less than in the regional approach, though the number of sources significantly increases (it corresponds to integral economic activity). The complexity of relations between the environmental quality and impact sources grows still further.

When it comes to monitoring areas, the highest priority is given to cities and areas from which drinking water is taken.

Among the environments, atmospheric air and the water of fresh water bodies (especially low flow) have the highest priority.

For air, the most important constituents are dust, sulfur, carbon and nitrogen oxides, heavy metals, benz(a)pyrene and pesticides.

For water, it is biogenic products, phenols and petroleum products.

Among the sources of pollution, the highest priority has motor transport, thermal power plants, non-ferrous metallurgy |mɪˈtalədʒɪ| enterprises, etc.

Studies show that geochemical imbalances of such elements as mercury, cadmium and lead occur quite frequently. The list of chemical substances to be studied at baseline stations and biosphere reserves is summarized in Table 3.2.

Table 3.2 List of chemicals to be studied in baseline stations and biosphere reserves (by Izrael, 1984)

The name of the chemicals to be studied	Environment				
	Atmosphere	Precipitation	Hydrosphere	Soils	Biota
Particulate matters	+				
Sulfur dioxide	+				
Ozone	+				
Carbon monoxide	+				
Nitrogen oxides	+				
Carbohydrates	+				
Benz(a)pyrene	+	+	+	+	+
Chlororganic compounds (DDT and others)	+	+	+	+	+
Heavy metals (Pb, Hg, Cd)	+	+	+	+	+
Carbon dioxide	+				
Freons	+				
Biogenic elements		+	+	+	+
Anions and cations		+			
Radionuclides		+			

Hydrometeorological and geophysical characteristics should include data on wind speed and direction, atmospheric pressure and temperature, humidity and precipitation, solar radiation intensity, including ultraviolet radiation, flow and level of water, water temperature, soil moisture and heat balance.

Biological observations include assessment of the state of biota (determination of reproduction rate), prediction of the response of biota (establishment of the sensitivity of biota to anthropogenic pollution in the dose-response system).

Background monitoring includes various observation and field study programs, as well as mathematical modeling and forecasting methods.

Questions for self-control

1. What is the mission of GEMS?

2. When did the specific idea for GEMS emerge?

3. How many monitoring programs was established by UNEP drawing on the SCOPE report?

4. Among monitoring programs that was established by UNEP within GEMS are:

a. Climate-related monitoring;

b. Terrestrial renewable-resource monitoring;

c. Geo-referenced monitoring;

d. Ocean monitoring;

e. Monitoring of long-range transport of pollutants;

f. Health-related monitoring (concerned with pollutional effects).

5. What more specific programs were set up concerning the collection of data in 1976?

6. Name the type of monitoring systems when conducting baseline monitoring.

7. Where are the baseline stations based? Name their locations in Ukraine.

8. Classification of some priority pollutants by priority classes:

1. 1 class	*A DDT and other chlororganic compounds*
2. 2 class	*B Microbiological contaminations*
3. 8 class	*C Sulfur dioxide, particulate matters*

4. BASIC ARRANGEMENTS FOR THE STATE ENVIRONMENTAL MONITORING SYSTEM OF UKRAINE

4.1 Legislative basis and principles of the SEMS functioning;

4.2 Regulatory and legal framework for the organisation and implementation of environmental monitoring;

4.3 The subjects of environmental monitoring in Ukraine;

4.4 Problems of the State Environmental Monitoring System (SEMS).

4.1 Legislative basis and principles of the SEMS functioning

One of the components of the system of environmental and socio-economic security of the country is a system of monitoring, accounting and control of the state of the natural environment and natural resource potential.

Under the conditions of growing global threats caused by climate change, increased likelihood of extreme natural phenomena or disasters (floods, overflows and droughts), growing scarcity of natural resources, pollution of both human and animal and plant habitats, as well as the comprehensive and constantly progressing informatization of humanity, issues of making optimal and operative decisions in the field of environmental protection have acquired significant weight.

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

The Law of Ukraine "On the Protection of the Natural Environment" (articles 20 and 22) envisaged establishment of the state environment monitoring system (hereinafter – SEMS) to conduct observations of the state of the environment, the level of pollution, the collection, processing, transmission, storage and analysis of information about the environmental situation, forecasting its changes and development of scientifically based recommendations for decision-making on the prevention of negative changes of the environment and observance of requirements of ecological safety.

Implementation of these functions entrusted to the Ministry of Environmental Protection and Natural Resources of Ukraine (the Ministry of Environment) and other central authorities that are parties of the SEMS, as well as to the enterprises, institutions and organizations whose activity leads or may lead to the deterioration of the environment.

The main principles of SEMS operation are defined in the Regulation of the Cabinet of Ministers of Ukraine № 391 dated 30.03.1998 “On Approval of Statement on the State Environmental Monitoring System”.

According to this Regulation, the State Environmental Monitoring System is a system of observation, collection, processing, transmission, storage and analysis of information on the state of the environment, forecasting its changes and development of scientifically sound recommendations for decision-making on the prevention of negative changes in the environment and compliance with environmental safety requirements.

The monitoring system is an integral part of the national information infrastructure, compatible with similar systems in other countries.

The monitoring system is an open information system, the priorities of which are to protect the vital ecological interests of man and society; preserve natural ecosystems; prevent crisis changes in the ecological state of the environment and prevent environmental emergencies.

The development and functioning of the monitoring system in order to integrate environmental information systems covering certain areas is based on the principles:

- consistency of regulatory and organizational and methodological support, compatibility of technical, informational and software support of its components;

- systematic observation of the state of the environment and technogenic objects affecting it;

- timeliness of receipt, complexity of processing and use of information on the state of the environment (ecological information) that is received and stored in the monitoring system;

- objectivity of primary, analytical and forecast information about the state of the environment (ecological information) and the efficiency of its communication to public authorities, local governments, public organizations, the media, the population of Ukraine as well as interested international organizations and the world community.

The monitoring system is aimed at:

- increase the level of study and knowledge about the ecological state of the environment;

- increasing the efficiency and quality of information services to users at all levels;

- improving the quality of justification of environmental protection measures and the efficiency of their implementation;

- promoting international cooperation in the field of environmental protection, rational use of natural resources and environmental safety.

4.2 Regulatory and legal framework for the organisation and implementation of environmental monitoring

The mentioned Statement defines the order of creation and functioning of GSMD in Ukraine, assigns the objects of environment to each of the subjects of monitoring at the level of SEMS subsystems. As of today, the 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 flora;

● Monitoring of fauna;

● Background environmental monitoring (on the territories of the nature reserve fund);

● Monitoring of waste generation, storage and disposal sites

● Monitoring the impact of genetically modified organisms on the environment.

According to the current legal structure, for each of the listed subsystems of SEMS it is necessary to create inherent legislative and regulatory tools for the organization and implementation of monitoring on the state of the environment. Specifically:

- The Law of Ukraine "On Atmospheric Air Protection" and the Cabinet of Ministers Resolution No. 827 of August 14, 2019 "Some Issues of State Monitoring in the Field of Atmospheric Air Protection" determine the practice and procedure of monitoring in the field of atmospheric air protection,

- The Water Code of Ukraine and the Resolution of the Cabinet of Ministers of Ukraine from September 19, 2018 № 758 "On Approval of the Procedure for State Water Monitoring" - 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 Provision on Land Monitoring" determine the procedure for land monitoring.

Table 4.1 Legal definition and support for the organization and implementation of the State Environmental Monitoring System [36]

Legal acts	The State Environmental Monitoring System (SEMS)									
	Subsystems									State monitoring of aquatic bioresources
	Monitoring in the field of atmospheric air protection	State water monitoring	Land monitoring	Forest monitoring	Monitoring of flora	Monitoring of fauna	Monitoring of the eco-network	Background monitoring	Monitoring of waste	
The Law of Ukraine “On the Protection of the Natural Environment”	+	+	+	+	+	+	+	+	+	+
The Regulation of the Cabinet of Ministers of Ukraine “On Approval of Statement on the State Environmental Monitoring System”	+	+	+	+	+	+	-	+	+	+
The Law of Ukraine "On Atmospheric Air Protection"	+									
The Regulation of the Cabinet of Ministers of Ukraine "Some Issues of State Monitoring in the Field of Atmospheric Air Protection"	+									
The Water Code of Ukraine		+								
Law of Ukraine "On Approval of the National Target Program for development of the water sector and ecological rehabilitation of the Dnieper River Basin for		+								

the period up to 2021"										
The Regulation of the Cabinet of Ministers of Ukraine "On Approval of the Procedure for State Water Monitoring"		+								
The Land Code of Ukraine			+							
The Law of Ukraine "On Land Protection"			+							
The Regulation of the Cabinet of Ministers of Ukraine "On Approval of the Provision on Land Monitoring"			+							
The Code of Ukraine on Subsoil	There is no word "monitoring" in the Code of Ukraine on Subsoils									
The Forest Code of Ukraine				+						
Procedure for forest monitoring (not available)				-						
The Law of Ukraine "On the plant life"					+					
Procedure for monitoring of plant life (not available)					-					
The Law of Ukraine "On the state system of biosafety in the development, testing, transportation and use of genetically modified organisms"	The current version of the Law does not contain provisions for monitoring the impact of GMOs on the environment									
Procedure for monitoring the impact of GMOs on the environment (not available)				-	-	-				
The Law of Ukraine "On the wild animals"						+				
Procedure for monitoring of wildlife (not available)						-				
The Law of Ukraine "On the Natural Reserve Fund of Ukraine"								+		
Procedure for conducting background environmental monitoring (not available)								-		
The Law of Ukraine "On the Ecological Network of Ukraine"							+			

Procedure for state monitoring of the ecological network (not available)							-			
The Law of Ukraine "On Waste"									+	
Procedure for monitoring of waste generation, storage and disposal sites									-	
The Law of Ukraine "On Fishery, Commercial Fishing and Protection of Aquatic Bioresources"										+
Procedure for the state monitoring of aquatic bioresources (not available)						-				-
Procedure for state monitoring of the condition of fishery water bodies (not available)		-								-

(+) - by-laws are approved at the appropriate level;
(-) - there are no by-laws

In contrast to these three subsystems, others have not been properly developed, because such legislative acts as:

- The Forest Code of Ukraine;
- The Law of Ukraine "On the plant life";
- The Law of Ukraine "On the wild animals";
- The Law of Ukraine "On the Ecological Network of Ukraine";
- The Law of Ukraine "On the state system of biosafety in the development, testing, transportation and use of genetically modified organisms";
- The Law of Ukraine "On the Natural Reserve Fund of Ukraine";
- The Law of Ukraine "On Waste"

legislative acts define the relevant monitoring subsystems as an integral part of the SEMS and indicate the need to establish procedures for the implementation of the relevant areas of monitoring, but have not received adequate regulatory support in the form of Procedures (provisions) for the realization of such monitoring.

Introduced by the Law of Ukraine "On Fishery, Commercial Fishing and Protection of Aquatic Bioresources", the state monitoring of the status of fishery water bodies should either be further developed in the form of an appropriate order (by-law), or requires amendments to the law in terms of attributing this monitoring to SEMS and its linkage to the state monitoring of waters.

The Code of Ukraine on Subsoil does not provide for monitoring in this area at all, while the Law of Ukraine "On the State Geological Survey of Ukraine" contains the concepts of "monitoring of the geological environment" and "monitoring of the mineral resource base" and, among other main tasks, assigns to the State Geological Survey of Ukraine the tasks of monitoring of the mineral resource base, geological environment and groundwater.

An important aspect of national legislation is the provisions of article 22 of the Law of Ukraine "On the Protection of the Natural Environment", which provide for the monitoring of the state of the natural environment and the level of its pollution by enterprises, institutions and organizations whose activities lead or may lead to environmental degradation.

In addition, it is stipulated that these enterprises, institutions and organizations are obliged to transfer analytical materials of their observations to the relevant state bodies without compensation. However, the above provision of the Law of Ukraine "On Environmental Protection" is not detailed in the majority of subordinate legal acts regulating the issue of environmental monitoring.

The procedure for state monitoring in the field of atmospheric air protection provides for the possibility of participation of enterprises, institutions and organizations in monitoring in the field of atmospheric air protection, provided that the requirements established for the subjects of the state air monitoring system are met.

One of the shortcomings of the legal and regulatory framework of the process of organization and implementation of environmental monitoring is unclear formulation of the responsibilities of the subjects of SEMS in the provisions on the relevant central executive authorities.

For example, the Regulation on the State Emergency Service of Ukraine only provides for the function of conducting hydrometeorological observations, as well as observations of the state of environmental pollution. The term "monitoring" is absent in the mentioned Regulation.

The functions of environmental monitoring are most clearly defined in the Provision on the State Agency of Water Resources of Ukraine, which states that this agency conducts state water monitoring in accordance with the procedure approved by the Cabinet of Ministers of Ukraine and provides references to the relevant regulatory legal act.

4.3 The subjects of environmental monitoring in Ukraine

In total, by the Regulation of the Cabinet of Ministers of Ukraine No. 391 dated 30.03.1998 "On Approval of Statement on the State Environmental Monitoring System" the subjects of environmental monitoring are defined:

- the Ministry of Environmental Protection and Natural Resources of Ukraine;
- the Ministry of Agrarian Policy and Food of Ukraine;
- the State Agency of Ukraine on Exclusion Zone Management; (except for state water monitoring);
- the Ukrainian Geological Survey;
- the Ministry for Communities and Territories Development;
- the State Space Agency of Ukraine;
- the State Emergency Service of Ukraine (Department of Hydrometeorology);
- State Forest Resources Agency of Ukraine;
- State Agency of Water Resources of Ukraine;
- the State Service of Ukraine on Geodesy, Cartography and Cadastre and their territorial bodies,

as well as enterprises, institutions and organizations that belong to their management sphere, regional, Kyiv and Sevastopol city administrations, and the executive body of the Autonomous Republic of Crimea on the protection of the natural environment.

The State Emergency Service of Ukraine (at the stations of the state hydrometeorological observation system) monitors:

- radionuclide content in the atmospheric air, transboundary transfer of pollutants;
- snow cover;
- soils of various purposes (pesticide and heavy metal residues);

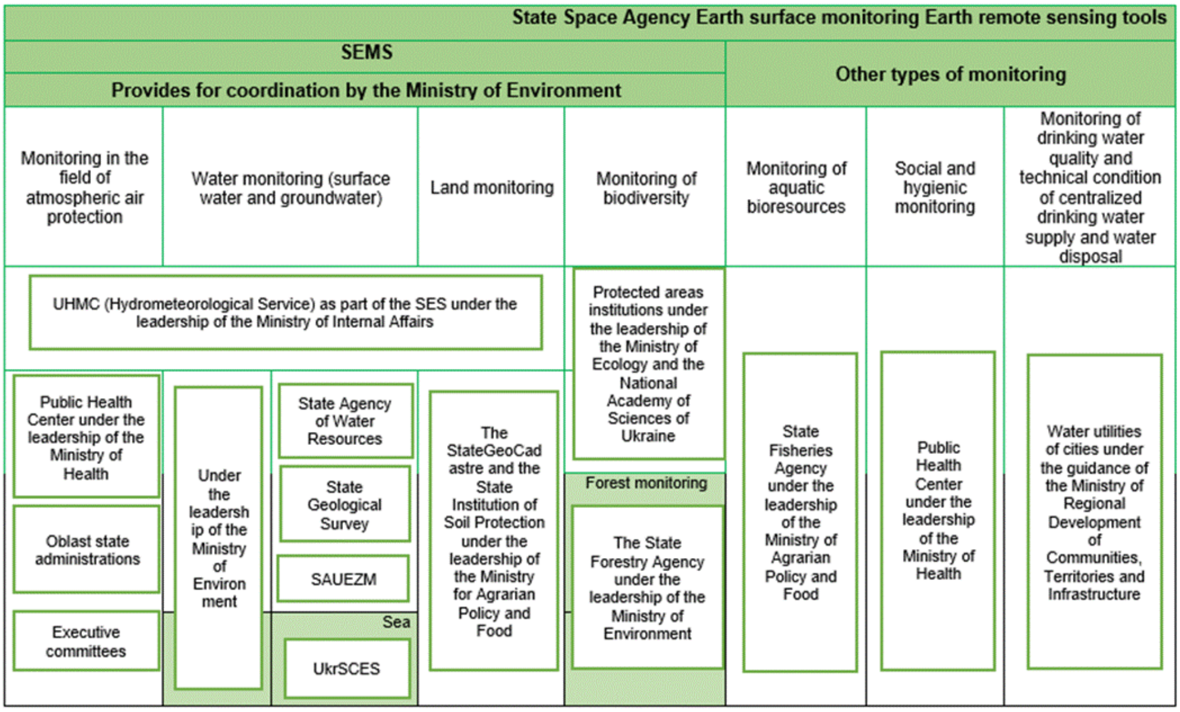


Figure 4.1 Institutional support of the State System of Environmental Monitoring and other related types of state monitoring

- radiation situation (determination of gamma-radiation exposure dose) of floods, overflows, snow avalanches, mudflows.

The State Agency of Ukraine on Exclusion Zone Management (in the Exclusion Zone and Zone of Unconditional (Mandatory) Resettlement) monitors:

- radionuclide content in atmospheric air;
- terrestrial ecosystems (bioindicator measurements);
- soils and landscapes (pollutants content, radionuclides, spatial distribution);
- sources of air emissions (pollutants content, volumes of emissions);
- radioactive waste storage and/or disposal facilities (radionuclide content, radiation situation).

The Ministry of Agrarian Policy and Food of Ukraine carried out monitoring of:

- soils of agricultural use (radiological, agrochemical and toxicological measurements, residual quantities of pesticides, agrochemicals and heavy metals);

- agricultural plants and their products (toxicological and radiological determinations, residual quantities of pesticides, agrochemicals and heavy metals);

- live-stock animals and their products (zootechnical, toxicological and radiological determinations, residual quantities of pesticides, agrochemicals and heavy metals).

The State Forest Resources Agency of Ukraine monitors:

- soils of forest fund lands (radiological determinations, residual quantities of pesticides, agrochemicals and heavy metals);

- forest vegetation (condition, productivity, damage by biotic and abiotic factors, biodiversity, radiological determinations);

- game fauna (species, quantitative and spatial characteristics).

Functions and objectives of *the State Agency of Water Resources of Ukraine* in the sphere of environmental monitoring:

- water quality in inter-branch and agricultural water supply systems;

- water bodies according to radiological indicators in the areas affected by radioactive contamination;

- in the transboundary sections of watercourses defined in accordance with intergovernmental agreements on cooperation on transboundary water bodies;

- irrigated and drained lands (depth and salinity of groundwater, salinity and alkalinity of soils);

- underflooding of rural and community settlements, coastal zones of water reservoirs (shore reshaping and underflooding of territories).

The State Service of Ukraine on Geodesy, Cartography and Cadastre conducts monitoring of:

- soils and landscapes (the content of pollutants, manifestations of erosion and other exogenous processes, spatial pollution of lands by industrial and agricultural production facilities);

- irrigated and drained lands (secondary waterlogging and salinization, etc.);

- shorelines of rivers, seas, lakes, reservoirs, limans, bays, hydraulic structures (dynamics of changes, damage to land resources).

Functions and objectives of *Minregion* (now integral part of the Ministry of Communities, Territories and Infrastructure Development) in the sphere of environmental monitoring:

- drinking water of centralized water supply systems (pollutant content, consumption volumes);

- wastewater from the city sewage network and treatment facilities (pollutant content, volume of inflows);

- green plantings in cities and urban-type settlements (plant damage degree by harmful insects and plant diseases);

- waterlogging of cities and urban-type settlements (dangerous increase in the level of groundwater).

The Ukrainian Geological Survey (The State Service of Geology and Mineral Resources of Ukraine) conducts monitoring of:

- groundwater (resources and use);

- endogenous and exogenous processes (species and spatial characteristics, activity of manifestation);

- geophysical fields (background and anomalous determinations);

- geochemical state of landscapes (content and distribution of natural and anthropogenic chemical elements and compounds).

Functions and objectives of *the State Space Agency of Ukraine* (SSAU) in the sphere of environmental monitoring:

- state of territories by remote sensing data (tracking thermal anomalies, flooding and flooding situation, ice conditions);

- seismic conditions and other geophysical phenomena on the territory of Ukraine and the entire Earth;

- radiation situation in the locations of special control units;

- space situation in near-Earth space (detection of falling spacecrafts, carrier rockets and their parts).

In June 2023, the list of subjects of monitoring was supplemented by *the State Environmental Inspection*, which conducts environmental monitoring in the mode of response to environmental emergencies and additionally monitors the state of the environment or its components and provides operational information about the state of the environment to the population.

The main tasks of the subjects of the monitoring system are:

- long-term systematic observations 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 governments, as well as the provision of information on the state of the environment (ecological information) to the population of the country and international organizations.

According to the Statement (1998), *the Ministry of Environment* is responsible for monitoring:

- soils in the protected areas (content of pollutants, including radionuclides);

- state environmental mapping of the territory of Ukraine to assess its condition and its change under the influence of economic activity;

- terrestrial ecosystems (background content of pollutants, including radionuclides);

- endangered species of flora and fauna and species under special protection.

At the same time, in the Regulation on the Ministry of Environment approved by the Cabinet of Ministers of Ukraine from 25.06.2020 No: 614, its powers and tasks on state environmental monitoring are defined in the following scope:

● organizes monitoring of the natural environment, ensures the functioning of the nationwide information and analytical system of environmental monitoring;

● creates and ensures network operation of the state-wide environmental automated information-analytical system to provide access to environmental information;

● determines environmental indicators for environmental assessment and methodological guidelines for their application;

● determines registers of the components of the observation network of the state environmental monitoring system;

● develops methodologies for monitoring the natural environment, in particular, by economic entities whose activities lead or may lead to deterioration of the natural environment;

● ensures in the sphere of protection and reproduction of waters (surface, underground, marine) rational use of water resources, namely, develops drafts of normative-legal acts, issues normative-legal acts within the limits of authority stipulated by the law on problems of organization and implementation of state water monitoring;

● performs general coordination and organization of state water monitoring, scientific and methodological support of state water monitoring, develops and approves the state water monitoring program;

● provides normative-legal regulation, namely, develops drafts of normative-legal acts, issues normative-legal acts within the limits of authority provided by the law, in the sphere of atmospheric air protection on the issues:

- conducting state monitoring in the field of atmospheric air protection;

- approval of the program of state monitoring in the field of atmospheric air protection;

● carries out general coordination and organization of atmospheric air monitoring;

● coordinates programs of state monitoring in the field of atmospheric air protection;

● establish a network of experimental land plots and plots with reference soils in order to carry out on them necessary observations, measurements and surveys of the ecological state of lands, changes in indicators of useful properties of soils under the influence of economic and other types of activities to carry out land monitoring at the national level.

Bodies of accreditation, standardization and metrology have a significant role within the activities of laboratories of the environmental segment. According to Article 6 of the Law of Ukraine "On Accreditation of Conformity Assessment Bodies", accreditation is carried out by a national body - the National Accreditation Agency of Ukraine, which conducts accreditation in accordance with national legislation, taking into account the requirements of international and European standards.

In addition, Ukraine has a state system of certification of products and quality management systems in the voluntary certification system UkrSEPRO in accordance with the requirements of a series of standards of this system. When laboratories are being accredited, specially developed criteria and procedures are used to determine technical competence, a comprehensive expert assessment of all factors affecting the development of calibration or test data based on the international standard ISO/IEC 17025 (the Ukrainian equivalent of DSTU ISO 17025).

In Ukraine there is also State Enterprise "Ukrmetrteststandart", which carries out certification in the state metrological system of measuring laboratories that perform measurements, and the results of which are used in the sphere of state metrological supervision.

In addition to the Central Executive Authorities and the institutions mentioned above, scientific institutions, in particular the structures of the National Academy of Sciences of Ukraine, are involved in environmental monitoring activities.

The Institute of Geophysics named after S.I. Subbotin of the National Academy of Sciences of Ukraine carries out geophysical monitoring - monitoring and forecasting of magnetic disturbances (geomagnetic observatories in Kyiv, Lviv, Odesa) and monitoring of seismic situation (more than 40 seismic stations on the territory of Ukraine). The I.I. Shmalhausen Institute of Zoology of the National Academy of Sciences of Ukraine is engaged in the maintenance of the Animal World Cadastre, and the M.G. Kholodny Institute of Botany of the National Academy of Sciences of Ukraine is responsible for the Plant World Cadastre.

The Resolution of the Cabinet of Ministers of Ukraine dated 30.03.1998 No. 391 "On Approval of the Statement on the State Environmental Monitoring System" assigns organizational integration of the subjects of the monitoring system to the Ministry of Environment, regional, Kyiv and Sevastopol city state administrations, executive authority of the Autonomous Republic of Crimea on environmental issues on the basis of national and regional (local) environmental monitoring programs consisting of programs of corresponding levels submitted by the subjects of the monitoring system.

In turn, environmental monitoring programs of corresponding levels are formed on the basis of concluded agreements on joint activities in the implementation of environmental monitoring at the corresponding level.

However, for a long time organizational integration of monitoring subjects, which is carried out on the part of the Ministry of Environment, was reduced only to formal attempts to obtain some information or data from the Central Executive Authorities - subjects of environmental monitoring, for their further accumulation and storage on electronic resources.

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 state environmental monitoring system as one of the root causes of environmental problems in Ukraine.

The National Security Strategy of Ukraine, enacted by the Decree of the President of Ukraine No. 287/2015 dated May 26, 2015, places the unsatisfactory state of the environmental monitoring system among the main threats to the environmental and national security of Ukraine.

The Decision of the National Security and Defence Council of Ukraine of 23 March 2021 "On Challenges and Threats to the National Security of Ukraine in the Environmental Sphere and Priority Measures for their Neutralization" provides for the creation of an effective system of state monitoring of the natural environment using remote sensing, space control, geophysical and geoinformation technologies by developing and approving draft regulations, strategies and concepts governing the functioning of the state environmental monitoring system, the national register of emissions and transfer of pollutants, development of hydrometeorological activities, and radiation monitoring.

Another decision of the National Security and Defense Council of Ukraine of July 30, 2021 "On the State of Water Resources of Ukraine" provides for the creation of an electronic map of Ukraine's water resources and the introduction of a permanent process for monitoring their effective use, in particular using Earth remote sensing technologies.

The Ministry of Environment and the Ministry of Internal Affairs (the State Emergency Service of Ukraine), with the involvement of stakeholders, have prepared to implement the above-mentioned documents:

● Draft Law of Ukraine on amendments to certain legislative acts of Ukraine concerning the State Environmental Monitoring System, information on the state of the environment (environmental information) and informational support for environmental management;

● Draft Order of the Cabinet of Ministers of Ukraine "On approval of the concept of the state targeted ecological program of environmental monitoring", which was submitted for coordination with the interested executive authorities (February 2022);

● Strategy for the development of hydrometeorological activities in Ukraine for the period until 2030, approved by the Order of the Cabinet of Ministers of Ukraine No. 1501-r dated November 24, 2021.

● Standard regulations on regional environmental monitoring centers.

Thus, Ukraine has established the basic principles of organization and functioning of the State Environmental Monitoring System, as well as regulated the procedure for carrying out monitoring on particular subsystems.

However, there are also some gaps in the legislation of Ukraine - in terms of determining the legal basis for monitoring of subsurface resources, procedures for monitoring of forests, biological diversity, the impact of genetically modified organisms on the environment, background environmental monitoring, places of formation, storage and disposal of waste.

Also, the Ukrainian legislation does not fully regulate the issue of participation in environmental monitoring of enterprises, institutions and organizations, whose activities lead or may lead to deterioration of the state of the natural environment.

A problematic aspect of normative-legal regulation is the unclear formulation of the powers of the subjects of environmental monitoring in the provisions on the relevant Central Executive Authorities.

At the same time, it should be noted that the issue of improving legislation in the field of environmental monitoring at different levels is identified as one of the necessary prerequisites for environmental and national security of Ukraine. For this purpose, appropriate legislative initiatives are being developed to create the necessary pre-conditions for the existence of an effective environmental monitoring system in Ukraine.

4.4 Problems of the State Environmental Monitoring System (SEMS)

According to the Analytical Note on the State and Prospects for the Development of the State Environmental Monitoring System (2023), the main problems of the environmental monitoring system in Ukraine are:

1) Lack of a procedure for forming a request for environmental monitoring information and lack or low level of use of SEMS information for making management decisions.

One of the main problems with both the SEMS and the environmental management system itself is the lack or unreliability of the relationship between these systems. This is the root cause of the inefficiency of the state environmental management system, because it either did not need monitoring information or needed extremely limited activities (for example, for the preparation of the Report on the State of the Natural Environment).

Preparation of legislative and legal acts, state target programmes, as well as other regulatory and governing information has not taken the basis of using data on the state of the environment. The information requirements of environmental management have not been studied yet.

The monitoring programmes of the Ministry of Health, Hydrometeorological Service, State Water Agency and other subjects of environmental monitoring remained unchanged for 30-50 years, while the content of these departmental monitoring programmes did not change either.

Ukraine has not developed Environmental Monitoring Strategies that would take as their basis certain information management needs, although in the EU countries such strategies are a common practice and are updated every 5 - 6 years, according to the scheme shown in the Figure 4.2 below.

Figure 4.2 The place of monitoring in the chain of environmental management system [36]

Relevant and reliable environmental information should become a necessary resource for the state environmental management system.

Learning to acquire experience and practice in the use of environmental information in public administration will lead to an increase in its role and importance in the process of making management decisions, and as a consequence - a significant increase in their efficiency and effectiveness.

Management decision-making in the sphere of environmental protection based on objective and qualitative environmental monitoring data will also have a positive impact on the level of public confidence in public administration in this sphere.

2) Low level of coordination, co-operation and communication between SEMS subjects.

Coordination in the environmental monitoring system is entrusted to the Ministry of Environment, however, in practice it has no leverage over other subjects of the SEMS, as financing of the subjects of the environmental monitoring is carried out without coordination with the Ministry of Environment.

As a result, data collection by different Central Executive Authorities is carried out under separate, uncoordinated environmental monitoring programmes, using different observation regulations and data processing methods, which makes it impossible to compare them and form a comprehensive analysis of the state of the environment in the country.

According to the current legislation, the SEMS subjects are not obliged to provide the Ministry of Environment with primary environmental monitoring data obtained at observation posts. Thus, the Ministry of Environment receives only aggregated data or descriptive information that is not subject to verification, statistical analysis and logistical processing.

3) Outdated material and technical base of the SEMS.

Instrumentation and technical equipment of the state environmental monitoring system can be characterised as morally and physically outdated, which does not provide measurement of the required range of indicators, does not provide for automated collection, analysis and storage of information and its prompt provision to the main consumers.

Most of the equipment used today by the Ukrainian Hydrometeorological Centre (as the monitoring subject with the largest number of observation sites, UHMC) was purchased back in the 80-90s. The work on obsolete equipment does not allow to obtain accreditation for laboratories and to compare monitoring data of the SEMS with those of other countries.

Some indicators cannot be measured due to equipment failure or unavailability. For example, measurement of benz(a)pyrene in air was stopped by the UGMC in 2014, and unsaturated hydrocarbons, benzene, toluene, ethylbenzene, meta-, para-xylene, ortho-xylene was discontinued in 2015.

There are also no modern systems for obtaining information from geostationary and polar-orbiting satellite meteorological systems. There are problems with introduction of GIS-technologies into the practice of environmental monitoring.

The situation with the instrumentation and technical base of the subjects of environmental monitoring is alarming, creating appropriate functional subsystems in case of emergency situations. First of all, these are functional subsystems "Observation and control of natural hydrometeorological phenomena and environmental pollution" and "Forecasting of hydrometeorological conditions and phenomena".

4) Imperfection and inconsistency of regulations on environmental monitoring between Central Executive Authorities.

The study of water quality conditions at most observation sites is carried out once a quarter or once a year, which does not provide an opportunity to obtain a complete picture of the condition of water bodies. To date, the observation regulations are not agreed between the SEMS subjects.

As a result, for example, pollution monitoring of the same river within the same observation point may be carried out twice in the same month by different agencies, but not by any agency for the following two months.

Since air quality observation data in most cases are not produced automatically according to regulations corresponding to the European ones, such data cannot be used for calculations according to European methodologies (for example, to calculate hourly average and daily average concentrations of pollutants in a methodologically correct way) and to compare indicators with WHO and EU recommendations.

As a result, the availability of data does not allow obtaining prompt and objective information on the state of the environment and using it to make management decisions in the field of environmental protection.

5) The need to revise (optimise) the location of observation posts.

Siting and number of stationary observation posts today is outdated and does not correspond to the real location of residential areas and industrial enterprises and requires revision.

For example, the required number of stationary air quality monitoring posts used by the Hydrometeorological Service today was determined back in the soviet times according to the methodology adopted at that time, which took into account the population size (for cities with a population of up to 50,000 - 1 post, 50-100,000 - 2 posts, 100-200,000 - 3 posts, etc.)

The siting of observation posts also took into account the density of the population and the proximity of industrial enterprises whose emissions could affect air quality. Today, the distribution of population and industry has changed considerably.

In addition, the EU legislation provides not only requirements for the siting and classification of observation points, but also for the implementation of observations of new ones, which were not foreseen under the soviet methodology i.e., those oriented at determining the impact of transport emissions on the population and background observation posts on the urban periphery.

6) Shortage of qualified and motivated personnel.

The work of SEMS specialists is paid in accordance with the salary levels stipulated for civil servants of the relevant institutions, ministries and agencies. The specificity of tasks assigned to the SEMS requires special knowledge and skills in the spheres of ecology, biology, chemistry, use of water resources, and knowledge of the latest methods of laboratory research, etc. The level of salaries that can be offered by public institutions is often not competitive compared to other spheres of the economy.

In addition, given the level of labour migration in Ukraine, as well as the need to update laboratory facilities and use the latest equipment, the issue of availability of qualified personnel will be particularly acute in the process of reforming the SEMS.

7) Outdated Ukrainian legislation in the field of environmental monitoring and its low level of adaptation to the requirements of the EU Directives.

The functioning of the State Environmental Monitoring System is regulated by the Resolution of the Cabinet of Ministers of Ukraine of more than 20 years ago ("On Approval of the Statement on the State Environmental Monitoring System" dated 30.03.1998 No. 391). Today Ukrainian environmental legislation in terms of monitoring is being adapted to the legislation of the European Union, but the regulatory framework of the environmental monitoring system meets international and European standards only in the areas of monitoring in the field of atmospheric air protection and water monitoring.

One of the types of monitoring that is not carried out in Ukraine according to the legislation, but is a requirement of the EU - monitoring of genetically modified organisms.

8) Insufficient financing of the SEMS from the state budget of Ukraine and insufficient attraction of funds from other sources of financing.

Funding of the SEMS from the state budget of Ukraine is on a residual principle. According to the Regulations of the SEMS, a certain part of the costs of establishing and operating the constituent parts and components of the monitoring system may be covered by innovation funds within the limits of the funds envisaged for environmental activities, international grants and other sources of financing.

International technical assistance resources are insufficient to meet the needs of modernisation of the material and technical base of the State Environmental Monitoring System and training of personnel, and for these needs it is necessary to allocate funds from the State Budget of Ukraine, because ensuring the organisation and maintenance of the SEMS is the task of state bodies, while international technical assistance funds are considered as an auxiliary source of funding.

9) Lack of a single resource providing access to primary environmental monitoring data aggregated from different sources.

The Regulation on the State Environmental Monitoring System provides for the creation of an electronic monitoring system designed to consolidate information on the state of the environment.

According to this document, "the monitoring system is an open information system, the priorities of its functioning are the protection of vital environmental interests of humans and society; preservation of natural ecosystems; prevention of crisis changes in the ecological state of the environment and prevention of environmental emergencies".

Questions for self-control

1. What does the abbreviation „SEMS” mean?

2. In what document were defined the main principles of SEMS?

3. Give the definition of the State Environmental Monitoring System in Ukraine

4. What subsystems does the SEMS include?

5. What is the only principle in the system of environmental monitoring in Ukraine?

6. What are the current shortcomings in the regulatory and legal support of the SEMS?

7. Who is ensured the organizational integration of environmental monitoring bodies at all levels in Ukraine?

8. What subsystems are regulated by the monitoring procedure?

9. Why is the level of use of DSMD information for management decision-making low in Ukraine?

10. How does the outdated material and technical base of the SEMC impede monitoring?

11. Why is it necessary to review (optimize) the placement of observation posts?

12. Which aspects of Ukraine's environmental monitoring legislation are outdated?

5. COMMON APPROACHES TO MONITORING. INFORMATION SUPPORT FOR ENVIRONMENTAL MONITORING

5.1 Methods of conducting monitoring;

5.2 Use of remote sensing methods for the earth or water surface;

5.3 Status of information disclosure and monitoring information systems.

Approaches to conducting monitoring include a wide range of organisational, human, technical, material and other logistical solutions with significant financial costs. These approaches can be roughly categorised into the following groups:

1) land-based and surface-based monitoring methods, including both automatic and semi-automatic sensors to ensure continuous observation of the state of atmospheric air and water resources, and methods involving visiting and conducting research directly at monitoring stations (observation points). This group also includes photo and video recording by UAVs (unmanned aerial vehicles) and the organisation of stationary photo and video surveillance.

2) the use of remote sensing methods of land or water surface implies obtaining (either from SSAU or by accessing available Internet resources and/or by purchasing abroad) space images of the required resolution with their subsequent decoding and interpretation. This group of methods also involves the use of photo and video recording by UAVs.

5.1 Land-based and surface-based monitoring methods

For air quality monitoring, they use manual, semi-automatic and automatic online sensors that record a range of air quality parameters. In addition, mobile observation points and mobile laboratories are used to assess the quality of atmospheric air.

For water monitoring purposes, automatic sensors are used in Ukraine less frequently, in locations where continuous monitoring of certain water quality parameters (for example dissolved oxygen levels) is usually justified. Basic physico-chemical properties of waters including oxygen content, pH, conductivity, etc. are automatically recorded.

Figure 5.1 Monitoring of water quality through automated environmental monitoring system: APS 9701 - Hydropost 1. Sviatohirsk, February 2020. Source: Communal enterprise of Donetsk oblast council "Environmental Monitoring Centre"

The rest of the monitoring requirements are met by expeditionary visits, where a researcher or team of researchers arrive (by vehicle or watercraft) at a specific sampling location (usually permanent, but random sampling may also occur). Their task is to collect and pre-prepare (water filtration, sample fixation, sample freezing, etc.) samples and perform in situ measurements.

Sampling is carried out with specialised equipment (air pumps, bathometers, bottom dredges, bottom torpedoes, specialised nets, push nets, soil samplers, and so on). Depending on the sampling purpose, these instruments must be made of certain materials to prevent contamination of the samples (for example, heavy metals). The samples are placed in specialised containers and, if necessary, fixed with the appropriate substances.

Figure 5.2 Monitoring forestry with drones
Source: https://dronemt.magneticonemt.com/monitorunh-lisovuh-hospodarstv/

Researchers at the sampling site also make measurements of the main physico-chemical parameters of the environment, using so-called portable analytical-measuring equipment (oxygen analyzers, pH-meters, ionometers, conductometers, thermometers, etc.).

The next task of the researchers is to take the selected samples to the laboratory, where the final and targeted preparation of the samples for analysis and the quantitative analysis of the ingredients itself takes place.

The approaches to forest, biodiversity and baseline monitoring in the NRF have their own specific characteristics. These types of monitoring tend to use remote sensing and aerial photography, pilot (aeroplanes and helicopters) and unmanned aerial vehicles, but also include a variety of ground-based monitoring approaches.

For example, ground-based monitoring (counting) of wildlife includes a significant list of various approaches to monitoring and counting: catch-up surveys in sample plots, linear runs, winter route counts of animals by tracks, ungulate counts by the amount of winter excrement, at feeding sites, deer in rutting areas, bear by the number of dens, winter and summer route counts of wolves, identification of beaver settlements and assessments of their productivity or by the number of dens, waterfowl nesting, and so on.

Thus, the approaches to monitoring described above oblige both monitoring subjects and their subordinate institutions directly involved in monitoring to provide organisational, personnel, technical and financial support for all activities indicated in Fig. 4.1, including:

1) fuel, means of delivery (car, vessel, boats), sampling equipment, equipment (pumps) and filters for sample filtration, portable equipment (its adjustment, verification, reagents and reference standards for adjustment), reagents for sample fixation, ware for sample placement and storage, containers for ware, GPS trackers for positioning, maps, schemes of stations and their depth (vertical) profiles, safety equipment for working in polluted or hazardous environment on water, on ice, etc;

2) purchase of measuring equipment for stationary (fixed) observation points, containers for their placement with conditioning and heating equipment, provision of laboratories with modern equipment, utensils, reagents, tripods, and other auxiliary attributes, provision of

laboratories with water, sewerage, power supply with gas-balloon equipment, and extraction systems;

3) obtaining permits from the city executive authorities for stationary installation of automatic (online) observation posts or sensors, including vandal-proof means of protection, obtaining arrangements (agreements) with the police for their protection, including means of signalling and video registration, installation of communication means, server equipment in case of online mode, etc.; solving issues of verification, component calibration, battery recharging, and others;

Figure 5.3 Air quality monitoring post in Horodok, Rivne oblast, 2021
Source: Rivne Regional State Administration

4) making information requests and concluding contracts with SSAU for the provision of remote sensing, in particular aerospace images and means of their decryption, or reaching agreements with the aviation service to obtain authorisations for the use of pilot equipment for the

purpose of aerial photo or other imagery or aerial monitoring (control), etc;

5) procurement of UAVs, their additional equipment (with video cameras, video or spectral filters, etc.) and training of operators on their safe and targeted use.

Figure 5.4 Laboratory of water monitoring of the Southern region

Source: Black Sea Centre for Water Resources and Soils

With all the above-mentioned complexity of organisation, logistics and maintenance of monitoring activities, it should be clearly recognised that all equipment (analytical, portable, sampling, etc.) and all personnel activities related to its use, including sample preparation and other activities, should comply with the requirements of departmental or interagency approved methodologies (preferably unified for the whole country or the EU), guidelines and other regulatory documents.

The equipment shall be verified (in accordance with the requirements of the authority exercising metrological supervision) and calibrated, reagents and solvents shall have an appropriate degree of purification and quality.

Accordingly, the personnel involved in sampling, sample preparation and quantitative measurements must be familiar with all of the above documents and be certified.

5.2 Use of remote sensing methods for the earth or water surface

One of the approaches to environmental monitoring is Earth remote sensing observation. The use of remote sensing provides information on the state of the environment and its components at the international, regional and local levels.

Remote sensing data can be combined with data from ground-based observation methods, as well as with modelling methods to comprehensively determine the state of the environment, forecast it, and trace changes in dynamics.

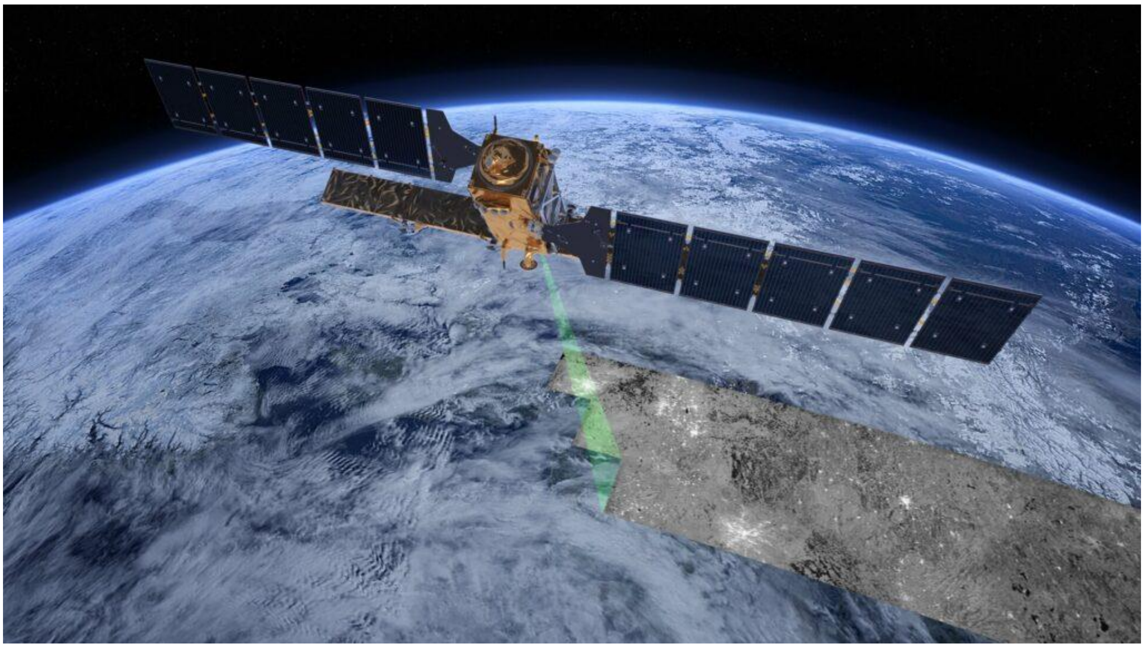


Figure 5.5 Sentinel-1B satellite (concept)

Source: ESA

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

The Copernicus programme was established in 2011 and became fully operational in 2014. The space part of the Copernicus information system is served by a set of dedicated Sentinel family satellites and assisting missions (operational commercial and public satellites). The Sentinel satellites are specifically designed to meet the needs of Copernicus and its users.

Since the launch of Sentinel-1A in 2014, the European Union has launched a programme to deploy a family of nearly 20 satellites in orbit until 2030.

This programme offers information services on Earth observation satellite data and local data (not from space). The programme is coordinated and managed by the European Commission.

Copernicus is implemented in partnership with EU Member States, EU agencies, the European Centre for Medium-Range Weather Forecasts (ECMWF), the European Space Agency (ESA), the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT), Mercator Océan and countries with which international agreements have been signed.

In the light of the Data Access Programme's information dissemination policy, Copernicus is of increasing interest, and in this context, the EU is looking for opportunities to share data for the benefit of Copernicus. Thus, the fastest way to get access to Copernicus data in the part of the data that requires authentication is to offer to share local observations from Ukraine.

On 25 May 2018, the State Space Agency of Ukraine and the European Commission signed an agreement on cooperation in the field of access to and use of data from the Sentinel satellites of the Copernicus programme. In exchange, the SSAU provides free open access to its own satellite data for use in the Copernicus programme.

The information services are provided free of charge to authorised Copernicus users with open access. However, this only includes data with low and medium spatial resolution.

Copernicus also obtains information from in situ systems, such as ground stations, which deliver data from a multitude of sensors on the ground, at sea or in the air. As a result, not only satellite observations, but also data from local ground, 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 to periodically calibrate satellite observation systems. As a result of observation data processing and modelling, various current and forecast thematic maps are created, features and anomalies are identified, and statistical data can be reviewed and updated.

The information received by the system is optimised through six thematic Copernicus service streams:

1. The Copernicus Atmosphere Monitoring Service (CAMS).

2. The Copernicus Marine Environment Monitoring Service (CMEMS).

3. The Copernicus Land Monitoring Service (CLMS).

4. The Copernicus Climate Change Service (C3S).

5. The Copernicus service for Security.

6. The Copernicus Emergency Management Service (Copernicus EMS).

Figure 5.6 Six thematic information services provided by the Copernicus Earth Observation Programme of the European Union

Source: https://www.nceo.ac.uk/

The Copernicus Atmosphere Monitoring Service (CAMS) provides consistent and quality-controlled information related to air pollution and health, solar energy, greenhouse gases and climate forcing, everywhere in the world.

The Copernicus Marine Service (or Copernicus Marine Environment Monitoring Service (CMEMS)) is the marine component of the Copernicus Programme of the European Union. It provides free, regular and systematic authoritative information on the state of the Blue (physical), White (sea ice) and Green (biogeochemical) ocean, on a global and regional scale. It is funded by the European Commission (EC) and implemented by Mercator Ocean International.

The Copernicus Land Monitoring Service (CLMS) provides data on land cover to a broad range of users in the field of environmental terrestrial applications. CLMS products include information on land use, land cover characteristics and changes, vegetation state, water cycle and earth surface energy variables.

The Copernicus Climate Change Service (C3S) supports society by providing authoritative information about the past, present and future climate in Europe and the rest of the World.

The Copernicus service for Security applications aims to support European Union policies by providing information in response to Europe's security challenges. It improves crisis prevention, preparedness and response in three key areas:

- Border surveillance;
- Maritime surveillance;
- Support to EU External Action.

The Copernicus Emergency Management Service (Copernicus EMS) provides all actors involved in the management of natural disasters, man-made emergency situations, and humanitarian crises with timely and accurate geo-spatial information derived from satellite remote sensing and completed by available in situ or open data sources.

The Copernicus EMS consists of two components:

1. a mapping component;
2. an early warning component.

The mapping component of the service (Copernicus EMS - Mapping) has a worldwide coverage and provides the above-mentioned actors (mainly Civil Protection Authorities and Humanitarian Aid Agencies) with maps based on satellite imagery.

Copernicus EMS - Mapping can support all phases of the emergency management cycle: preparedness, prevention, disaster risk reduction, emergency response and recovery.

The early warning component of the Copernicus EMS consists of three different systems:

● The European Flood Awareness System (EFAS), which provides overviews on ongoing and forecasted floods in Europe up to 10 days in advance.

● The European Forest Fire Information System (EFFIS), which provides near real-time and historical information on forest fires and forest fire regimes in the European, Middle Eastern and North African regions.

● The European Drought Observatory (EDO), which provides drought-relevant information and early-warnings for Europe.

Global Flood Awareness System (GloFAS), Global Wildfire Information System (GWIS) and Global Drought Observatory (GDO) complete the previous three above systems at global level.

The Copernicus space observation system is based on the use of observation data from six satellite families: Sentinel-1, Sentinel-2, Sentinel-3, Sentinel-4, Sentinel-5, Sentinel-6.

Figure 5.7 Copernicus Sentinel-6 was launched in 2020
Source: https://www.copernicus.eu/en/about-copernicus/infrastructure-overview/discover-our-satellites

Each satellite family consists of two or four satellites. Some of the satellites have already been launched, while others are still under development or preparation for launch.

5.3 Status of information disclosure and monitoring information systems

In accordance with the Regulation on the State Environmental Monitoring System, the SEMS is an integral part of the national information infrastructure compatible with similar systems in other countries.

Currently, there is no single information and analytical system in Ukraine that provides comprehensive information on the state of the environment, but there are systems of various central executive bodies developed to display information on specific environmental monitoring objects. Only state information resources are discussed below.

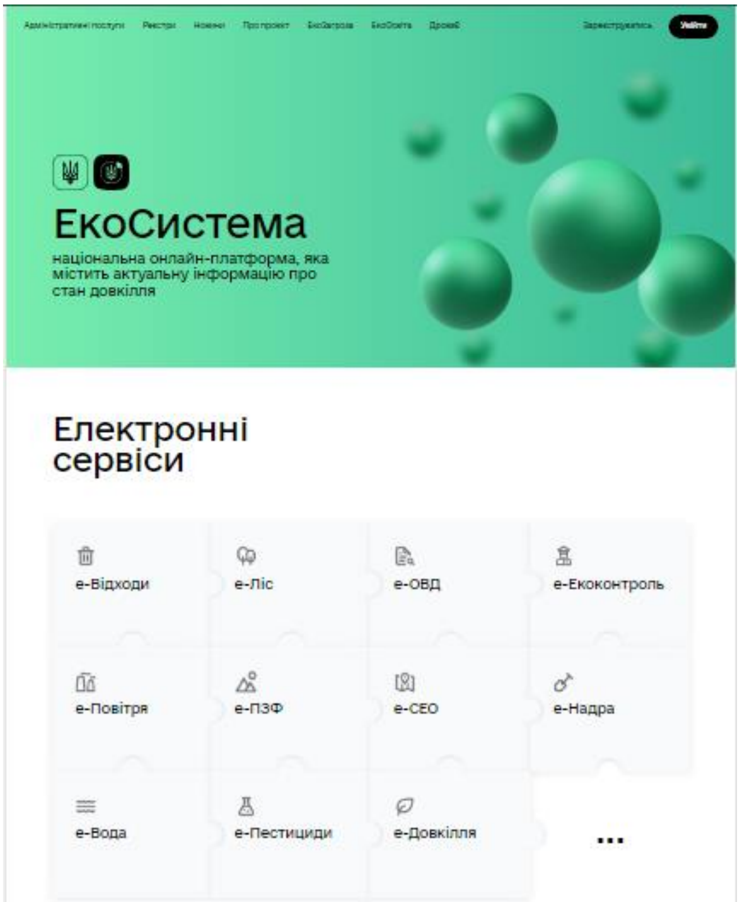


Figure 5.8 Interface of the main page of the environmental platform "EcoSystem"

Source: https://eco.gov.ua/

The Unified Environmental Platform "EcoSystem" is a national environmental automated information and analytical system for providing access to environmental information, owned by the Ministry of Environment. The Ministry of Environment launched the platform in a test mode in May 2021, and in October 2021, the government adopted a resolution "On the Unified Environmental Platform "EcoSystem".

This platform was created to publish environmental information and provide environmental administrative services. As of the beginning of 2023, EcoSystem contains 10 online services (14 in development), 6 active registers of open environmental data (10 registers in development), and 3 integrated information resources:

- State cadastre of territories and objects of the nature reserve fund (wownature.in.ua);
- National register of pollutant emissions and transfers;
- During the full-scale war, the Ministry of Environment launched EkoZahroza, the official website and mobile application of the Ministry of Environment, which provides information on the state of air, water, soil and other environmental data. The website also allows Ukrainians to report any environmental crimes they have witnessed.

The Ministry of Environment has published 7 datasets on the open data portal, including:

● The list of permits for air pollutant emissions from stationary sources of objects of the 1st, 2nd, 3rd groups with their numbers and validity period;

● List of permits for the import and export of wild fauna and flora species, certificates for travelling exhibitions, re-export and introduction of these specimens from the sea, except for sturgeon and products made from them;

● A list of notifications on transboundary transport of hazardous waste;

● Data on issued licences for the production of highly hazardous chemicals and licensees;

● A list of pesticides and agrochemicals permitted for use;

● Register of environmental auditors and legal entities entitled to conduct environmental audits.

Public data of the State Water Resources Agency is available on 2 websites:

1) Data.gov.ua - data is provided in the following areas:

- State Water Cadastre in the section "Water Use";

- Information on the accounting system, types of information stored by the State Agency of Ukraine for Water Resources;

- Data on state monitoring of surface waters, etc.

2) The launch of the State Portal "Water Resources" announced in 2018 launched a powerful information resource, which is currently operating in test mode and is awaiting data obtained in the process of preparing and implementing river basin management plans.

An independent press portal, Texty.org.ua, has created an interactive map called "Clean Water" based on data from the State Water Agency, which shows the degree of river pollution in Ukraine. The map includes more than 400 river water control points, where you can view up to 16 pollution parameters and find out how pollution levels have changed over the past five years.

Regarding groundwater monitoring, the website of the State Research and Production Enterprise "Geoinform of Ukraine" (SRPE "Geoinform of Ukraine") states that groundwater monitoring is carried out throughout Ukraine using the automated information system of the State Water Cadastre, which was created by the SRPE "Geoinform of Ukraine" and contains information (with the possibility of selecting data by region, by water management area, by groundwater basins and by river basins):

- general data on the water point,

- aquifer index and interval,
- geological section of the water point,
- hydrogeological characteristics of the water point (test results: flow rate, drawdown, water head, static level, filtration coefficients, water conductivity; filter: type, diameter, installation interval, etc,)
- observation data on the groundwater level,
- catalogue of the chemical composition of groundwater at the water point - general data and macro components.

Based on the results of the data collection, the SRPE "Geoinform of Ukraine" publishes the "Hydrogeological Yearbook on the State of Groundwater in Ukraine", which is a summary of changes in groundwater production, quality and level groundwater regime by year. This Hydrogeological Yearbook provides a brief overview of the groundwater regime in natural and disturbed conditions and the quality of groundwater.

In 2017, the State Geological Service of Ukraine published the State Geological Map of Ukraine (scale 1:200,000) developed by the Northern State Regional Geological Enterprise "Pivdengeologiya" of the Ministry of Environment and Natural Resources of Ukraine on the website of the SRPE "Geoinform of Ukraine".

According to independent experts of international technical assistance (EUWI+), the state of disclosure of information on air quality by the State Emergency Service of Ukraine is unsatisfactory. The Hydrometeorological Centre publishes only meteorological data and data on environmental radiation background. The website also provides descriptive information on the hydrological situation on Ukrainian water bodies. Unfortunately, there is no information on water quality.

The website of the Borys Sreznevsky Central Geophysical Observatory offers downloads of only its publications.

Among the SES data sets, there are no data sets relevant to state environmental monitoring.

The StateGeoCadastre has posted on its portal of public information in the section "Information on Land Monitoring" operational information on the implementation of land protection measures.

The website of the State Enterprise "Institute of Soil Protection of Ukraine" contains a downloadable "Periodic report on the state of soils on agricultural lands of Ukraine", based on the results of the 9th cycle (2006-2010) of agrochemical survey of lands. The National Report on the State of Soil Fertility of Ukraine for 2010, as well as scientific collections on the results of similar studies for 2017 and 2018 are also available there.

As for the publication of information on biodiversity, in 2013, the Unified Information and Analytical System "Environment of Ukraine" was created, which contains information on the Red Book of Ukraine, the Green Book of Ukraine, and the cadastres of flora and fauna of Ukraine (this system is functioning, although it needs significant improvement). In addition, information on the results of scientific research commissioned by the Ministry is published on the website of the Ministry of Environment in the Biodiversity section.

The State Forestry Agency has also posted information on forest reproduction and data from the State Forest Cadastre on the open data portal.

Questions for self-control

1. What are the general approaches to environmental monitoring that can be divided into?

2. What do ground and surface monitoring methods include?

3. Does the group of remote sensing methods involve the use of photo and video recording with the help of UAVs?

4. Where are automatic sensors typically used for water monitoring?

5. Name a few types of specialised sampling equipment.

6. What are the requirements for environmental monitoring equipment?

7. What European Union programme is one of the best examples of international observation and decision-making systems using remote sensing?

8. Why does Copernicus also collect information from in-situ systems?

9. What information will the Copernicus Earth Monitoring Service products include?

10. The Copernicus EMS service consists of the following components:

a. mapping component;

b. maritime surveillance;

c. earth surface energy variables;

d. early warning component.

11. Is there currently a single information and analytical system in Ukraine that provides complete information on the state of the environment?

12. List the main state institutions involved in environmental monitoring that provide open data on the state of the environment.

6. MONITORING IN THE FIELD OF ATMOSPHERIC AIR PROTECTION

6.1 Notion about air pollution;

6.2 The state of atmospheric air in Ukraine;

6.3 Procedure for state monitoring in the field of atmospheric air protection and subjects of monitoring in Ukraine;

6.4 Network and observation posts;

6.5 Material and technical support;

6.6 Key stages of modernisation of the national air monitoring system;

6.7 International approaches to air quality monitoring. Air Quality Index (AQI).

6.1 Notion about air pollution

High quality air, together with water, is a key element for human life and all components of the biosphere. The high velocity of mass movement in the atmosphere leads to the migration of polluted air over long distances, within the ozone layer, and also to negative consequences, such as acid rain or accelerated karst processes.

The Earth's outer shell forms an atmosphere up to 20 km thick (Table 6.1).

Air pollution is contamination of the indoor or outdoor environment by any chemical, physical or biological agent that modifies the natural characteristics of the atmosphere.

Air pollution includes all contaminants found in the atmosphere. These dangerous substances can be either in the form of gases or particles.

The sources of air pollution are both natural and human-based. As one might expect, humans have been producing increasing amounts of pollution as time has progressed, and they now account for the majority of pollutants released into the air.

Table 6.1 The major components of dry clean air in ground atmospheric layer

Gas	**Molecular mass**	**Relative amount in dry air, %**	
		by volume	**by weight**
Nitrogen *(N_2)*	28,02	78,08	75,53
Oxygen *(O_2)*	32,0	20,95	23,14
Argon *(Ar)*	39,94	0,93	1,28
Carbon dioxide *(CO_2)*	44,01	0,033	0,05
Neon *(Ne)*	20,18	0,0018	0,001
Helium *(He)*	4,0	0,0005	0,00007
Krypton *(Kr)*	16,05	0,00015	0,00008
Xenon *(Xe)*	83,7	0,0001	0,00003
Nitrous oxide (N_2O)	44,02	0,00005	0,00008
Hydrogen (H_2)	2,02	0,00005	0,000003
Ozone (O_3)	48,0	0,00004	0,00007

Air pollution has been a problem throughout history. Even in Ancient Rome people complained about smoke put into the atmosphere.

The effects of air pollution are diverse and numerous. Air pollution can have serious consequences for the health of human beings, and also severely affects natural ecosystems.

Air pollution is considered to be the most dangerous form of pollution in terms of volume, as pollution of industrialised cities with toxic agents becomes irreversible and negatively affects public health.

According to the World Health Organisation (WHO), 92% of the world's population breathes air that is polluted beyond acceptable limits.

Particulate matter (PM) and *ground-level ozone* are now generally recognized as the two pollutants that most significantly affect human health. Long-term and peak exposures to these pollutants range in severity of impact, from impairing the respiratory system to premature death.

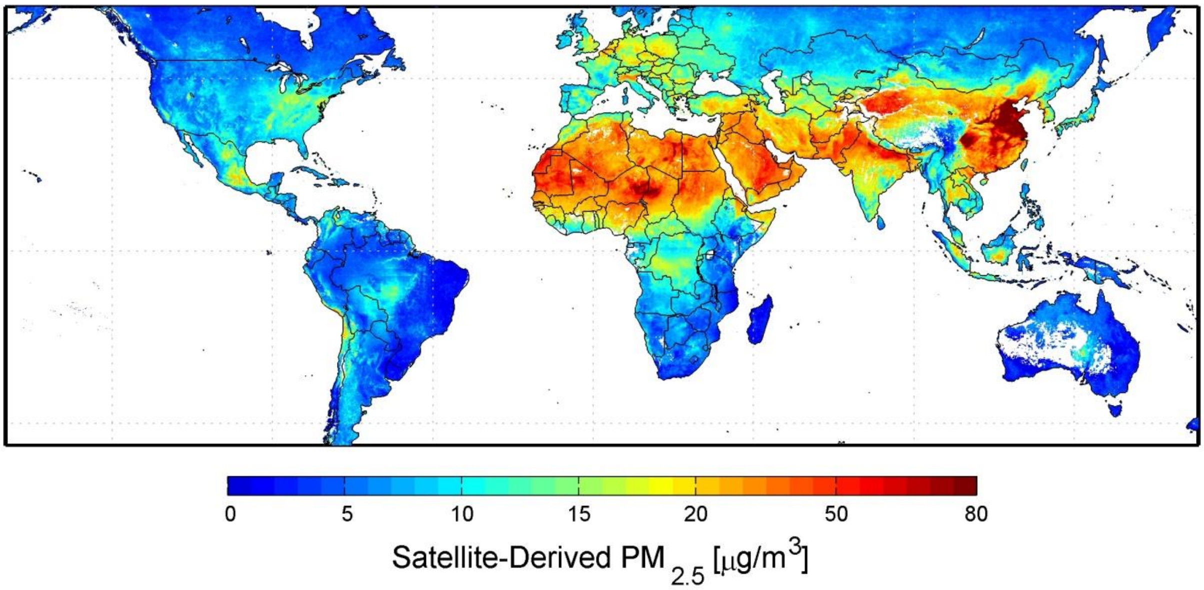


Figure 6.1 Global satellite-derived map of $PM_{2.5}$ averaged over 2001-2006

Source: https://www.nasa.gov/topics/earth/features/health-sapping.html

Particle pollution, also called particulate matter or PM, is a mixture of solids and liquid droplets floating in the air. Some particles are released directly from a specific source, while others form in complicated chemical reactions in the atmosphere.

Particles come in a wide range of sizes. Particles less than or equal to 10 micrometers in diameter are so small that they can get into the lungs, potentially causing serious health problems. Ten micrometers is less than the width of a single human hair.

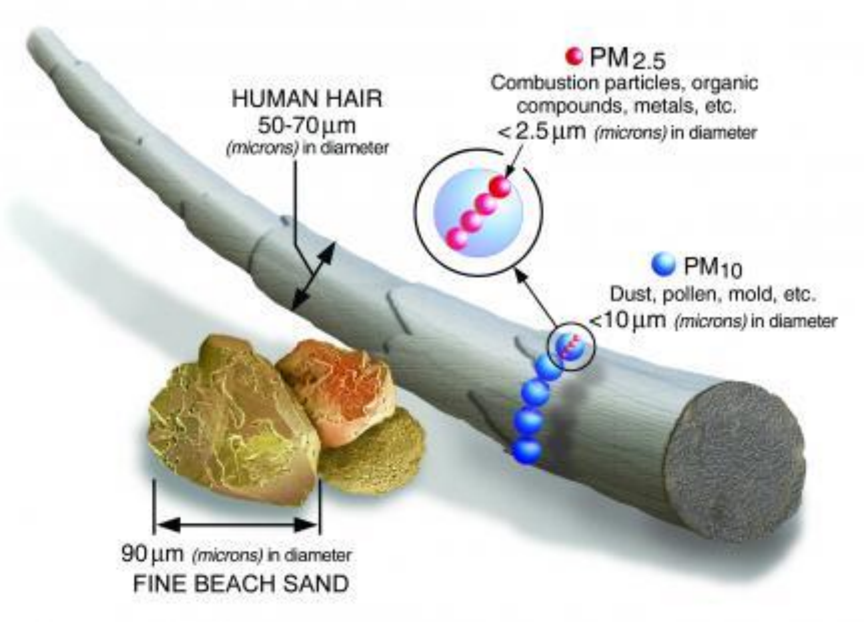


Figure 6.2 Size comparisons for PM particles

Source: https://www.epa.gov/pm-pollution/particulate-matter-pm-basics

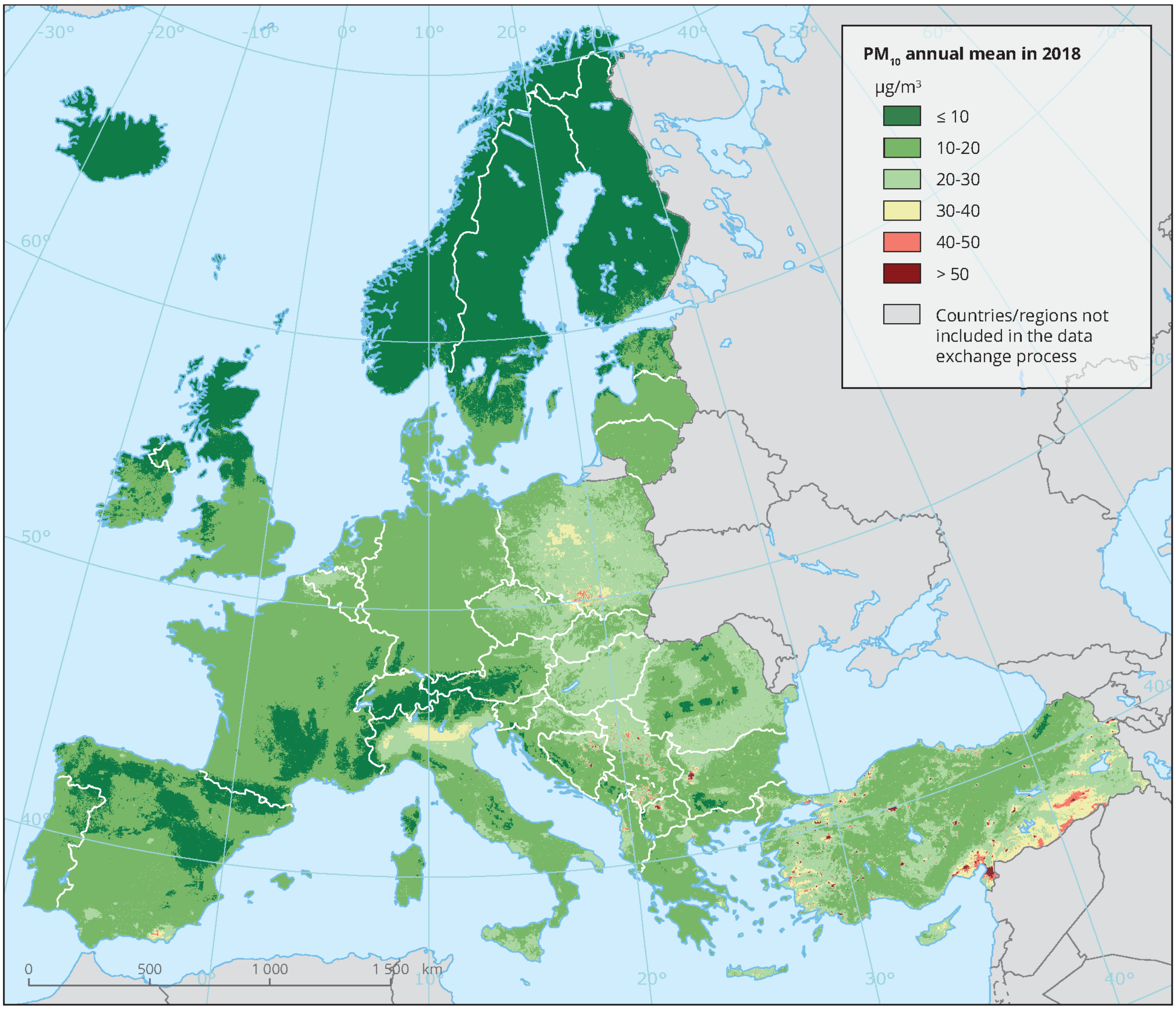
<u>Coarse dust particles (PM_{10})</u> are 2.5 to 10 micrometers in diameter. Sources include crushing or grinding operations and dust stirred up by vehicles on roads.

<u>Fine particles ($PM_{2.5}$)</u> are 2.5 micrometers in diameter or smaller, and can only be seen with an electron microscope. Fine particles are produced from all types of combustion, including motor vehicles, power plants, residential wood burning, forest fires, agricultural burning, and some industrial processes.

PM can act as a catalyst for chemical reactions on its surface. Thus, the toxic effect of PM is enhanced by the content of other pollutants in the air. All these features make it impossible to clearly define the “safe” concentration of PM in the air. That is why the WHO experts recommend values that determine the minimum risk to public health.

The map (Fig. 6.3) shows the calculated PM_{10} concentrations (annual average), which combine monitoring data with the results of the

European Monitoring and Evaluation Programme (EMEP) chemical transport model and other additional data.



Reference data: ©ESRI

Figure 6.3 PM_{10} annual mean in 2018

Source: https://www.eea.europa.eu/data-and-maps/figures/pm10-annual-mean-in-2

Ground-level ozone forms when heat and sunlight allow the reaction of two other pollutants: nitrogen oxides and volatile organic compounds.

These chemicals come from industrial plants, electric utilities, vehicle exhaust, wildfire smoke, and oil and gas extraction. High heat can accelerate this process. The resulting ground-level ozone can build up to unhealthy levels − especially without wind or rain to mix up the air.

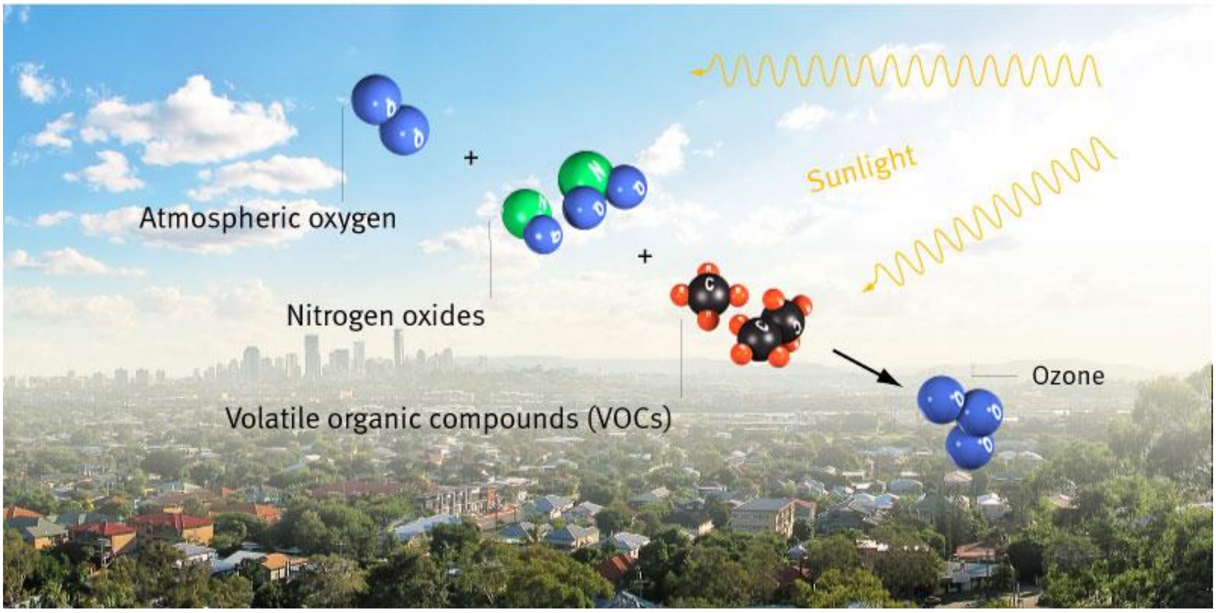


Figure 6.4 Formation of ground-level ozone

Many countries regulate ozone because of the damage the pollutant does to plants and people (Fig. 6.5 below). In the United States, for example, the current health-based standard for ground-level ozone, set by the U.S. Environmental Protection Agency, is 70 ppb (based on the maximum daily 8-hour average). The Chinese national ozone air quality standard is a daily maximum 8-hour average greater than 160 micrograms per cubic meter, equivalent to about 80 ppb.

There are various sources of air pollution, both anthropogenic and of natural origin:

- burning of fossil fuels in electricity generation, transport, industry and households;

- industrial processes and solvent use, for example in chemical and mineral industries;

- agriculture;

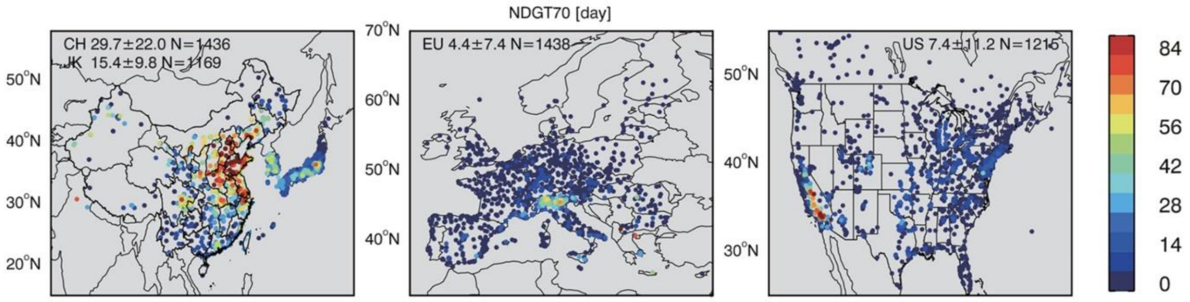


Figure 6.5 Comparison of one ozone metric, NDGT70 (total number of days with a daily maximum 8-hour average value greater than 70 ppb), between China and other industrialized regions -- Japan and Korea (JK), Europe (EU), and the United States

Source: ES&T Letters, CIRES

- waste treatment;

- volcanic eruptions, windblown dust, sea-salt spray and emissions of volatile organic compounds from plants are examples of natural emission sources.

Table 6.2 Comparative description of emissions of natural and anthropogenic pollutants

Pollutant	**Natural origin**	**Anthropogenic origin**
Carbon monoxide (*CO*)	−	$3,5 \cdot 10^{8}$
Sulphur dioxide (SO_2)	$1,4 \cdot 10^{8}$	$1,45 \cdot 10^{8}$
Nitrogen dioxide (NO_2)	$1,4 \cdot 10^{9}$	$(1,5 - 2,0) \cdot 10^{7}$
Particulate matters	$(7,7 - 22,0) \cdot 10^{10}$	$(9,6 - 26,0) \cdot 10^{10}$
Polyvinylchloride materials, freons	−	$2,0 \cdot 10^{6}$
Ozone (O_3)	$2,0 \cdot 10^{9}$	−
Hydrocarbons (C_nH_m)	$1,0 \cdot 10^{9}$	$1,0 \cdot 10^{6}$
Lead (*Pb*)	−	$2,0 \cdot 10^{5}$
Mercury (*Hg*)	−	$5,0 \cdot 10^{3}$

Air pollutants can be released directly into the atmosphere (primary emissions) or can form as a result of chemical interaction involving precursor substances.

The air pollutant emissions cause air pollution, however, reductions in emissions do not always automatically result in similar cuts in concentrations. There are complex links between air pollutant emissions and air quality.

These include emission heights, chemical transformations, reactions to sunlight, additional natural and hemispheric contributions and the impact of weather and topography. Significant cuts in emissions are essential for improving air quality.

6.2 The state of atmospheric air in Ukraine

Ukraine has the highest number of deaths related to air pollution for every 100,000 people, based on a ranking of 120 countries in 2017. According to the Global Burden of Disease (GBD) database in 2019, 42,900 premature deaths in Ukraine were related to air pollution, which corresponds to about 10% of all cases of morbidity and mortality.

Studies based on the analysis of Copernicus Sentinel 5p satellite imagery and quality-controlled air pollution data from the Copernicus Atmospheric Monitoring Service conducted in 2018-2020 have shown that the situation with air quality in Ukraine (until February 2022) was diverse and related to the distribution of major urban and industrial centres.

In general, Dnipro, Donetsk, Kyiv, Luhansk and Zaporizhzhia regions are the most affected by air pollution. From the perspective of the most polluted cities, it is worth highlighting 6 key urban areas - Dnipro, Donetsk, Kryvyi Rih, Kyiv, Mariupol and Zaporizhzhia.

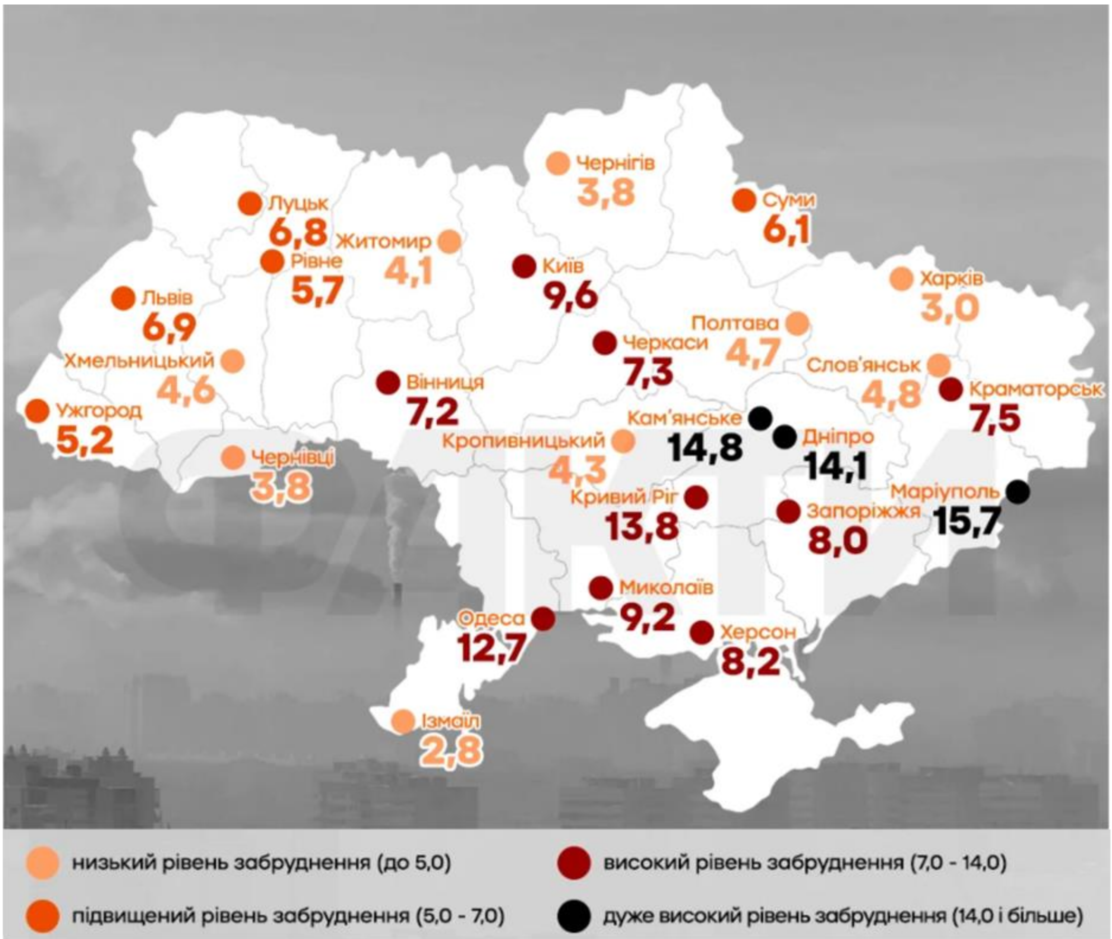


Figure 6.6 Air pollution index in Ukrainian cities in 2020

Source: Boris Sresnevsky Central Geophysical Observatory

The distribution of nitrogen dioxide (NO_2) was relatively uniform. Some regions (Kyiv, Donetsk, Zaporizhzhia oblasts, etc.) had significantly higher concentrations of NO_2 content than in other regions of the country. High concentrations were mainly observed in the largest cities, industrial and coal mining areas.

The human impact on carbon monoxide (CO) concentrations was noticeable in the lowlands of major steel production centres such as Mariupol, Zaporizhzhia, Kryvyi Rih and Kamianske. The highest pollution was observed in Dnepropetrovsk, Kyiv and Zaporizhzhia oblasts.

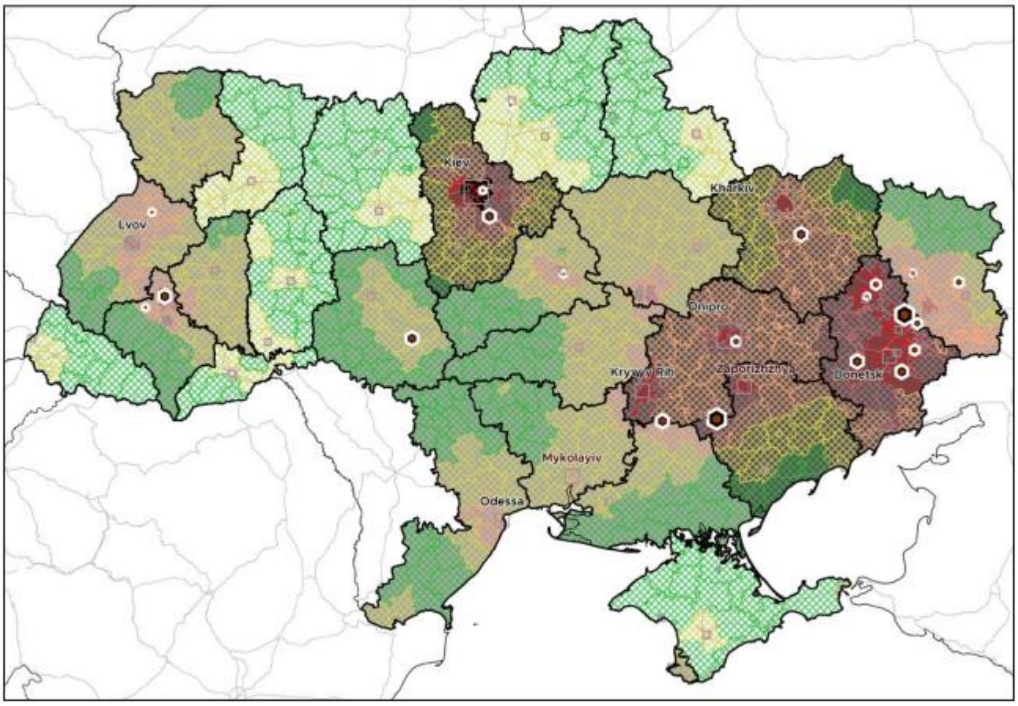


Figure 6.7 Average NO_2 concentrations in oblasts and administrative districts in the context of coal-fired power plant locations. Coal-fired power plants are indicated as dark red hexagons, categorised by their capacity [1]

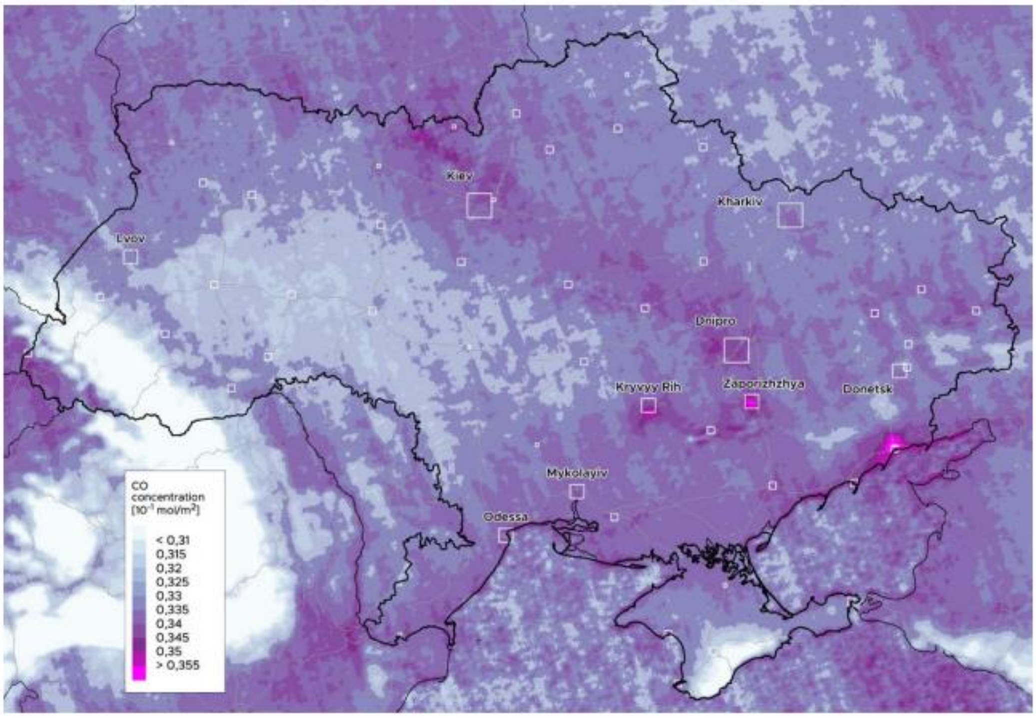


Figure 6.8 Average CO concentrations on the territory of Ukraine in the period from May 2018 to April 2020 [1]

Ukraine generally has low concentrations of formaldehyde (HCHO) and sulphur dioxide (SO_2). Areas with higher SO_2 concentrations are concentrated around urban areas, especially in eastern Ukraine, with active coal mines, coke, chemical and heavy industries.

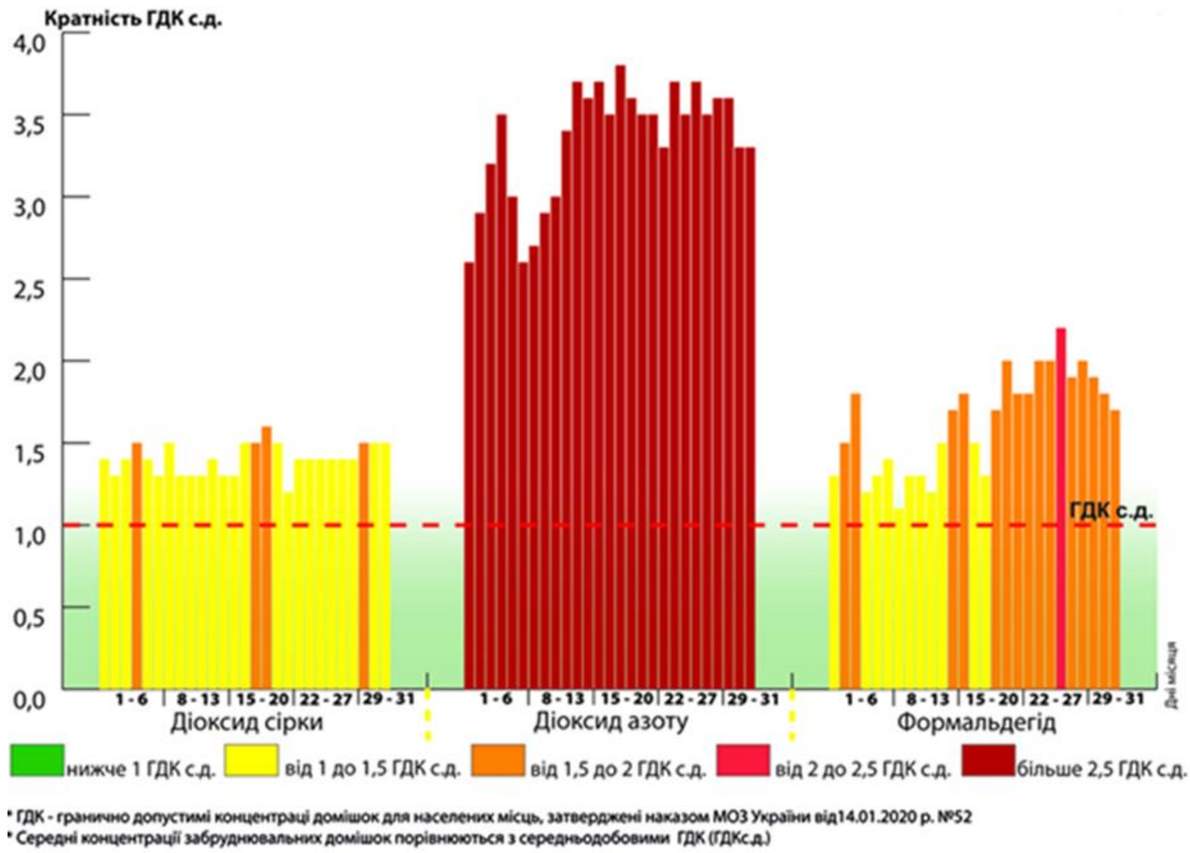


Figure 6.9 Daily average concentrations of pollutants in the atmospheric air of Kyiv in multiples of the MACd.a., May 2023

Source: Boris Sresnevsky Central Geophysical Observatory

Concentrations of particulate matter ($PM_{2.5}$ and PM_{10}) decreased from the south to the north of the country, while the highest concentrations are observed in the industrial region of eastern Ukraine. Average PM concentrations were 2.5 times higher than World Health Organisation (WHO) standards in 127 districts with the highest values in Donetsk and Dnipropetrovsk regions, as well as in Kyiv. Even the country's average $PM_{2.5}$ was above the WHO limit in March 2017, November 2018 and February 2019.

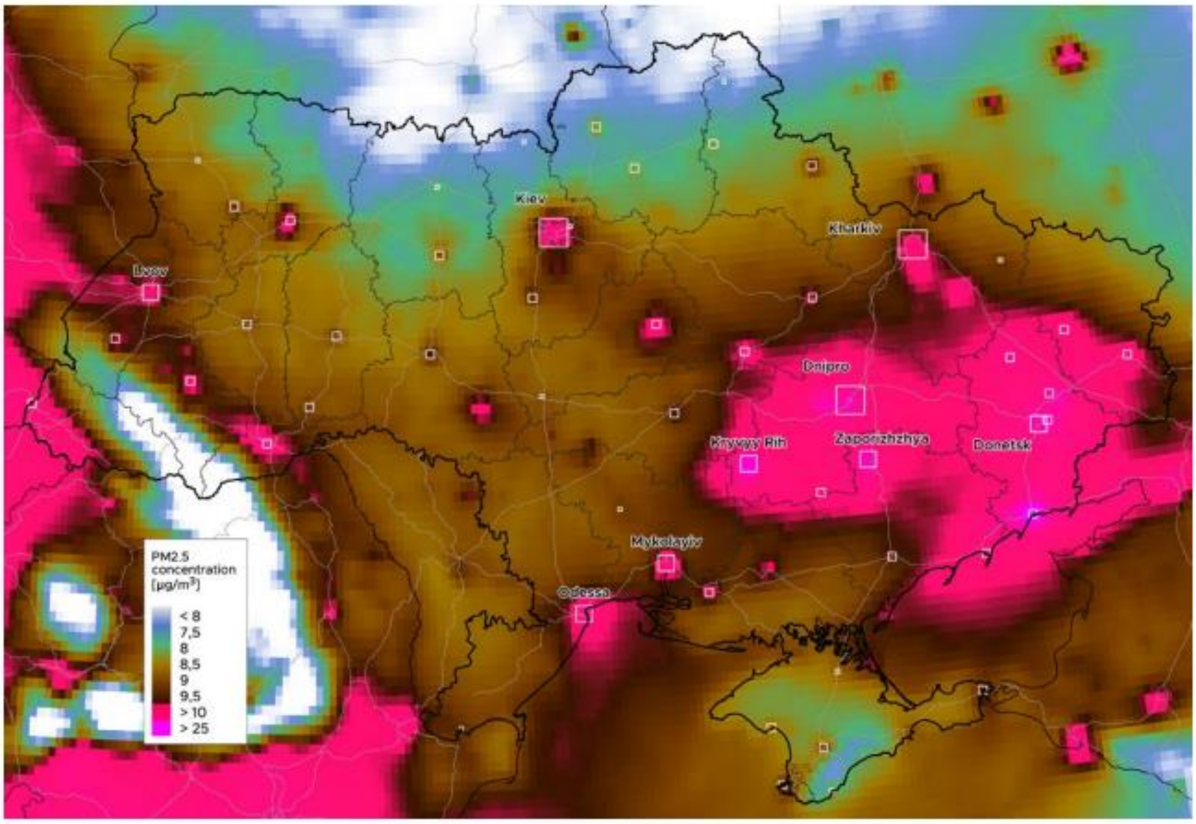


Figure 6.10 Average concentrations of $PM_{2.5}$ on the territory of Ukraine in the period from July 2017 to July 2020 [1]

The WHO recommended values of PM_{10} content were exceeded in the city of Mariupol and in some areas of four cities (Kryvyi Rih, Dnipro, Zaporizhia and Donetsk) located in south-western Ukraine.

In September 2018 and March 2020, the national average PM_{10} content reached the WHO limit.

Full-scale war has led to intensification of atmospheric air pollution in areas of intense military operations. According to the Ministry of Environmental Protection and Natural Resources' EkoZahroza system, the greatest damage caused by military operations is to the air, which, according to SaveDnipro experts, is about 77%. In particular, according to the data of the Ministry, the volume of emissions of harmful substances into the atmospheric air during the war is equal to the volume of emissions of one metallurgical enterprise for a whole year of operation.

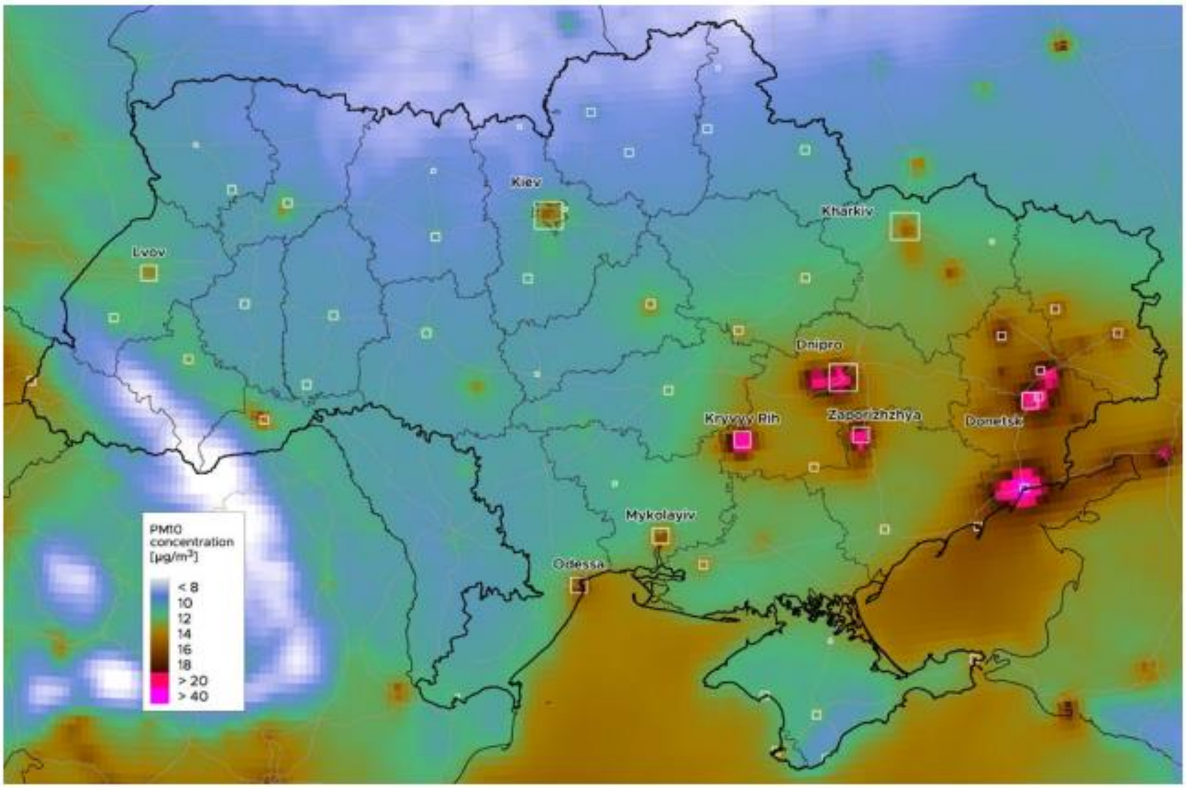


Figure 6.11 Average PM_{10} concentrations in Ukraine in the period from July 2017 to July 2020 [1]

However, it is difficult to objectively calculate the damage caused by military air emissions because pollutants are volatile and their transport and dispersion rates depend on various factors, such as atmospheric pressure, air humidity, wind speed and landscape.

In general, in order to systematically analyse the impact of war factors on the state of atmospheric air, it is important to take into account both negative factors - missiles hitting oil infrastructure, fires at industrial and energy facilities, fires in forests, etc., and positive factors for atmospheric air, but critical for the country such as reduction of anthropogenic load due to systemic industrial crisis, decline in business activity and reduced use of motor vehicles due to increased fuel costs and population reduction in Ukraine due to forced migration (about 11 million people), which reduced their impact on air pollution due to the above factors.

6.3 Procedure for state monitoring in the field of atmospheric air protection and subjects of monitoring in Ukraine

As already noted, under the current legal structure, each of the SEMS subsystems needs to create inherent legislative and regulatory instruments for the organisation and implementation of monitoring of the state of environmental objects.

One of the subsystems for which such tools have been created is monitoring of atmospheric air. This is the Law of Ukraine "On Atmospheric Air Protection" and the Resolution of the Cabinet of Ministers of Ukraine No. 827 dated 14 August 2019 "Some Issues of State Monitoring in the Field of Atmospheric Air Protection", which determine the order and procedure of monitoring in the field of atmospheric air protection.

The peculiarities of this procedure are that:

● contemporised procedure for air monitoring does not provide for the preparation of national monitoring programmes, because the object level of such programmes is zones and agglomerations;

● this procedure defines a mandatory list of monitoring indicators;

● depending on the peculiarities of pollution in a particular region or locality, obliges to take certain actions to implement monitoring procedures or measurement (assessment) regimes.

State monitoring in the field of atmospheric air protection (or atmospheric air monitoring) is carried out in order to collect, process, store and analyse information on the quality of atmospheric air, assess and forecast its changes and the degree of danger, develop scientifically based recommendations for making management decisions in the field of atmospheric air protection, in the field of environmental protection, as well as informing the population about the quality of atmospheric air, and the impact of its pollution on the population's health and livelihood.

On the basis of data and information obtained as a result of atmospheric air monitoring, it is determined the level of atmospheric air pollution in a certain area for a certain period of time, compliance of the state of atmospheric air with air quality requirements; exercise control and assessment of the measures aimed at limiting emissions of pollutants into the atmospheric air, assessment of the impact of atmospheric air pollution on the environment, health and livelihood of the population.

Monitoring of atmospheric air is carried out according to the indicators of atmospheric air quality and atmospheric precipitation for pollutants defined in List A of the Procedure for State Monitoring in the Field of Atmospheric Air Protection.

Air quality monitoring and subsequent management is carried out in accordance with the division of Ukraine's territory into zones and agglomerations.

Annex 1 of the Procedure sets out the list of zones and agglomerations for which air monitoring programmes are developed, which describe the current state of the monitoring system in the relevant territory and identify measures to improve such systems.

An agglomeration is defined as an area with a population of more than 250,000 people, designated for the purposes of monitoring and management of atmospheric air quality; a zone is a part of the territory of a state, designated for the purposes of monitoring and management of atmospheric air quality.

Table 6.3 List of pollutants to be assessed, and precipitation components and indicators (List A)

Pollutants in outdoor air	Indicators and components of precipitation
1. Sulfur dioxide	1. Ammonium ions
2. Nitrogen dioxide and nitrogen oxides	2. Hydrocarbonate ions
3. Benzene	3. Potassium ions
4. Carbon monoxide	4. Calcium ions
5. Lead	5. Total acidity
6. Particulate matter (PM_{10})	6. Magnesium ions
7. Particulate matter ($PM_{2,5}$)	7. Sodium ions
8. Arsenic	8. Nitrate ions
9. Cadmium	9. Sulfate ions
10. Mercury	10. Chloride ions
11. Nickel	11. pH
12. Benz (a) pyrene.	
13. Ozone	

The boundaries of the zones coincide with the boundaries of the corresponding administrative-territorial units. The zones do not include agglomerations located on their territory.

The following agglomerations are established on the territory of Ukraine for the purposes of atmospheric air monitoring and atmospheric air quality management:

1) Vinnytsia;

2) Horlivka;

3) Dnipro;

4) Donetsk;

5) Zhytomyr;

6) Zaporizhzhia;

6-1) Ivano-Frankivsk;

7) Kyiv;

8) Kryvyi Rih;

9) Luhansk;

10) Lviv;

11) Makiivka;

12) Mariupol;

13) Mykolaiv;

14) Odesa;

15) Poltava;

16) Sevastopol;

17) Simferopol;

18) Sumy;

19) Kharkiv;

20) Kherson;

21) Khmelnytskyi;

22) Cherkasy;

23) Chernivtsi;

24) Chernihiv.

The boundaries of the agglomerations coincide with the boundaries of the respective cities.

Depending on the level of atmospheric air pollution (exceeding certain assessment thresholds) by one or another pollutant from List A, the following regimes are applied:

● mode of fixed measurements (carried out on fixed observation networks, continuously and using the assessment methods specified in Annex 3 to the Procedure);

● mode of combined estimation (provides a combination of fixed measurements and modelling method, or indicative measurements);

● mode of modelling or objective assessment (applied when pollutant levels are below the lower assessment threshold defined in paragraph 2 of Annex 2).

The procedure for state monitoring in the field of atmospheric air protection does not provide for diagnostic studies on a wider list of pollutants than those specified in List A in order to identify new hazards.

However, by the decision of local executive authorities and local self-government bodies, if there are specific air pollution features in the zone or agglomeration, the monitoring programme for the relevant territory may be supplemented with pollutants from List B of paragraph 1 of Annex 2 of the Procedure.

Table 6.4 List of pollutants to be assessed, precipitation components and indicators (List B)

1. Ammonia
2. Aniline
3. Hydrogen chloride
4. Hydrogen cyanide
5. Iron and its compounds (in terms of iron)
6. Nitric acid
7. Sulfuric acid
8. Xylene
9. Volatile organic compounds
10. Manganese and its compounds (in terms of manganese dioxide)
11. Copper and its compounds (in terms of copper)
12. Soot
13. Hydrogen sulfide
14. Carbon sulfide
15. Phenol
16. Hydrogen fluoride
17. Chlorine
18. Chloroniline
19. Chromium and its compounds (in terms of chromium)
20. Zinc and its compounds (in terms of zinc).

To carry out atmospheric air monitoring for each zone and agglomeration, a state monitoring programme in the field of atmospheric air protection (hereinafter referred to as the programme) is approved in the form established by the Ministry of Environment.

By Order № 147 from 25.02.2021 the Ministry of Environment has approved the form of the Program of state monitoring in the field of atmospheric air protection, which provides, in particular, the inclusion of:

- information on the air quality management authorities that have developed the program;

- information on the atmospheric air quality observation network and atmospheric air observation laboratories available in the relevant zone or agglomeration (in particular, this includes a list of observation sites, their addresses and geographical coordinates, maps with the location of observation sites, addresses of existing atmospheric air monitoring laboratories, information on indicators analysed by atmospheric air monitoring laboratories and the applied analysis methods, information on atmospheric air monitoring entities that monitor atmospheric air quality at the relevant observation sites);

- a list of pollutants estimated at observation points in the relevant zone or agglomeration, the methods used to measure, calculate, predict or estimate the level of pollutants at observation points and established assessment regime (data on the basis of which the assessment regime was established);

- information on planned activities to establish observation points and/or improve the existing atmospheric air quality observation networks, create and/or improve the atmospheric air observation laboratories (in particular, the list of observation sites planned to be installed, their addresses and coordinates, maps with the scheme of location of observation sites, information on the subjects of atmospheric air monitoring that plan to install observation sites and/or establish atmospheric air monitoring laboratories);

- the stages, mechanism and time frame for the implementation of the planned activities.

In addition, there should be reflected information about:

- sources of atmospheric air pollution;

- emissions of pollutants from stationary and mobile sources;

- information on the certification of equipment, devices and procedures for their verification of the network of observation sites.

The Ministry of Environment, the Ministry of Health, the State Emergency Service, the State Agency of Ukraine on Exclusion Zone Management, the executive authority of the Autonomous Republic of Crimea on environmental protection, regional state administrations, the Kyiv City State Administration, and executive bodies of city councils are responsible for air monitoring.

The Ministry of Environment ensures the overall organisation and coordination of atmospheric air monitoring entities.

The Ministry of Health: As part of state monitoring in the field of air protection, the Ministry of Health monitors the levels of pollutants defined in List A (currently, 7 parameters from this list are actually monitored). Also, 15 parameters from List B are being determined.

The Ministry of Health also determines the possible impact of air pollution on the health and vital functions of the population based on observations of pollutant levels and the results of state air monitoring obtained by other entities involved in state air quality monitoring.

Laboratory centres of the Ministry of Health carry out monitoring in places of residence and recreation, including natural areas of resorts. The Ministry of Health's laboratory centres monitor the air at 2,133 mobile and 16 stationary posts (2017 data).

The Public Health Centre of the Ministry of Health monitors the quality of atmospheric air in residential and recreational areas, including road areas, sanitary and hygienic zones, school grounds, medical facilities, etc. In addition, air quality analysis may be carried out based on complaints from citizens.

Based on the results of observations, the Ministry of Health institutions define three levels of environmental pollution assessment: 1) very polluted, 2) polluted, and 3) slightly polluted.

The State Agency of Ukraine on Exclusion Zone Management establishes observation points and monitors the levels of pollutants specified in List A in the exclusion zone and the zone of unconditional (mandatory) resettlement of the territory affected by radioactive contamination as a result of the Chornobyl disaster (within the limits of volumetric activity of radionuclides).

The State Emergency Service of Ukraine:

- establishes observation points and monitors the levels of pollutants, indicators and components of precipitation specified in List A on the observation network of the National Hydrometeorological Service;

- provides the subjects of atmospheric air monitoring with hydrometeorological forecasts.

The Ukrainian Hydrometeorological Centre (UHMC) of the SES is subordinated to 27 territorial units.

The UHMC's air monitoring network (excluding the temporarily occupied Autonomous Republic of Crimea and parts of Donetsk and Luhansk oblasts) covers 39 cities of Ukraine, which is only 8.5% of the total number of 460 cities.

Most observation points of the Hydrometeorological Centre are located in large cities, so it covers relatively completely the list of agglomerations given in the Procedure for State Monitoring in the Field of Atmospheric Air Protection, but does not meet the need for monitoring in the territory of the respective zones (see Figure 6.12 below).

At present, air pollution observations are carried out at 129 stationary observation posts and 2 transboundary observation posts (Svityaz and Rava-Ruska). Samples are analysed in 27 laboratories of the network. Air samples are analysed for 25 pollutants, of which 9 substances from List A (that is, 32.1% of the 28 required parameters) and 16 from List B.

Figure 6.12 The SES's air pollution observation network, as of 2018

Source: The Ukrainian Hydrometeorological Centre

From the "List B", the observation network of the Ukrainian Hydrometeorological Centre detects ammonia, aniline, nickel, nitrogen oxide, hydrogen chloride, iron, soot, hydrogen sulphide, cadmium, phenol, hydrogen fluoride, manganese, chromium, copper, zinc; the following substances are not monitored: benzene, ozone, hydrogen cyanide, mercury and its compounds, ethylbenzene, carbon disulfide, toluene, nitric acid, sulfuric acid, xylene, chlorine, chloroaniline, arsenic and its compounds (in terms of arsenic).

The State Emergency Service monitors radioactive contamination of the surface air layer in two ways: sampling of atmospheric aerosols by pumping large volumes of air through special fibre filters and collection of fallout from the atmosphere on horizontal gauze tablets. Seven stations of the radiometric network of hydrometeorological organisations are equipped with filter air units for aerosol sampling; atmospheric precipitation is sampled at 51 stations.

A significant part of the observation points is located in the areas of nuclear power plant impact, along the borders with neighbouring countries and in the areas contaminated by the Chornobyl accident, while the remaining sampling points are located in large industrial cities.

The executive authority of the Autonomous Republic of Crimea on environmental protection establishes observation sites and monitors the levels of pollutants specified in List A within the territory of the Autonomous Republic of Crimea.

Regional, Kyiv city state administrations and executive bodies of city councils establish observation sites and monitor the levels of pollutants specified in List A within the territory of the respective zone or agglomeration.

Figure 6.13 – Stationary post of the automated atmospheric air monitoring system of the Kiev Regional State Administration

According to the Procedure, by decision of local executive authorities, executive authorities in certain zones and agglomerations may monitor the levels of pollutants specified in List B.

In each zone and agglomeration, the air quality management authorities shall establish commissions for state monitoring in the field of air protection and air quality management.

The State Environmental Inspectorate (SEI), although not an air monitoring entity as defined by the Procedure, provides selective sampling at emission sources. In particular, as of 2017, more than 65 parameters were measured at more than 3,000 major emission sources belonging to more than 1,500 enterprises.

Scientific institutions are also involved in the monitoring of atmospheric air (as well as water and soil):

- Ukrainian Hydrometeorological Institute (UkrHMI);
- State Institution "O.M. Marzieiev Institute for Public Health of the National Academy of Medical Sciences of Ukraine";
- other research institutions subordinated to the Ministry of Environment.

It should be noted that Ukraine also has a public air monitoring system operating in parallel with the state monitoring system. The public monitoring system helps the state monitoring system to be more extensive, especially in small towns and rural areas.

Over the entire observation history, 1,430 stations have been installed in Ukraine. By the end of 2022, only more than 580 points across the country remain active.

Unfortunately, public monitoring systems have suffered a lot, because they have been actively developed in recent years precisely in the east of Ukraine and in the south of Ukraine, where there were industrial cities, as well as in Kyiv region. In Donetsk Oblast, according to experts of the "Clean Air for Ukraine" programme, 90% of all stations were lost, in Kharkiv Oblast - 50-65%.

The largest public monitoring networks are EcoCity, LUN Misto Air and Save Dnipro. All networks provide citizens with data on the microclimate, including air conditions, pressure, and temperature. Almost all stations provide data on the amount of dust in the air.

For example, state-owned networks provide total dust content, while public systems, on the contrary, provide information on the content of fine dust in the 2.5-10 μm fraction, as this is considered the most dangerous by the World Health Organization.

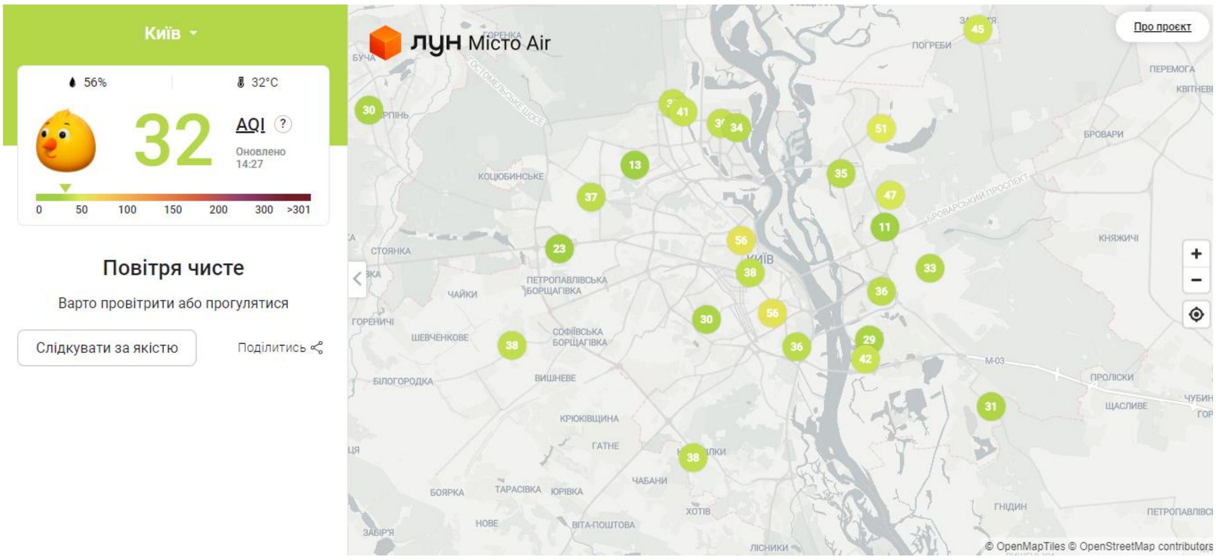


Figure 6.14 A view of the main page of the LUN Misto Air real time public network on the state of the air in Kyiv according to the air quality index

Source: https://misto.lun.ua/air/kyiv

The information about threats and pollution received by the EcoCity monitoring posts is transmitted to the EkoZagroza system from the Ministry of Environment. Other services have access to this network and can alert the public if necessary.

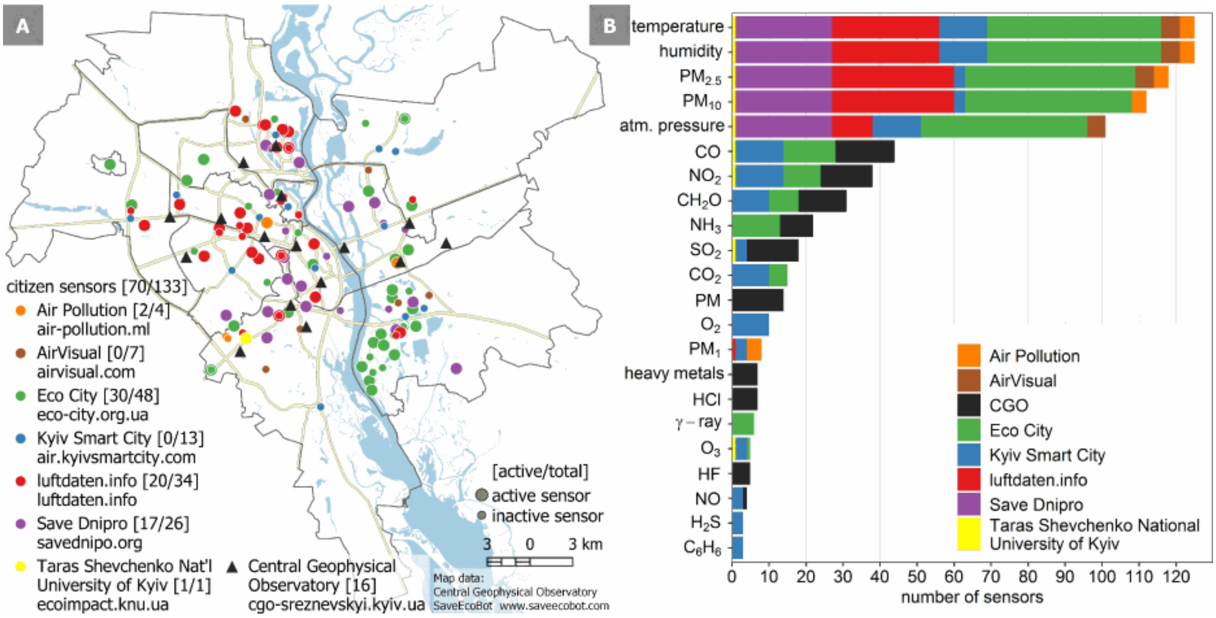


Figure 6.15 Air quality monitoring stations in Kyiv (A); parameters they measure (B) as of August 2020

Source: www.saveecobot.com

6.4 Network and observation posts

The network, namely the number of observation posts and the number of designated line gauges for each post, together with the frequency of sampling, are crucial in calculating the number of samples required for proper state environmental monitoring.

According to a report by international experts analysing the compliance of the air monitoring system in Ukraine with EU legislation [16], the UHMC takes air samples four times a day at set hours (01, 07, 13, 19 hours) every day, except Sundays and holidays.

It is roughly estimated that at the 129 UHMC posts available today, the total annual sample volume reaches 154800 samples.

Under the zoning system proposed by international experts (25 zones and 25 agglomerations), there is a need to establish a network of approximately 160 fixed (reference) observation sites in zones and agglomerations, as well as 12 fixed observation sites in rural neighbourhoods throughout Ukraine.

Sampling of arsenic, cadmium, nickel, and benzo(a)pyrene (polycyclic aromatic hydrocarbons) should be carried out at 56 of these fixed observation points.

Fixed measurements in accordance with the Procedure for State Monitoring in the Field of Atmospheric Air Protection involve the use of reference test methods that are already used in the EU monitoring system.

The reference test methods for the main pollutants (sulphur dioxide, nitrogen dioxide and nitrogen oxides, benzene, carbon monoxide, particulate matter (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 pollutants (arsenic, cadmium, nickel, benzo(a)pyrene), the Procedure for State Monitoring in the Field of Air Protection defines reference methods that involve sampling and their subsequent analysis by chemical laboratories.

In addition, according to the requirements of the EU Atmospheric Air Quality Directives, the new methods of atmospheric air quality observation - modelling and objective assessment - are introduced in the state atmospheric air monitoring system. These methods involve the use of measurement data in combination with pollutant emission, geographical and meteorological data.

Thus, if a network of fixed observation points with automatic analysis of pollutant levels is established in accordance with EU legislation, the state air monitoring system will need new elements:

- The national reference laboratory, which ensures unity, accuracy and traceability of measurements throughout the entire monitoring system of atmospheric air through calibration, verification of measuring equipment, determination of compliance of equipment and observation networks with legal requirements;

- A system for the collection, analysis, exchange and release of data on atmospheric air quality that is capable of providing such functions for the entire state observation network i.e., automatic, laboratory-analytical, modelling and objective assessment.

Table 6.5 The most common instrumental methods of air pollution control

Determination technique	Name of indicators
Gas chromatography	Hydrogen sulphide, methylamine, aniline, dimethyl(diethyl)-, trimethyl(triethyl)amine, acrolein, methanol, cyclohexane (-ol), (-non), 3,4-benzpyrene, chloroprene, benzene, ethylbenzene, toluene, xylene, chloroform
Turbidimetry	Sulphuric acid, sulphates
Photometry	Phosphatic acid, methylmercaptan, phenol, methanol, formaldehyde, carboxylic acids C_4-C_9, nitrogen oxides, ammonia, chlorides, hydrogen cyanide, hydrogen fluoride, pyridine, sulphur dioxide, hydrogen sulphide, total vanadium, lead and selenium
Atomic absorption spectroscopy	Iron, cadmium, cobalt, magnesium, manganese, copper, nickel, lead, chromium, zinc, mercury
Potentiometry	Boric acid, hydrogen fluoride

At the same time, due to the decrease in the number of measurements carried out by sampling and laboratory analysis, it is necessary to optimise the system of laboratories in the field of atmospheric air quality analysis.

6.5 Material and technical support

The state of the existing material and technical base of the SEMS for the majority of monitoring subjects requires improvement. The main problems are outdated equipment purchased back in 1950-1990, shortage of reagents and expendable materials, as well as loss of equipment due to malfunction and military actions in eastern Ukraine.

In particular, the laboratory equipment of the UHMC for the measurement of benzo(a)pyrene was lost due to the military operations in eastern Ukraine in 2014. There is no equipment for $PM_{2.5}$, PM_{10} and ground-level ozone analysis at this institution.

The subsystem of monitoring in the field of atmospheric air protection involves the use of both automatic equipment that can be installed permanently or operate in the mode of a mobile post, and air sampling for further analysis in the laboratory.

To date, a number of cities and oblast state administrations have independently implemented their own independent regional environmental monitoring systems.

Other cities and regional administrations pursue independent policies in the field of environmental monitoring. Communal observation networks and automatic monitoring systems have already been introduced in Kyiv oblast (16 fixed automatic observation points), in Kyiv city (7 automatic fixed observation points) and in several cities in Dnipropetrovsk oblast (Dnipro, Pavlograd, Nikopol, Kryvyi Rih).

Thus, as of January 2023, a network of seven high-precision observation points for the state of atmospheric air is operating in Kyiv. These stations are one of the elements of the system of civil protection, because they control the state of air in the city, taking into account the factors of increased danger during wartime.

The equipment at the monitoring stations complies with European standards and is certified.

Figure 6.16 High-precision air monitoring station in Kyiv
Source: https://kyivcity.gov.ua/

Dust in three fractions ($PM_{1.0}$, $PM_{2.5}$ and PM_{10}), nitrogen oxides (NO, NO_2, NO_x), carbon monoxide (CO), sulphur dioxide (SO_2), ozone (O_3), benzene (C_6H_6) as well as meteorological parameters are measured in automatic mode. All data are recorded minute by minute, stored on the server and displayed in a user-friendly format on the website: asm.kyivcity.gov.ua.

However, to date, utility monitoring networks are not coordinated, the equipment being installed is disparate, and data collection methodologies and indicators are not consistent with the Ministry of Environment, making it difficult to utilise such data at the national level.

Observation post (point) is a pavilion specially equipped for automatic recording of pollutant levels or air sampling for pollutant content, equipment for measuring meteorological parameters (ambient temperature, atmospheric pressure, humidity, wind direction and strength), as well as supporting equipment, in particular for heating and air conditioning.

The operation of the observation post shall be ensured continuously, except for periods defined for calibration and/or maintenance operations.

Modern automatic observation stations should be equipped with analysers for $PM_{2.5}$ and PM_{10} particulate matter, sulphur dioxide, nitrogen oxides, carbon monoxide, ground-level ozone, volatile organic compounds and sensors for wind speed, atmospheric pressure, air temperature and humidity.

The cost of such an item is about UAH 8-12 million per unit, depending on the list of parameters to be measured.

6.6 Key stages of modernisation of the national air monitoring system

According to a report by international experts [16], it is recommended to upgrade the air monitoring system in stages.

At the first stage, within the framework of a pilot project, it is recommended to start with measurements of selected priority pollutants in different types of areas depending on the priority source of pollution (urban background, traffic, industry).

One of the reasons for using a staged approach is to create conditions for the personnel of monitoring subjects to familiarise themselves with new measurement techniques and technologies, as well as to acquire the skills necessary to work with automated observation points, and to start procedures for ensuring and controlling data quality in the newly established observation networks.

Pollutants from Lists A and B that can be measured automatically at the first stage of modernisation include: SO_2, H_2S, NO_2, PM_{10}, $PM_{2.5}$, O_3, CO, VOCs (volatile organic compounds with carbon as the main component), trace elements and surface-active substances.

After getting acquainted with the new automatic measurements, it is recommended to start expanding the network of automatic observations, which will continue during the second and third stages of modernisation.

Another element of the air monitoring system in accordance with EU legislation is the functioning of the national reference laboratory as part of the data quality assurance and control system.

As noted in the above-mentioned report of international experts on the results of the analysis of compliance of the existing national air monitoring system with the requirements of the EU Air Quality Directives, the quality of air pollution data is crucial for reliable analyses of air pollution levels, health effects and planning of pollution reduction measures.

The establishment of a national reference laboratory is a complex task and is recommended only after gaining some experience in the use of automatic instruments and measurement methods that meet the requirements of the EU air quality directives.

The reference laboratory is recommended to be established at the second stage of modernisation. The cost of setting up a national reference laboratory in accordance with EU Directives is estimated at €1.5 million.

In addition to the above, an important element of the modern air monitoring system is the system for collecting and processing monitoring data, which includes a database on air quality throughout the country.

The national database should contain all verified air quality data. It is proposed to create a procedure in Ukraine, whereby observation networks (local, industrial) will be responsible for verifying data in their own network and for sending verified automatic data to the central database.

Manual results will be periodically sent to the database from the chemical laboratory(s). The air quality database should be connected to software that includes tools for publishing real-time air quality data on the Internet.

The authority responsible for administering the national database should also ensure that air quality is assessed annually (for exceedances of limit values based on verified data), that air quality is reported and that relevant information is disseminated to public authorities, zone or agglomeration authorities and other stakeholders for further action.

6.7 International approaches to air quality monitoring. Air Quality Index (AQI)

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 key air quality indicators along with meteorological monitoring;

● Availability of a system for collecting, analysing and transmitting data on air quality;

● A strategy for maintaining and developing the monitoring system;

● Availability of communication tools on the state of air quality.

CAMS is one of the six services that make up Copernicus, the European Union's Earth observation programme. The main concept of Copernicus is to provide information on air quality and atmospheric composition within and outside Europe based on satellite and ground observations combined with forecasting models.

Copernicus provides data to users through various services. These include the Climate Change Service (C3S) and the Atmospheric Monitoring Service (CAMS), both operated by the European Centre for Medium-Range Weather Forecasts (ECMWF).

The main objectives of Copernicus atmosphere monitoring are:

- description of the current situation;
- forecasting the situation for several days ahead;
- analysis of consistent retrospective data for recent years.

The service supports many applications in a variety of fields, including environmental monitoring, healthcare, meteorology and climatology, renewable energy.

CAMS services are focused on five main areas:

1. Air quality and atmospheric composition;
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 (such as carbon monoxide, oxidised nitrogen compounds, sulphur dioxide), ozone and aerosols;
- provides practical real-time analysis and 4-day forecasts, as well as reanalysis of European air quality, allowing us to continuously assess the air we breathe;
- provides public and private organisations involved in the use of solar energy with relevant and accurate information about solar radiation resources on the Earth's surface, which is important in areas such as healthcare, agriculture and renewable energy.

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

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

7) SILAM with FMI (Finland).

In addition to these, there is also the ENSEMBLE model, which is a combination of all the above models. Data from this model is available for the whole of Europe.

CAMS is implemented by the European Centre for Medium-Range Weather Forecasts (ECMWF) on behalf of the European Commission. ECMWF is an international, independent organisation supported by 34 countries. It is both a research institute and a round-the-clock operational service that produces and disseminates numerous weather forecasts for its member countries.

CAMS can also provide forecast 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.

Air quality information is assessed using the European Air Quality Index, which is defined by the EEA.

Air Quality Index (AQI) is used by government agencies to communicate to the public how polluted the air currently is or how polluted it is forecast to become. Public health risks increase as the AQI rises. Different countries have their own air quality indices, corresponding to different national air quality standards.

EPA (U.S. Environmental Protection Agency) calculates the AQI for five major air pollutants regulated by the Clean Air Act: ground-level ozone, particle pollution (also known as particulate matter), carbon monoxide, sulfur dioxide, and nitrogen dioxide. For each of these pollutants, EPA has established national air quality standards to protect public health.

To make it easier to understand, the AQI is divided into six categories:

Air Quality Index (AQI) Values	Levels of Health Concern	Colors
When the AQI is in this range:	*..air quality conditions are:*	*...as symbolized by this color:*
0 to 50	Good	Green
51 to 100	Moderate	Yellow
101 to 150	Unhealthy for Sensitive Groups	Orange
151 to 200	Unhealthy	Red
201 to 300	Very Unhealthy	Purple
301 to 500	Hazardous	Maroon

Figure 6.17 The air quality index includes AQI categories and colours, corresponding index values and warnings for different levels of health hazard

Source: https://www.epa.gov/

Each category corresponds to a different level of health concern. The six levels of health concern and what they mean are:

"Good" AQI is 0 to 50. Air quality is considered satisfactory, and air pollution poses little or no risk.

"Moderate" AQI is 51 to 100. Air quality is acceptable; however, for some pollutants there may be a moderate health concern for a very small number of people. For example, people who are unusually sensitive to ozone may experience respiratory symptoms.

"Unhealthy for Sensitive Groups" AQI is 101 to 150. Although general public is not likely to be affected at this AQI range, people with lung disease, older adults and children are at a greater risk from exposure to ozone, whereas persons with heart and lung disease, older adults and children are at greater risk from the presence of particles in the air.

"Unhealthy" AQI is 151 to 200. Everyone may begin to experience some adverse health effects, and members of the sensitive groups may experience more serious effects.

"Very Unhealthy" AQI is 201 to 300. This would trigger a health alert signifying that everyone may experience more serious health effects.

"Hazardous" AQI is greater than 300. This would trigger a health warnings of emergency conditions. The entire population is more likely to be affected.

The European Air Quality Index. Index is calculated for the five most important air pollutants regulated by European legislation: O_3 (ozone), NO_2 (nitrogen dioxide), SO_2 (sulphur dioxide), $PM_{2.5}$ and PM_{10} (suspended particles with diameters less than 2.5 micrometres and 10 micrometres respectively). For each pollutant, the index value ranges from 1 (good) to 5 (very bad).

The European Air Quality Index is calculated for different air pollutants separately by concentration (depending on the air pollutant, on a daily average or instantaneously): the higher the concentration, the higher the index. The European Air Quality Index is represented by an integer number corresponding to five concentration ranges specific to each pollutant.

The total hourly European Air Quality Index is defined as the highest value of five individual pollutant indices calculated over the same time period. For example, if the indices for O_3, NO_2, SO_2, $PM_{2.5}$ and PM_{10} are 1, 3, 1, 2, 2 respectively, the average index would be three.

The total daily European Air Quality Index is the highest value of the total hourly European Air Quality Index for the respective day. The overall daily European Air Quality Index is used in the news on Euronews.

<u>United Kingdom</u>. The most commonly used air quality index in the UK is the Daily Air Quality Index.

This index has ten points, which are further grouped into four bands: low, moderate, high and very high. Each of the bands comes with advice for at-risk groups and the general population.

Currently, there is no air quality standard (AQI) <u>in Ukraine</u>. Nevertheless, Ukrainians have access to a growing number of networks and apps with information on the air quality index and air pollution levels, including SaveEcoBot, EcoCity, AccuWeather, Waqi.info, and others.

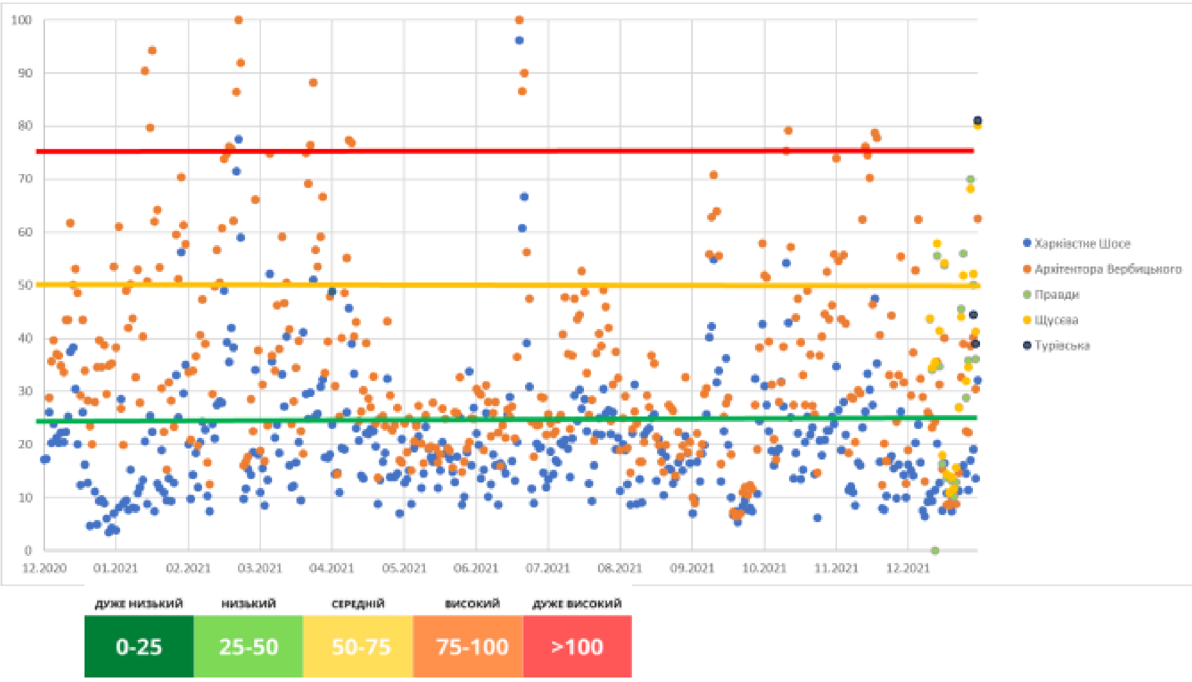


Figure 6.17 Dynamics of atmospheric air quality in Kyiv in the period from 01.01.2021 to 31.12.2021 (according to the common air quality index CAQI)

Source: Report on the state of the natural environment in the city of Kyiv for 2021

For example, the map of air pollution is available in real time with the main indicators, namely $PM_{2.5}$ and PM_{10} particulate matter, ozone, CO_2, SO_2, etc. on Waqi.info. These maps also take into account meteorological indicators that affect the migration of pollutants in the ambient air.

Another example of application of a comprehensive indicator of atmospheric air condition is the so-called Common Air Quality Index (CAQI), which is formed automatically on the basis of indicators of several major pollutants: $PM_{2.5}$ and PM_{10} (dust particles), SO_2 (sulphur dioxide), NO_2 (nitrogen dioxide), O_3 (ground-level ozone), CO (carbon monoxide). The lower the CAQI, the better the air quality.

This indicator is used in particular in the municipal network of air quality monitoring points in Kyiv. Air quality data can be monitored in real time on the online map at http://asm.kyivcity.gov.ua/ and in the Kyiv Digital mobile application.

Questions for self-control

1. Name several major components of dry clean air in ground atmospheric layer in a descending order.

2. Air pollution includes contaminants in the form of ***...*** or ***...*** (fill in the missing words).

3. What are the two air pollutants that most significantly affect human health? In what way they affect human health?

4. What kinds of anthropogenic sources of air pollution do you know?

5. What kinds of natural sources of air pollution do you know?

6. What determines the situation with air quality in Ukraine?

7. The highest concentrations are observed of particulate matter ($PM_{2.5}$ and PM_{10}) in Ukraine are observed in:

a. around urban areas;

b. industrial region of eastern Ukraine;

c. in areas of intense military operations.

8. What are the main effects of war and intense armed hostilities on air quality?

9. What are the main features of the Procedure for monitoring in the field of atmospheric air protection?

10. What is the list of atmospheric air quality and precipitation indicators for pollutants for which atmospheric air is monitored?

11. Monitoring of atmospheric air and subsequent management of its quality is carried out in accordance with the division of the territory of Ukraine into ... and ... (fill in the missing words).

12. Depending on the level of air pollution (exceeding certain assessment thresholds) by a particular pollutant from List A, the following regimes are applied:

a. mode of fixed measurements;

b. mode of manual sampling;

c. mode of combined estimation;

e. mode of modelling or objective assessment.

13. When can the monitoring programme be supplemented with pollutants from the List B?

14. What functions in the field of air monitoring are assigned to the SES?

15. What new elements should be created to bring the national air monitoring system in line with EU legislation?

16. What is the Air Quality Index used for? Does the calculation of this index differ from country to country?

7. THE STATE WATER MONITORING

7.1 Water resources in Ukraine;

7.2 The concept of water security;

7.3 Legal basis and peculiarities of state water monitoring in Ukraine;

7.4 Network and observation posts for water monitoring;

7.5 Methodological basis for water quality assessment;

7.6. Specific aspects of marine water monitoring;

7.7 European policy in the field of sea water quality and monitoring;

7.8 Water quality index.

Water is a scarce and incredibly valuable resource that is essential for sustaining life as well as agricultural and industrial development.

The protection and ecological rehabilitation of water resources is one of the priorities in environmental policy. In the second half of the last century and at the beginning of this century, a number of unresolved water-related problems were continuously growing.

Every year, water consumption is increasing, and a decline in its quality has a significant impact on human health.

7.1 Water resources in Ukraine

In Ukraine, there are water bodies of national and local importance.

Water bodies of national importance include:

1) inland sea waters, territorial sea, as well as seaport areas;

2) groundwater, which is a source of centralised water supply;

3) surface waters (lakes, reservoirs, rivers, canals, except for canals on irrigation and drainage systems), as well as their tributaries of all orders, located and used on the territory of more than one oblast;

4) water bodies within the territories of the natural reserve fund of national importance, as well as categorised as therapeutic.

Water bodies of local significance include:

1) surface waters that are located and used within one region and are not classified as water bodies of national importance;

2) groundwater that cannot be a source of centralised water supply.

Surface fresh water bodies of Ukraine cover 24.1 thousand square kilometres or 4.0 % of the total territory (603.7 thousand square kilometres) of the state. These objects include rivers, lakes, reservoirs, ponds, canals, etc.

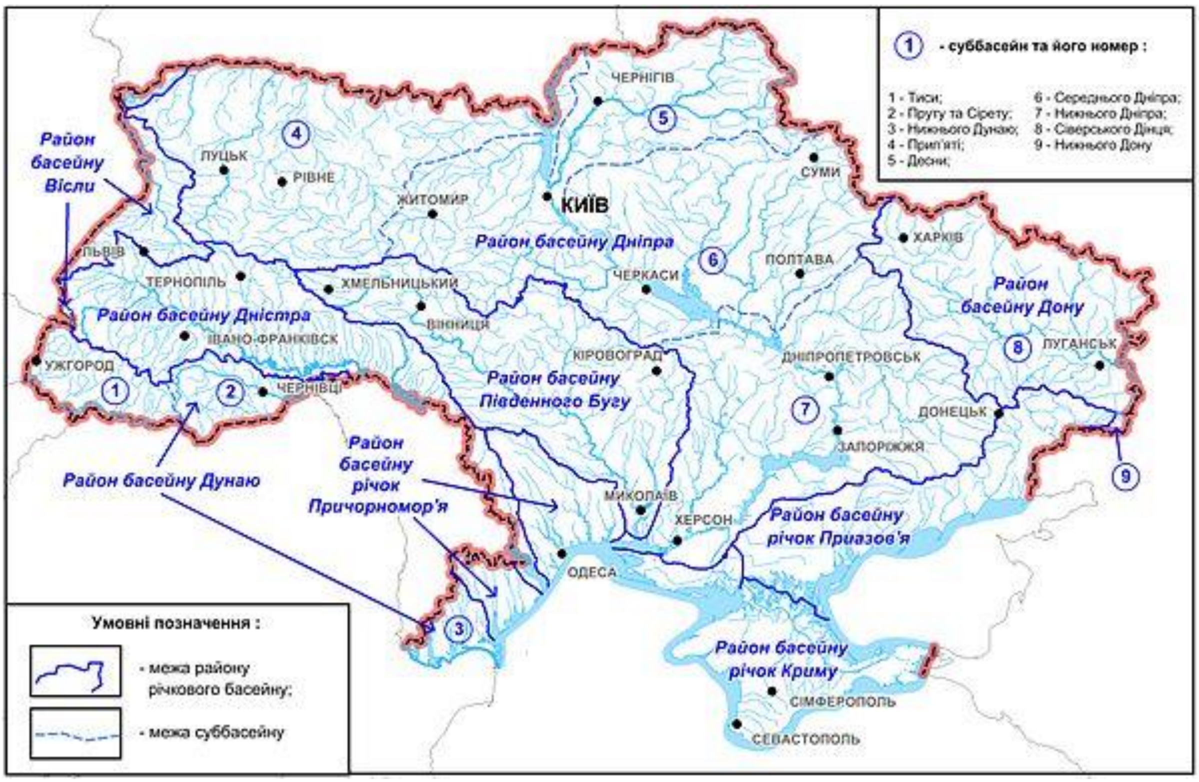


Figure 7.1 Hydrographic zoning of Ukraine

There are 9 river basin districts in Ukraine: Dnieper, Dniester, Danube, Southern Bug, Don, Vistula, rivers of Crimea, rivers of the Black Sea region, rivers of the Azov region. Within the established areas of river basins, sub-basins can be distinguished. A sub-basin is a part of a river basin from which water runoff is carried out through connected water bodies and watercourses to the main river of the basin or a water management area downstream.

Geographically, almost all river basins (with the exception of the Southern Bug) belong to international water bodies - a fact that implies transboundary water ecological relations and the need for accelerated development of basin management of water resources.

Table 7.1 Renewable surface water resources by major river basin
Source: http://www.fao.org/nr/water/aquastat/countries_regions/UKR/

Name of basin	% part of country area	Internal RSWR	Inflow		Total RSWR	Outflow to:
		million m³/year	million m³/year	from	million m³/year	
Dnipro (Dnieper)	65	20 400	24 700 *	Belarus; Russian Fed.	45 100	Black Sea
Dniester	12	9 200	10 120	Republic of Moldova	19 320	Black Sea
Coastal	7	3 100	110	Republic of Moldova	3 210	Black Sea
Danube	7	9 400 **	84 050 ***	Border with Romania	93 450	Black Sea
Donets	4	2 700	1 200	Russian Federation	3 900	Russian Fed.
Southern Bug	3	3 400	-		3 400	Black Sea
Western Bug+ San	2	1 900	-		1 900	Poland
Total	**100**	**50 100**	**120 180**		**170 280**	

* *Dnieper from Belarus: 24 500 = 31 900 minus 7 400 of Pripyat, which enters already from UKR to BLR*
Dnieper from Russian Federation: 200 (Desna, branch of Dnieper)
** *Cisa + Prut*
*** *Total flow of border river 168 100, accounted 50 percent = 84 050*

In total, Ukraine has 63119 rivers, including 9 large rivers (with catchments of more than 50 thousand square kilometres), 81 medium-sized rivers (from 2 to 50 thousand square kilometres), and 63029 small rivers (less than 2 thousand square kilometres). Their total length is 206.4 thousand square kilometres, of which 90% are small rivers.

In order to provide the population and sectors of the economy with the necessary quantity of water, Ukraine has built 1,103 reservoirs with a total volume of more than 55 billion cubic metres and about 48,000 ponds, 7 large canals with a length of 1,021 kilometres and a supply of 1,000 cubic metres of water per second, and large-diameter aqueducts that deliver water to low-water regions of Ukraine.

A relatively small part of the territory is occupied by swamps, marshlands and wetlands - 3.6 million hectares - but they play an important stabilising role.

Local water resources, that is formed within Ukraine, amount to 52.4 cubic kilometres of average annual water volume.

Water resources are distributed over the territory of the country very unevenly. There are more resources in the north and less in the south, where major water consumers are located.

Ukraine also has groundwater reserves. The total amount of projected usable groundwater resources in the country reaches up to 57.2 million cubic metres per day. However, the territorial distribution of groundwater is uneven.

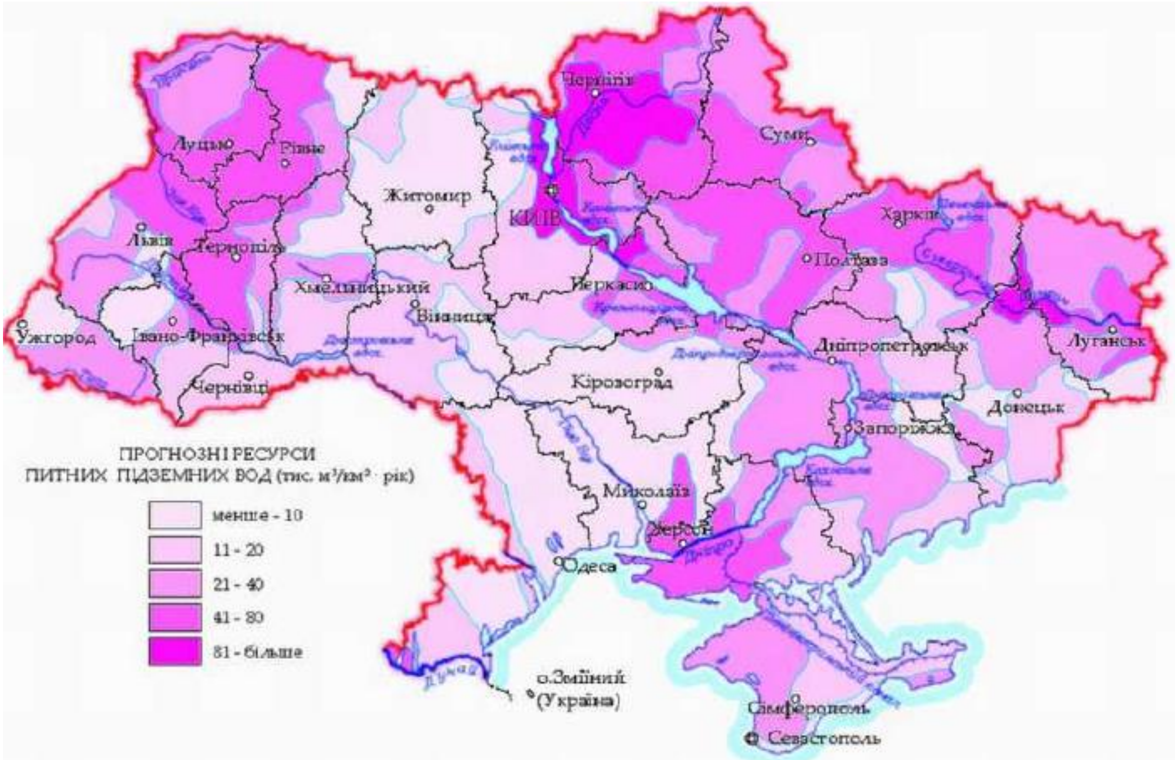


Figure 7.2 Estimated resources of potable ground water in Ukraine

Judging by the amount of water per capita, Ukraine belongs to countries with insufficient water resources, according to international standards.

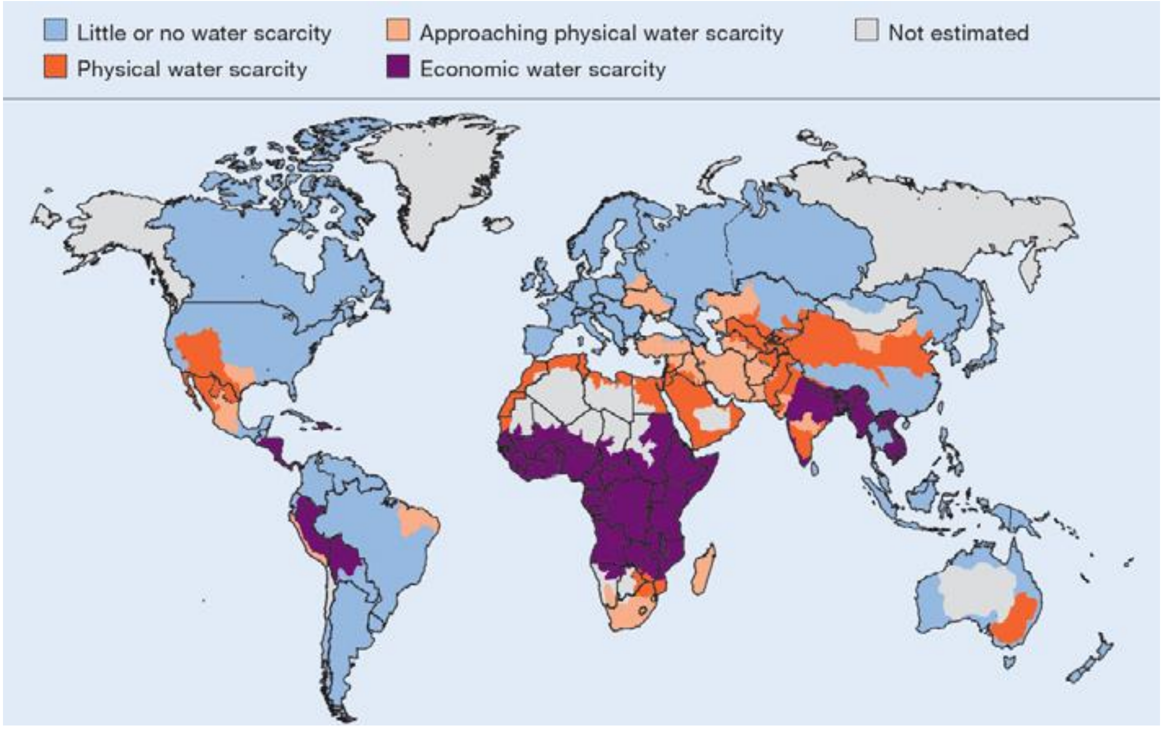


Figure 7.3 Global water scarcity map

Source: Comprehensive Assessment of Water Management in Agriculture

Among 152 countries, Ukraine ranks 111th in terms of domestic freshwater resources per capita.

Due to the limited water resources and the specifics of their distribution, river flows are heavily regulated. Reservoirs and ponds collectively hold about 58 billion cubic metres of water, which is more than the local runoff of all the country's rivers.

The regulation of flow in majority of Ukrainian rivers has reached and even exceeded the highest economically and environmentally sound limits. The Dnipro reservoir cascade accounts for most of Ukraine's regulated runoff.

Such regulation has dramatically reduced and often completely destroyed the ability of rivers to self-purification. In addition, many reservoirs (more than 1,100) and ponds (about 28,000) have caused an increase in the water table over large areas, as well as changes in groundwater systems.

Water use in Ukraine has a multifaceted approach to the use of water resources. Consumer properties of water resources determine the possibility of their complex and integrated use by many sectors of the economy. The major consumers of water in Ukraine are households, agriculture and industry.

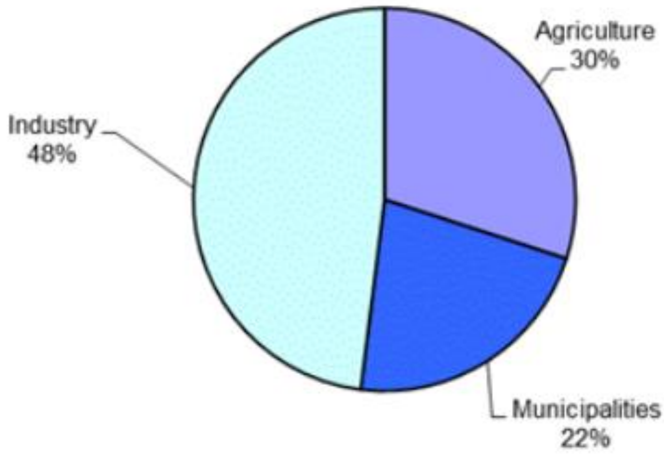


Figure 7.4 Water withdrawal by sector
Source: http://www.fao.org/nr/water/aquastat/countries_regions/ Profile_segments/UKR-WU_eng.stm

The water consumption structure data analysis and the water supply and drainage system basic parameters dynamics, as well as the data on water quality dynamics, have shown that water use structure does not address the peculiarities of forming and territorial-time dividing the country’s water resources and causes the creation of catastrophic situations within the population’s water supply and economic entities for quantitative and qualitative indicators.

The situation with water use is intense and further development will not be possible if new stresses are added.

Surface waters are much polluted, with the chief pollutants being poisonous chemicals, oil products, heavy metallic salts, phenols, and biogenic elements.

The connection of surface water pollution with economic activity in the past 10-12 years breaks down as follows: 60-65% is due to industry; 16-20% to agriculture; 18-20% to communal activity; and around 1% to various spread-out contamination sources.

In the current structure of the processes of underground water pollution of Ukraine’s territories, two levels are distinguished:

• almost complete pollution of subsoil waters (first from the day’s surface water horizon), by remnants of mineral fertilizers, pesticides, heavy metals, oils, etc.;

• local pollution of the first urgent and deeper horizons of the active water cycle zone as a result of accelerated pollution migration under the influence of operating water off takes, mines, etc.

In the context of the full-scale war that has been going on for more than a year, water quality is a serious issue that requires special attention. Because of the war, Ukrainian water resources cannot perform their functions. Regular shelling has worsened the quality of water in Ukraine. According to the Ministry of Environment, all hazardous substances from explosions and mine detonations as well as military artillery fall into the Dnipro River. In addition, mass graves infiltrate and contaminate groundwater. In some regions, people do not have access to fresh clean water because they do not have proper water filters.

The war on the territory of Ukraine poses an immediate threat to neighbouring countries. All the chemicals that flow into the Dnipro River then end up in the Black and Azov Seas. In addition, military operations in the Black Sea led to the sinking of ships and leakage of oil. As a result, pollution spreads across the seas and reaches neighbouring countries.

7.2 The concept of water security

Water security is ensured access to sufficient quantity and acceptable quality water for all: for people, the economy and nature.

According to UN-Water (UN-Water coordinates the efforts of UN entities and international organizations working on water and sanitation issues), water security is defined as the capacity of a population to safeguard sustainable access to adequate quantities of acceptable quality water for:

• sustaining livelihoods, human well-being, and socioeconomic development,

• ensuring protection against water-borne pollution and water-related disasters, and

• for preserving ecosystems in a climate of peace and political stability.

The key challenges to ensure water security for people in Ukraine are [47]:

1) challenges of water availability because of:

- natural water scarcity, climate change and extreme weather events (floods, droughts, heat waves, etc.) that affect both the water availability and water quality;

- anthropogenic impacts or inefficient management of available water resources, leading to depletion and contamination of water resources;

2) problems of equal access to drinking water and sanitation for the population: the growing geographical, social and economic inequalities of different groups of consumers.

3) problems regarding the quality of drinking water due to:

- poor quality of water in the sources (surface water, mainly, Dnipro River is a source of drinking water for 80 % of population of Ukraine, rivers flow regulated by dams, contaminated by organic compounds, nutrients and pollutants, sediments and eutrophication);

- outdated technology of water treatment and wastewater treatment;
- insufficient technical condition of the infrastructure and networks;
- a significant weakening of state control over the quality of water sources and drinking water.

4) Accessibility of water supply and sanitation services is becoming crucial. In a country where experts estimate that there are more than 70 per cent of households who cannot pay their utility bills, including water supply and sanitation, there is a real threat to ensuring the human right to water supply and sanitation and the destruction of water and sanitation, service delivery.

7.3 Legal basis and peculiarities of state water monitoring in Ukraine

In Ukraine, national activities in the field of water quantity and water quality monitoring are regulated by the Water Code of Ukraine, the Law on Environmental Protection, the Law on Hydrometeorological Activities, the Law on Amendments to Certain Legislative Acts of Ukraine Concerning the Implementation of Integrated Approaches in Water Resources Management Based on the Basin Principle as well as a number of resolutions of the Cabinet of Ministers of Ukraine and orders of ministries and agencies.

But in general, until recently, the actual quantity of surface water and water quality control systems in Ukraine were inherited from the former Soviet Union.

In 2014, Ukraine signed the Association Agreement between Ukraine and the European Union. According to this Agreement, Ukraine had to adapt its water legislation to six EU Directives:

- Directive 2000/60/EC establishing a framework for the Community action of water policy (Water Framework Directive);

- Directive 2008/56/EC establishing a framework for community action in the field of marine environmental policy (Marine Strategy Framework Directive);

- Directive 91/676/EEC concerning the protection of waters against pollution caused by nitrates from agricultural sources (Nitrates Directive);

- Directive 98/83/EC on the quality of water intended for human consumption (Drinking Water Directive);

- Directive 91/271/EEC concerning urban waste-water treatment (Urban Waste Water Directive);

- Directive 2007/60/EC on the assessment and management of flood risks (The Floods Directive).

A great deal of work has been done in this area, and it is necessary to note the positive changes in the field of state water monitoring that have taken place over the past few years.

In particular, in October 2016, Ukraine adopted a new Water Code, according to which a new advisory body, the Basin Council, was to be established in accordance with European legislation and Ukraine's obligations under the Association Agreement.

Ukrainian legislation in the field of water monitoring also includes:

Resolutions of the Cabinet of Ministers of Ukraine:

On Approving the Procedure for the Development of River Basin Management Plans dated 18.05.2017 № 336;

On Approval of the Procedure of State Monitoring of Water Resources dated 19.09.2018 № 758;

On Approval of the Marine Environmental Strategy of Ukraine dated 11.10.2021 № 1240-р.

Orders of the Ministry of Environmental Protection and Natural Resources of Ukraine:

- On Identification of Sub-Basins and Water Management Units within the Established River Basin Districts;

- On Delineation of River Basin Districts, Sub-Basins and Water Management Units;

- On Approving the Procedure for the Development of Water Balances;

- On Approving the List of Pollutants for the identification of the Chemical Condition of Surface and Groundwater Bodies;

- On Approving the Model Regulation on River Basin Councils.

The new procedure of the programme for water monitoring, approved by the Cabinet of Ministers of Ukraine in 2018, came into force on 1 January 2019. This procedure is harmonised with EU directives and helps to obtain more detailed information on the state of water in the country.

State water monitoring is carried out in order to collect, process, store, summarise and analyse information on the state of water bodies, forecast its changes and develop scientifically based recommendations for decision-making in the field of water use, protection and reproduction, and is an integral part of the state environmental monitoring system.

Key differences and advantages of the new monitoring procedure:

1. Monitoring is in line with the basin principle of river management, that is, assessment of the status is carried out for the whole basin rather than for a section of the river within the administrative unit.

At the legislative level, integrated water resources management based on the basin principle was introduced back in 2016 and, as already mentioned, Basin Councils (river basin management bodies) and River Basin Management Plans have been established.

Having analysed the condition of the whole river with tributaries, streams, estuaries and so on, we will be able to choose necessary measures for river restoration, because the basin principle of water resources management also implies that the financial mechanism guarantees a direct link between payment for water use and financing of priority water protection measures within the basin.

Currently, there are 13 active Basin Councils in Ukraine according to the number of geographical basins of large rivers. Their working procedures are taken from European experience.

Figure 7.5 Formation of basin councils in Ukraine

2. Before the reform, monitoring concerned the whole river, i.e. several measurements were carried out either in the head of the river or after settlements, and the results were attributed to the whole river. Now monitoring is done for each individual water body.

3. There used to be one standard for all rivers - mountain rivers. For example, rivers on the plains are often brown in colour due to the presence of humic acid, so they were assessed as dirty, although in fact this is the norm for these rivers. Another aspect of comparing rivers - not with each other, as before, but the same river basin with itself - in dynamics.

4. The old monitoring took into account a small number of indicators, mostly chemical, some of which in general were not significant. The new procedure has 45 priority pollutant substances, the absolute novelty is biological indicators, hydromorphological and those specific to this particular basin. It is also important that different indicators are applied to surface, groundwater and sea water.

5. Under the old methodology, there was no classification of the status of the river as a whole, because data assessment tools existed only for parameters, so it was difficult to draw any conclusions from monitoring. Now there are 5 classes of ecological status, and 2 classes of chemical status of the water body. All standards are similar to those working in the EU.

6. The new monitoring system provides for a clear division of responsibilities between the organisations measuring indicators without duplication of powers. The Ministry of Environment fulfils the function of construction and coordination of work.

7. It is planned to increase the number of water monitoring posts from hundreds to several thousand.

8. A six-year monitoring cycle was introduced.

Also, the Procedure for State Water Monitoring provides for the authority of the Ministry of Natural Resources to develop, taking into account the proposals of subjects of state water monitoring, and approve programmes for state water monitoring.

The Ministry of Environment approved the "On Approval of State Water Monitoring Programmes" by Order No. 410 dated 31.12.2020:

1) The State Water Monitoring Programme (in terms of diagnostic and operational monitoring of surface waters);

2) The State Water Monitoring Programme (in terms of diagnostic monitoring of coastal and marine waters of the Black and Azov Seas)

The State Water Monitoring Programme (in terms of diagnostic and operational monitoring of surface waters) also defines the scope of monitoring works for the State Emergency Service, the State Water Agency and the State Agency of Ukraine on Exclusion Zone Management, which indicates the beginning of proper coordination over the process of implementation of state water monitoring.

At the same time, the Procedure for State Water Monitoring does not provide for the preparation of national monitoring programmes, because the object level of such programmes is the districts of river basins (or their sub-basins).

The following *monitoring sub-spheres* have been identified as part of the implementation of water monitoring:

● monitoring of surface water bodies (in addition to rivers and lakes, includes significantly modified water bodies, transitional waters and coastal waters, which are the subject of river basin management plans): depending on the monitoring objectives, provides for observations of hydromorphological, hydrobiological characteristics of surface water bodies, quantitative and qualitative parameters of physico-chemical, ecological and chemical status of water, chemical characteristics of suspended solids, bottom sediments, biota, etc.;

● monitoring of groundwater bodies: involves observation of quantitative parameters of groundwater and characteristics of its chemical status);

● monitoring of marine waters: depending on the monitoring objectives, it involves observations of hydrobiological characteristics of the state of the marine environment (territorial sea and exclusive maritime economic zone of Ukraine), ecological and qualitative state of water, chemical characteristics of suspended substances, bottom sediments, biota, etc.).

Depending on the goals and objectives of state water monitoring, the following *procedures* are established:

- ***procedure of diagnostic monitoring*** of surface and groundwater bodies (carried out to determine the main anthropogenic impacts on the state of water bodies, assessment of changes caused by anthropogenic factors, and further development of the state water monitoring programme). Diagnostic monitoring is carried out every six years, or more frequently when necessary, and may cover a much wider list of pollutants than those specified in Annex 1 to the Procedure;

- ***procedure of operational monitoring*** of surface and groundwater bodies (carried out for water bodies where there is a risk of failure to achieve environmental objectives, as well as water bodies from which water is withdrawn to meet the needs of the population in the amount of 100 cubic metres per day). Operational monitoring is carried out continuously for such indicators that pose a threat to the aquatic ecosystem and have been detected as a result of diagnostic monitoring;

- ***procedure of research monitoring*** of surface water bodies (carried out for surface water bodies in order to establish the causes of deviation from environmental objectives, to clarify the scale and consequences of accidental water pollution and to establish the causes of the risk of failure to achieve ecological purposes). In other words, research monitoring is carried out depending on the needs of public administration;

- ***procedure for marine water monitoring***, the purpose of which is to determine the ecological status of marine waters, establish reference conditions for marine waters, assess progress towards the achievement of established environmental objectives, and evaluate trends in long-term natural and anthropogenic changes in the state of marine waters.

Diagnostic, operational and research monitoring is carried out according to the basin principle.

The results of the state water monitoring are:

- ✓ primary information (observation data) provided by the subjects of state water monitoring;
- ✓ generalised data relating to a certain period of time or a certain territory;
- ✓ assessment of ecological and chemical status of surface water bodies, ecological potential of artificial or significantly altered surface water bodies, quantitative and chemical status of groundwater bodies, ecological status of marine waters and identification of sources of negative impact on them;
- ✓ forecasts of water status and its changes;
- ✓ science-based recommendations necessary for management decision-making in the field of water use and protection and reproduction of water resources.

Based on data and information obtained as a result of state monitoring of surface water bodies and groundwater bodies, they determine the ecological and chemical status of surface water bodies, the ecological potential of artificial or significantly altered surface water bodies, and the quantitative and chemical status of groundwater bodies, which is used to develop river basin management plans and assess the level of achievement of environmental objectives.

The subjects of state water monitoring are the Ministry of Environment, the State Water Agency, the State Geological Survey and the State Emergency Situations Service.

Without being identified as subjects of water monitoring, a number of agencies should provide the subjects of state water monitoring with data obtained from the results of such monitoring or supervision (control) on a monthly basis free of charge. In particular:

The State Fishery Agency provides the subjects of state water monitoring with information on state monitoring of aquatic bioresources in fishery water bodies (or their parts).

StateGeoCadastre provides topographic, geodesic and cartographic information and geospatial data to the subjects of state water monitoring according to the procedure determined by legislation.

SSAU provides the subjects of state water monitoring with archived and operational aerospace information from remote sensing of the Earth on the territory of Ukraine.

The Ministry of Health also conducts monitoring research for terrestrial surface waters and drinking water quality control, determining chemical, bacteriological, radiological and virological parameters.

Table 7.2 Groups and number of safety parameters of drinking water

Source: ДСанПіН 2.2.4-171-10

Групи показників	Підгрупи	Кількість показників
епідемічної безпеки		11
	мікробіологічні	9
	паразитологічні	2
санітарно-хімічні		25
	органолептичні	4
	фізико-хімічні	21
	неорганічні компоненти	18
	органічні компоненти	3
санітарно-токсикологічні		39
	неорганічні компоненти	25
	органічні компоненти	12
	інтегральний показник	2
радіаційні		8
фізіологічної повноцінності		9

The Ministry of Health has a fairly high level of capability in instrumental analyses of fresh and sea water. For surface waters (fresh and sea waters) laboratory centres of the Ministry of Health carry out analytical measurements of 11 physico-chemical characteristics and 36 parameters of pollutants. The capacity of the Ministry of Health laboratory centres to analyse groundwater is lower: 7 physico-chemical characteristics and 5 pollutants.

The State Agency for Water Resources of Ukraine carries out:

- monitoring of water quality in water management systems of inter-sectoral and agricultural water supply;
- monitoring of water quality of water bodies by radiological indicators on the territories subjected to radioactive contamination;
- monitoring of water quality at transboundary watercourse sections identified in accordance with intergovernmental agreements on co-operation on transboundary water bodies;
- state water monitoring in accordance with the procedure approved by the Cabinet of Ministers of Ukraine.

Currently, the State Water Resources Agency has subsystems for: 1) surface water monitoring and 2) irrigated and drained lands.

According to the State Environmental Monitoring Programme in terms of radiological and hydrochemical observations of surface water conditions in control sections, approved by the State Water Agency's Order No. 14 dated 10 February 2015, the State Water Agency monitors water quality by physical and chemical indicators at 436 observation points, including 67 points at drinking water intakes, and 217 points for radionuclide content in water.

Instrumental measurements are carried out by 27 laboratories. Every year, about 4,000 samples are taken from Ukrainian water bodies for instrumental and laboratory measurements.

Order of the Ministry of Environment dated 06.02.2017 No. 45 "On approval of the List of pollutants for determining the chemical state of surface and groundwater bodies and the ecological potential of artificial or significantly altered surface water bodies" defines 45 priority pollutants for surface waters (there are 58 in total, with detailing of cyclodiene pesticides, polyaromatic hydrocarbons, etc.). Of the above list of 58 ingredients, the State Water Agency monitors 13 of them, representing 22.4 per cent of capacity.

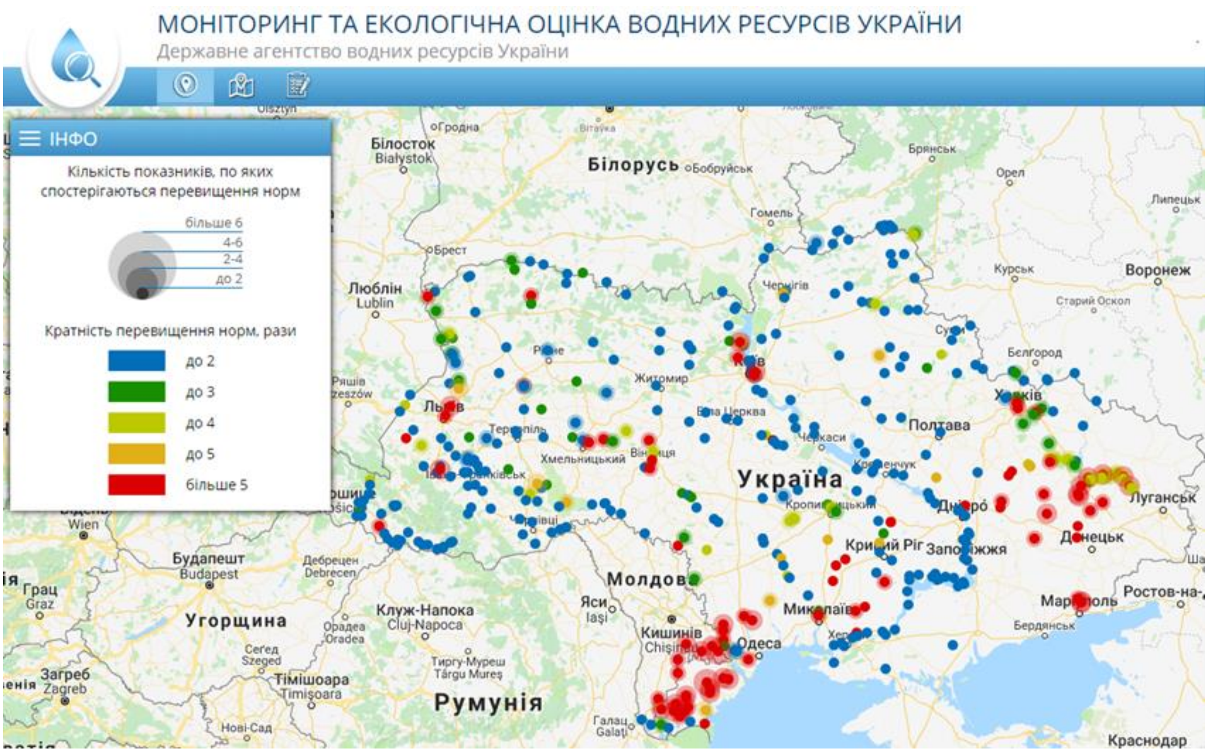


Figure 7.6 Water monitoring network of the State Water Resources Agency and assessment of water quality as of 2019

Source: http://monitoring.davr.gov.ua/EcoWaterMon/GDKMap/Index

Of the list of 16 chemical and physico-chemical indicators, laboratories of the State Water Agency monitor 13 (81.2%), in addition, they carry out detailed analysis of macro-component composition of water (for 6 parameters), as well as monitor 20 indicators not specified in the annexes to the Procedure for State Water Monitoring.

Observations of ground water levels on reclaimed lands and in rural settlements are carried out using about 32,000 observation wells on the area of 2.26 million hectares of irrigated and 2.96 million hectares of drained agricultural lands.

In addition to this, the State Water Agency maintains governmental accounting of surface waters in terms of accounting of surface water bodies and maintains the State Water Cadastre under the sections "Surface Water Bodies" and "Water Use".

Maintaining of the governmental accounting and the State Water Cadastre is stipulated by Chapter 6 of the Water Code of Ukraine. The State Water Cadastre is a systematised set of data on surface waters, groundwater, inland sea waters and territorial sea, as well as volumes, regime, water quality and water use, and also water users (except secondary water users).

The task of governmental water accounting is to establish data on water quantity and quality, as well as data on water use, on the basis of which water is distributed among water users and measures for rational use and protection of water and reproduction of water resources are developed.

The State Geological Survey of Ukraine monitors groundwater (resources and use). 95% of the observation network of the state groundwater monitoring is formed by wells drilled at the level of different aquifers, as well as springs, and less often wells.

As of 01.01.2021, it consisted of 846 observation points, including 272 observation points for groundwater, 203 observation points for interlayer water, and 371 observation points at the reference sites for studying the conditions for the formation of operational groundwater reserves (Fig. 7.7)

Groundwater monitoring is carried out throughout the territory of Ukraine using the database of the automated information system of the State Water Cadastre "Groundwater" created in the State Research and Production Enterprise (SRPE) "Geoinform of Ukraine".

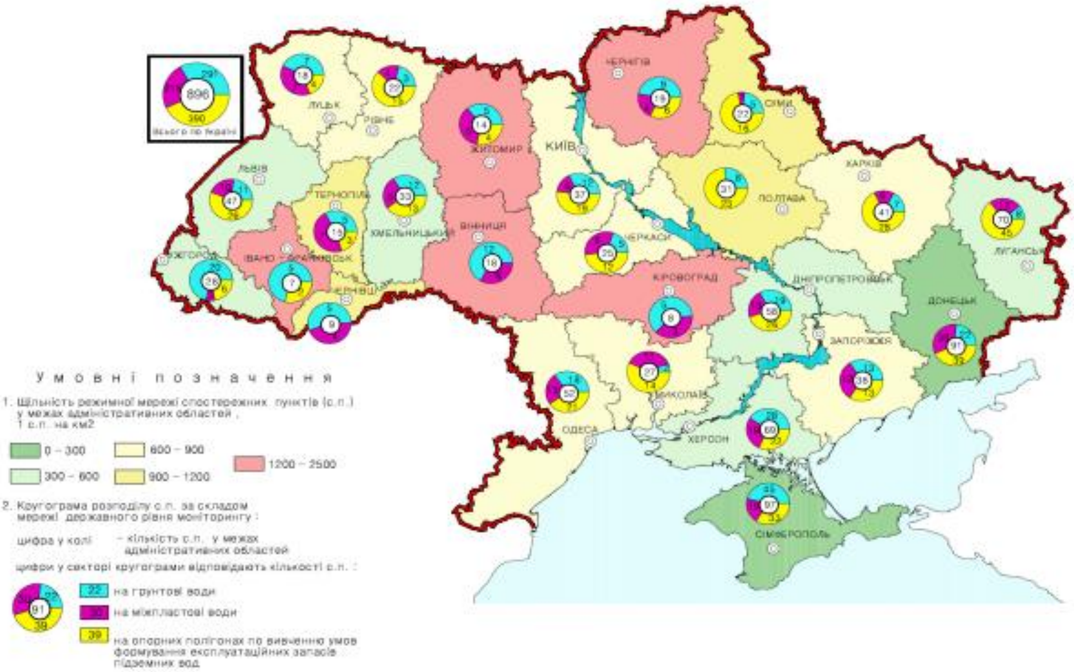


Figure 7.7 Groundwater monitoring network as of 2018

Source: The State Geological Survey of Ukraine

Instrumental analysis of groundwater quality is carried out in six laboratories of state enterprises of the State Geological Survey. State geological enterprises investigate all six required chemical and physical-chemical parameters of groundwater and fully cover the study of macro-component composition. At the same time, out of 45 pollutants from the list of priority pollutants, the State Geological Survey and its enterprises investigated only 4.

The State Emergency Service of Ukraine (SES). According to the State Water Monitoring Programme (in terms of diagnostic and operational monitoring of surface waters), the State Emergency Service (UHMC) is responsible for diagnostic and operational monitoring of waters for biological, physico-chemical and hydromorphological indicators.

Surface water quality monitoring is carried out on 103 rivers, 9 reservoirs, 7 lakes, 1 canal, 1 liman at 204 sites at 327 water abstraction points (see Fig. 7.8 below) in accordance with the State Water

Monitoring Programme (in terms of diagnostic and operational monitoring of surface water) approved by the Order of the Ministry of Environment No. 410 dated 31.12.2020.

Figure 7.8 Observation points for surface water quality based on hydrochemical indicators of the Hydrometeorological Service network in Ukraine in 2016

Samples are analysed in 11 laboratories. In surface water bodies, 10 out of 29 biological indicators (in accordance with the Procedure for State Water Monitoring) are performed by the SES, 12 out of 14 chemical and physico-chemical indicators are performed, and 2 out of 8 hydromorphological indicators are performed. In addition, the SSES monitors 4 indicators that are included in the list of priority pollutants (PP) and 6 indicators that are absent in the Procedure.

Radioactive contamination of surface waters is monitored in 5 sites of the Dnipro water system (Upper Dnipro and the cascade of Dnipro reservoirs) and in 4 sites on the Desna, Danube, Southern Bug rivers and in the Dnipro-Bug liman.

Samples are taken once a month (in the Dnipro-Bug liman once a quarter), and in the selected material the determination of caesium-137 content in solution and suspension and the determination of dissolved strontium-90 content is carried out.

As part of the programme to control the environmental impact of nuclear power plants, surface water is sampled at 10 locations and 29 locations around operating NPPs. Research in the areas of NPP influence is carried out by 4 laboratories twice a year.

7.4 Network and observation posts for water monitoring

The main objective of terrestrial surface water monitoring is to obtain information on the quality of surface waters necessary for the implementation of measures for their protection. In this regard, the main tasks of the monitoring service include the following:

1) observation and control of water pollution level by physical, chemical and hydrobiological indicators;

2) study of the dynamics of pollutants and identification of conditions under which sharp fluctuations of pollution levels occur, in order to provide forecasts of pollution of water bodies;

3) study of the patterns of self-purification processes of polluted surface waters and accumulation of pollutants in bottom sediments;

4) study of patterns of substances removal through river estuaries to determine the balance of these substances in water bodies.

Observation site for surface water quality is a location on a water body or watercourse where a set of works for obtaining data on qualitative and quantitative characteristics of water is carried out.

An important stage in the organisation of work is the selection of the location of the observation site. The main objects that need monitoring are: places of wastewater and rainwater discharge of cities, settlements, agricultural complexes, wastewater of individual enterprises, TPPs (thermal power plants), NPPs (nuclear power plants); places of discharge of collector-drainage water, diverted from irrigated or drained lands; final sections of large and medium-sized rivers, flowing into the sea, or inland water bodies; borders of economic districts, republics, countries, which cross transit rivers.

Figure 7.9 View of the surface water quality monitoring site

Two schemes of placement of hydrochemical observation sites are used: object and territorial.

The object scheme is used to study the hydrochemical regime of large and medium-sized water bodies and includes points of great economic importance; in the main-stream stations of large rivers flowing into the seas; on large lakes and reservoirs.

The territorial scheme is used for background observations, research and regional generalisation of the features of the hydrochemical regime of small rivers, which are located in the sections closing comparably small river water intakes, that perfectly reflect the local conditions of the natural areas of the studied area.

Water body or watercourse quality observation sites are divided into *4 categories* based on the following criteria:

- the importance of a water body as a source of drinking, domestic, industrial and agricultural water supply;

- the degree of fishery use of the water body;

- the level of pollution of the water body;

- the size and volume of the water body, the size and water content of the watercourse, regime data, physical and geographical features are also taken into account.

Category I includes sites located on water bodies that are of significant economic importance and are subject to the greatest anthropogenic impact.

Category II includes locations within cities and settlements with centralised use of surface water for domestic and drinking needs; this category of water bodies is characterised by significant anthropogenic impact.

Category III includes sites located on water bodies where the anthropogenic impact is moderate or low.

Category IV includes sites on uncontaminated water bodies (background plots).

One or several cross-sections are investigated at observation sites.

An observation site is a conventional cross-section of a water body or watercourse where a set of works is carried out to obtain information on water quality.

Observation cross section are placed taking into account hydrometric conditions and morphological features of the water body, presence of pollution sources, volume and composition of wastewater.

At watercourses with no organised discharge of return water, at the mouths of polluted tributaries, at unpolluted sections of watercourses, at the end sections of rivers and at places where the state border of Ukraine is crossed, one cross section shall be installed.

In case of organised discharge of return water, two or more sections should be installed on watercourses. The first (background) gauging station is recommended to be located at a distance of 1 km above the source of pollution, the second - in the pollution zone, at a distance of 1 km above the nearest place of water intake, the third - in the place of sufficient blending of wastewater with river water.

In the process of observation of a water body, in total at least three cross sections shall be established, distributed as evenly as possible over its water area, and taking into account the configuration of the shoreline.

Each cross section has several *verticals and horizontals*.

A vertical is a conventional vertical line from the water surface to the bottom of a water body or watercourse, on which the research for obtaining information on water quality is carried out.

The number of verticals in a cross section on a watercourse is determined with account of conditions of blending of watercourse waters with return waters, as well as with tributary waters. In case of heterogeneous chemical composition of water at least three verticals shall be installed in the cross section, and in case of homogeneous - one vertical on the stem of the watercourse. The number of verticals also depends on the width of the pollution zone.

A cross section horizontal is a zone on the vertical (inland) where a set of investigations is performed for obtaining information on water quality. The number of horizontals on the vertical is determined taking into account the depth of the water body. In addition, it is necessary to separate additional horizontals in each layer of change in water density.

Observation sites are necessarily combined with hydrological posts at which water discharge is measured or with areas provided with calculated hydrological data.

The list of monitoring sites, responsible executors, indicators and frequency of measurements are determined by the Programme of State Water Monitoring (in terms of diagnostic and operational monitoring of surface waters) approved by the Order of the Ministry of Environment No. 410 dated 31.12.2020.

7.5 Methodological basis for water quality assessment

Water quality and quantity are intimately linked although not often measured simultaneously.

Water quantity is often measured by means of remote hydrological monitoring stations which record water level, discharge, and velocity. Monitoring of water quantity can be undertaken, to a certain degree, with a minimal amount of human intervention, once a monitoring station has been set up.

In contrast, water quality is usually determined by analysing samples of water collected by teams of personnel visiting monitoring stations at regular intervals.

The quality of any body of surface or ground water is a function of either or both natural influences and human activities.

Without human influences, water quality would be determined by the weathering of bedrock minerals, by the atmospheric processes of evapotranspiration and the deposition of dust and salt by wind, by the natural leaching of organic matter and nutrients from soil, by hydrological factors that lead to runoff, and by biological processes within the aquatic environment that can alter the physical and chemical composition of water. As a result, water in the natural environment contains many dissolved substances and non-dissolved particulate matter.

Water quality is neither a static condition of a system, nor can it be defined by the measurement of only one parameter. Rather, it is variable in both time and space and requires routine monitoring to detect spatial patterns and changes over time.

There is a range of chemical, physical, and biological components that affect water quality and hundreds of variables could be examined and measured (Fig. 7.10). Some variables provide a general indication of water pollution, whereas others enable the direct tracking of pollution sources.

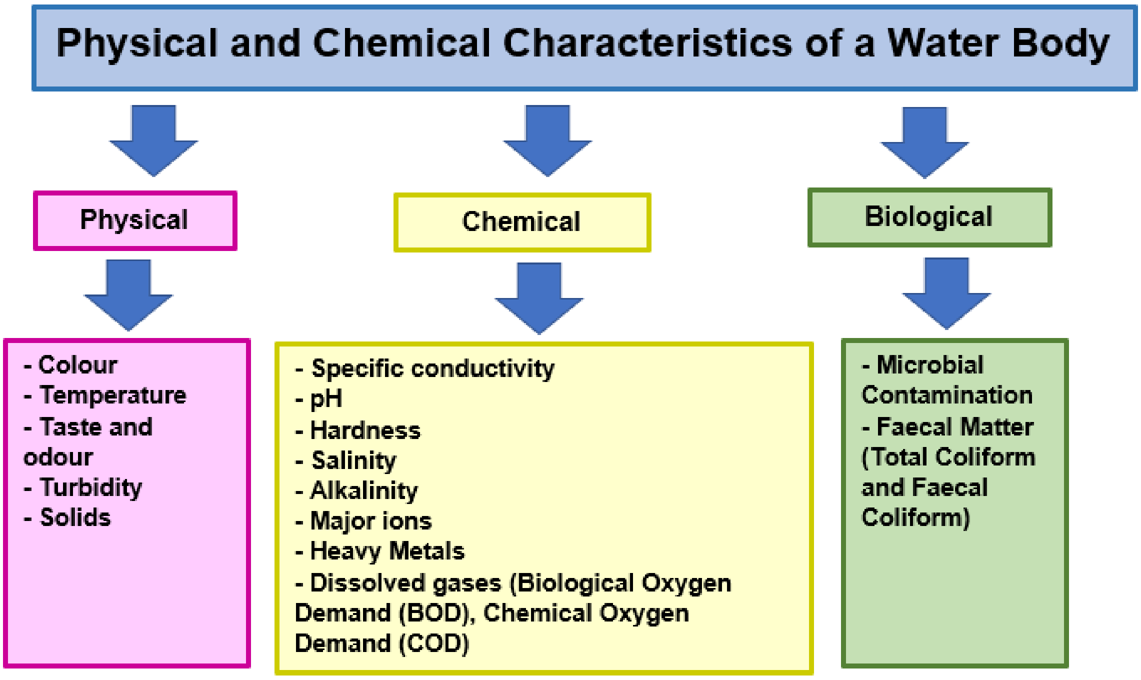


Figure 7.10 Key characteristics of the quality of water bodies

The content of pollutants in water is regulated by sanitary norms and rules as well as requirements and is measured by concentration in mg/dm^3.

Characterisation of hazard of a substance in water for humans and living organisms is MAC and hazard class. There are 4 hazard classes for pollutants in water environment:

- I - highly dangerous;

- II - very dangerous;

- III - dangerous;

- IV - moderately dangerous.

MAC is the maximum concentration at which a pollutant does not directly or indirectly affect the state of public health (when acting on the organism throughout life) and does not worsen sanitary and hygienic conditions of water use.

The methodological scheme of hygienic MACs suggests studying the influence of pollutants according to three signs of harmfulness:

- sanitary and toxicological (sensitivity of living organisms to the effects of toxic substances);

- organoleptic (taste, colour, odour);

- general sanitary (intensity of BOD (Biochemical Oxygen Demand), mineralisation processes of substances containing nitrogen, development and die-off of saprobic microflora, that is, intensity of water self-purification processes).

Hygienic MACs are aimed at ensuring safe conditions of water use for humans. Fishery MACs are focused on the protection of water bodies as a basis for fisheries and fish farming.

Among the methods of natural water quality assessment used in Ukraine are:

Graphical method. It is based on drawing up a graphical model of surface water quality, which is a circular diagram with radius scales corresponding to a certain hydrochemical indicator (Fig. 7.11). The division value of each radius is equal to the maximum value of the indicator concentration, which determines water suitability for a certain type of water use, i.e., MAC of pollutants in a water body.

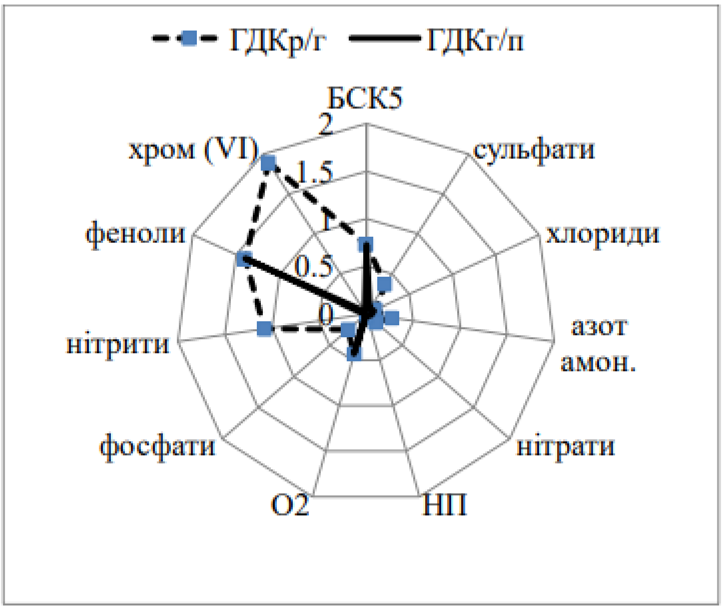


Figure 7.11 Example of implementation of the graphical method of assessment for two types of water use: fishery and domestic water use [46]

Application of this method allows to determine simultaneously the presence of exceedance of MPC for the content of all quality indicators, for which observations are carried out.

Water Pollution Index (WPI). Calculated using 6 indicators (NH_4^+, NO_2^-, petroleum products (PP), phenols, dissolved O_2, BOD_5) according to the formula:

$$ІЗВ = \frac{1}{6}\sum_{i=1}^{n}\frac{C_i}{ГДК_i},$$

where Ci is the arithmetic mean of the water quality indicator.

The chemical pollution indicator CPI-10 (ПХЗ-10 in Ukrainian) is determined by 10 indicators, among which there are general, mandatory for assessment (dissolved O_2, BOD, suspended solids, nitrogen group substances, etc.), and substances most characteristic for a particular water body:

$$ПХЗ\text{-}10 = \sum_{i=1}^{10} \frac{C_i}{ГДК_i}.$$

For the concentrations of pollutants that do not exceed the MAC, the C/MAC ratio is assumed to be 1.

Assessment by BOD$_5$. BOD is a measure of the amount of oxygen removed from the aquatic environment by aerobic microorganisms to meet their metabolic needs in the breakdown of organic matter, and systems with high BOD tend to have low dissolved oxygen concentrations. It indirectly characterises the ecological state of water bodies.

BOD Level in mg/liter	Water Quality
1 - 2	**Very Good:** There will not be much organic matter present in the water supply.
3 - 5	**Fair:** Moderately Clean
6 - 9	**Poor:** Somewhat Polluted - Usually indicates that organic matter present and microorganisms are decomposing that waste.
100 or more	**Very Poor:** Very Polluted - Contains organic matter.

There are 4 levels of water pollution from "very good" to "very poor" and 3 types of ecological state of water bodies: stage of turnover changes, the threshold limit and non-turnover changes.

According to the “Methodology for assigning a body of surface water to one of the classes of ecological and chemical status of the surface water body, as well as assigning an artificial or significantly altered surface water body to one of the classes of ecological potential of artificial or significantly altered surface water body” approved by Order of the Ministry of Environment and Natural Resources of Ukraine on January 14, 2019 № 5, five classes are used to classify the ecological state of the body of surface water.

Figure 7.12 Dynamics of changes in the average annual values of the BOD5 indicator along the Dnipro River channel in 2020-2021
Source: National Report on the State of the Natural Environment in Ukraine in 2021

The attribution of a surface water bodies to one of the classes of ecological and chemical statuses of the surface water bodies is carried out separately for each surface water bodies and includes the following:

- analysis of changes in the indicators that determine the status of the surface water bodies over time;
- graphical or statistical processing of monitoring data;
- determination of trends in changes in the surface water bodies;
- assessment of long-term changes in reference conditions (conditions reflecting the state of the environment under no or minimal anthropogenic impact) and changes caused by anthropogenic influence;
- assessment of the main anthropogenic impacts on the condition of surface water bodies;
- assessment of water use.

Determination of the ecological status of surface water bodies is made by biological, hydromorphological, chemical and physical-chemical indicators, which characterise their status in general and are supplemented by biological indicators.

Table 7.3 List of biological, hydromorphological, chemical and physical-chemical characteristics to determine the ecological status of surface water bodies

Biological parameters	
Rivers	**Lakes**
Composition and mean quantitative parameters: - phytobenthos; - macrophytes; - phytoplankton. Composition and quantification of benthic invertebrates. Composition, mean quantitative characteristics and age structure of fish.	Composition and mean quantitative parameters: - phytobenthos; - macrophytes; - phytoplankton. Composition and quantification of benthic invertebrates. Composition, mean quantitative characteristics and age structure of fish.
Transitional waters	**Coastal waters**
Composition and mean quantitative parameters: - phytobenthos; - macrophytes; - phytoplankton. Composition and quantification of benthic invertebrates. Composition, mean quantitative characteristics and age structure of fish.	Composition and mean quantitative parameters: - phytobenthos; - macrophytes; - phytoplankton. Composition and quantification of benthic invertebrates.
Hydromorphological parameters	
Rivers	**Lakes**
Hydrological regime: - quantitative indicators of water flow and water flow dynamics; - hydraulic connection with groundwater. Length of the river. Morphological conditions: - variability in river depth and width; - structure and substrate of the river bed; - structure of the riparian zone.	Hydrological regime: - quantitative measures of water volume and dynamics of water body filling; - water exchange; - hydraulic connection with groundwater. Morphological conditions: - lake depth variability; - quality, structure and substrate of the lake bed; - structure of lake shores.
Transitional waters	**Coastal waters**
Morphological conditions: - depth variability;	Morphological conditions: - depth variability;

- amount, structure and bedrock of the seabed; - structure of the ebb and flow zone. Ebb and flow tidal regime: - freshwater flow; - openness to waves.	- structure and bedrock of the seabed; - tidal zone structure. Ebb and flow tidal regime: - direction of the dominant currents; - openness to waves.
Chemical and physical-chemical parameters	
Rivers	**Lakes**
Common physical-chemical parameters: - temperature; - hydrogen pH; - dissolved oxygen; - content of dissolved salts (salinity, conductivity); - biological oxygen demand; - chemical oxygen demand; - nutrients (TN (Total Nitrogen), $N\text{-}NH_4^+$, $N\text{-}NO_3^-$, $N\text{-}NO_2^-$, TP (Total Phosphorus), $P\text{-}PO_4^{3-}$). Specific pollutants: - synthetic and non-synthetic pollutants entering into a water body.	Common physical-chemical parameters: - transparency; - temperature; - hydrogen pH; - dissolved oxygen; - content of dissolved salts (salinity, conductivity); - biological oxygen demand; - chemical oxygen demand; - nutrients (TN, $N\text{-}NH_4^+$, $N\text{-}NO_3^-$, $N\text{-}NO_2^-$, TP, $P\text{-}PO_4^{3}$). Specific pollutants: - synthetic and non-synthetic pollutants entering into a water body.
Coastal waters	**Transitional waters**
Common physical-chemical parameters: - transparency; - temperature; - hydrogen pH; - dissolved oxygen; - biological oxygen demand; - nutrients (TN, $N\text{-}NH_4^+$, $N\text{-}NO_3^-$, $N\text{-}NO_2^-$, TP, $P\text{-}PO_4^{3-}$).; - silicium; - dihydrogen sulphide; - the sum of substances suspended in water. Specific pollutants: - synthetic and non-synthetic pollutants entering into a water body.	Common physical-chemical parameters: - transparency; - temperature; - dissolved oxygen; - content of dissolved salts (salinity, conductivity); - nutrients (TN, $N\text{-}NH_4^+$, $N\text{-}NO_3^-$, $N\text{-}NO_2^-$, TP, $P\text{-}PO_4^{3-}$). Specific pollutants: - synthetic and non-synthetic pollutants entering into a water body.

For graphical representation, each of the classes of ecological status of the surface water bodies is indicated by the corresponding colour:

I class of ecological condition, corresponding to the ecological condition "high", marked in blue;

II class of ecological condition, corresponding corresponds to the ecological condition "good", indicated by the green color;

III class - "moderate", marked in yellow;

IV class - "poor", indicated by the color orange;

V class of ecological condition, corresponding to the ecological condition "bad", is indicated in red.

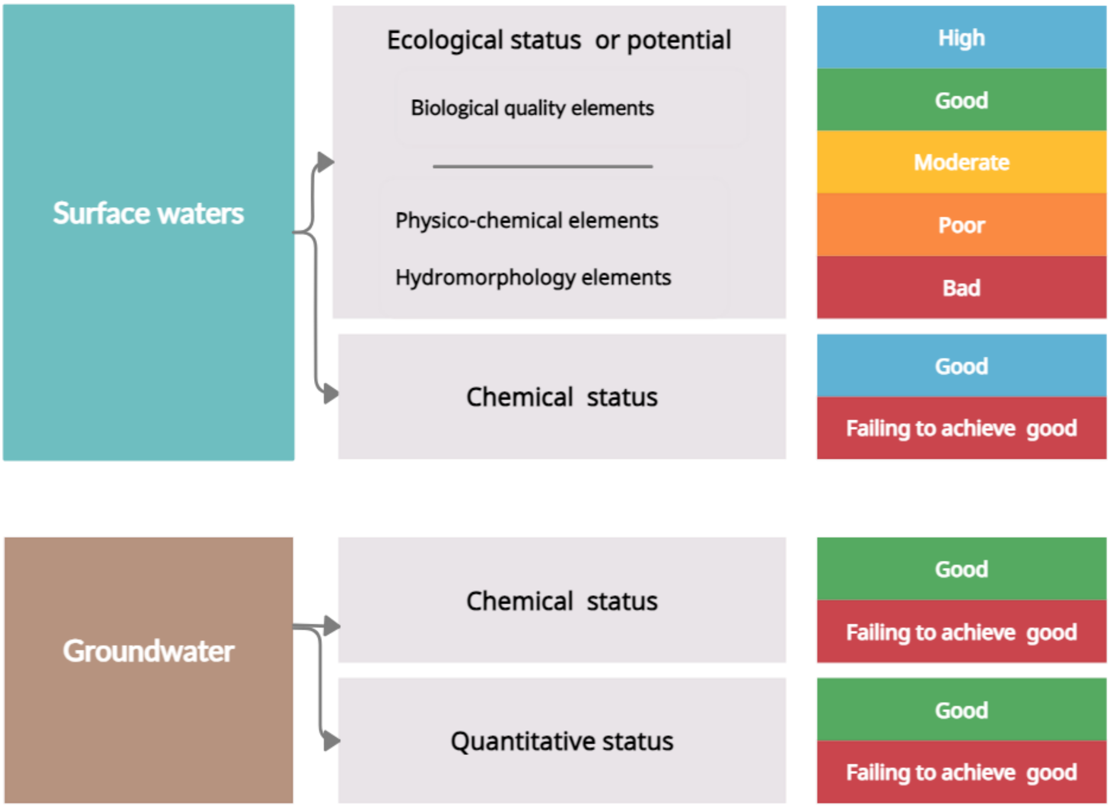


Figure 7.13 Assessment of status of surface waters and groundwater according to the WFD

Source: https://water.europa.eu/freshwater/europe-freshwater/water-framework-directive

Class of the ecological state of the body of surface water is determined by biological, hydromorphological, chemical and physical-chemical indicators. Determination of the class for each of the parameters is performed by comparing its value with the limit values of the classes established in the typospecific classification.

Class of ecological status of surface water bodies is determined by the worst indicator.

A generalised definition of the ecological status of surface water bodies is obtained by combining the results of the determination of classes of ecological status for biological, hydromorphological, chemical and physical-chemical parameters.

The chemical state of the surface water body is determined according to the List of Pollutants for the identification of the Chemical Condition of Surface and Groundwater Bodies…, approved by the order of the Ministry of Environment dated February 6, 2017 № 45.

Two classes are used to classify the chemical state of the surface water body. For graphic representation, each of the classes is marked with the corresponding color:

I class of chemical state, which corresponds to the chemical condition "good," indicated by the blue color;

II class of chemical state, which corresponds to the chemical condition "failing to achieve good," indicated by the red color.

Determination of the general condition of the surface water bodies is made by the worst indicator according to the algorithm for determining the general condition of the surface water bodies (see Figure 7.14 below).

For criteria of establishing reliability of correct determination of ecological and chemical status of surface water bodies there are 3 levels of reliable determination: high, medium, low.

7.6. Specific aspects of marine water monitoring

Seawater covers approximately 71 per cent of the total land area.

Marine pollution is a serious problem nowadays. Many people fail to realise that marine pollution not only affects the seas and oceans, but also the rest of the earth.

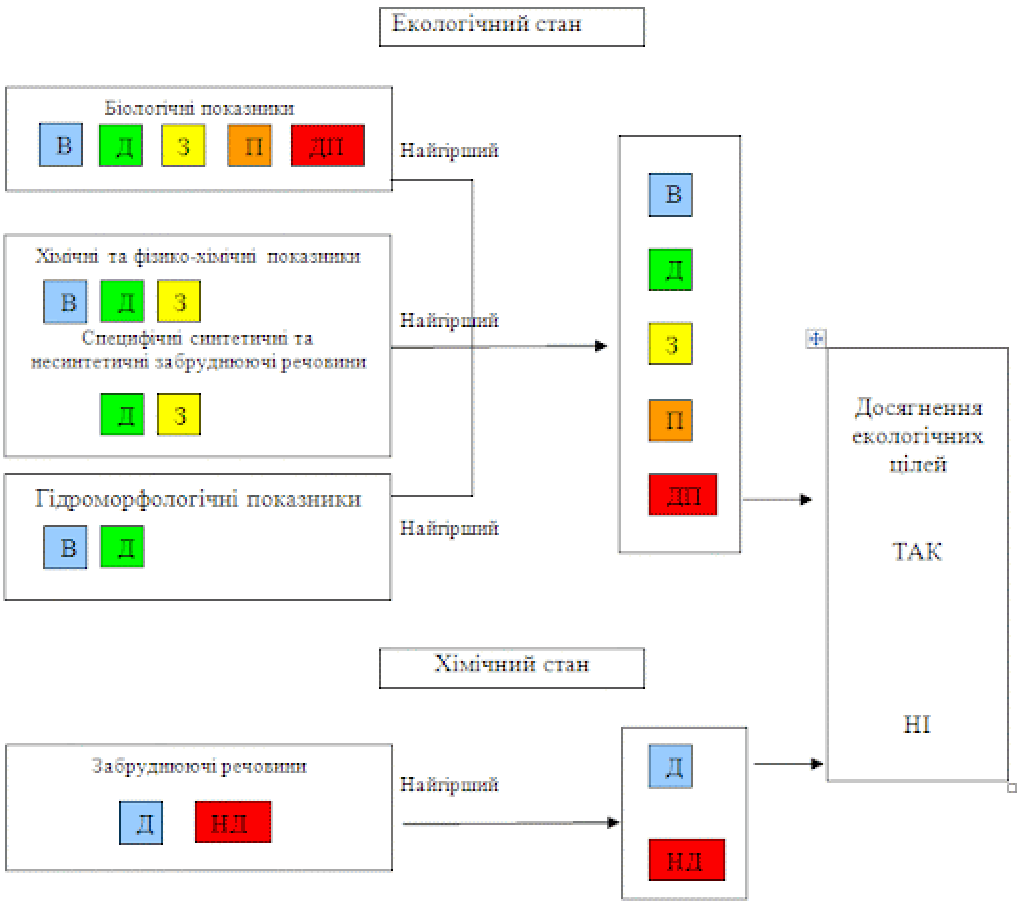


Figure 7.14 Algorithm for determining the general condition of the surface water body

Ocean and marine pollution have a direct impact on both marine organisms and indirectly affects human health and resources.

The predominant sources of marine pollution are land-based sources, as well as shipping and waste discharges into the sea. The main sources of marine pollution include:

- discharge of industrial and domestic water directly into the sea or with river runoff;
- input from land of various substances used in agriculture and forestry;
- intentional disposal of pollutants in the sea;
- losses of various substances during ship operations;
- accidental discharges from ships or underwater pipelines;

- mining of minerals on the seabed;
- inflow of pollutants from the atmosphere.

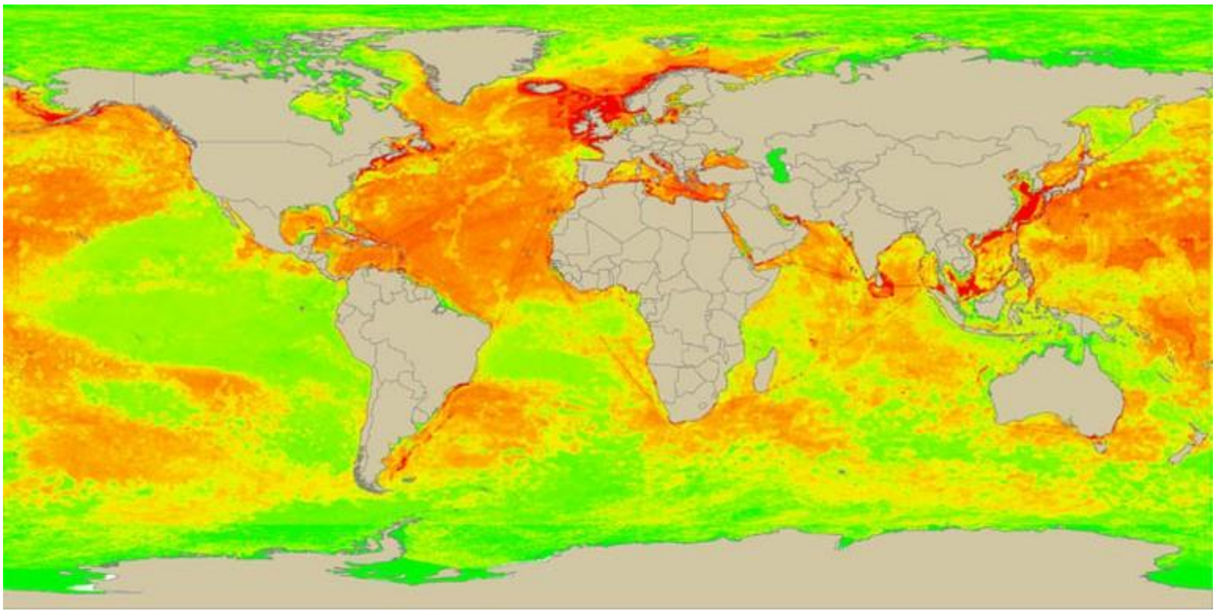


Figure 7.15 Global Map of Human Impacts to Marine Ecosystems
Source: http://www.nceas.ucsb.edu/GlobalMarine/models

Researchers at the National Centre for Ecological Analysis and Synthesis (NCEAS) have found that 60 percent of the world's oceans are polluted due to human influence. The most polluted areas are the Persian Gulf and the Gulf of Aden, as well as the waters of the North, Baltic, Black and Azov Seas.

The growing threats from anthropogenic pressure on the Azov and Black Seas cause their unsatisfactory ecological condition, which is significantly aggravated by the negative impact of climate change.

The most critical indicators of the state of the marine environment and dangerous factors of negative impact are eutrophication and its consequences (in particular, mass "blooming" of water), significant pollution of marine ecosystems with toxic and carcinogenic substances, microbiological pollution, reduction of biodiversity, reduction of natural resources of the Azov Sea including aquatic bioresources, decline in the quality and availability of recreational resources, as well as emergence of threats to public health.

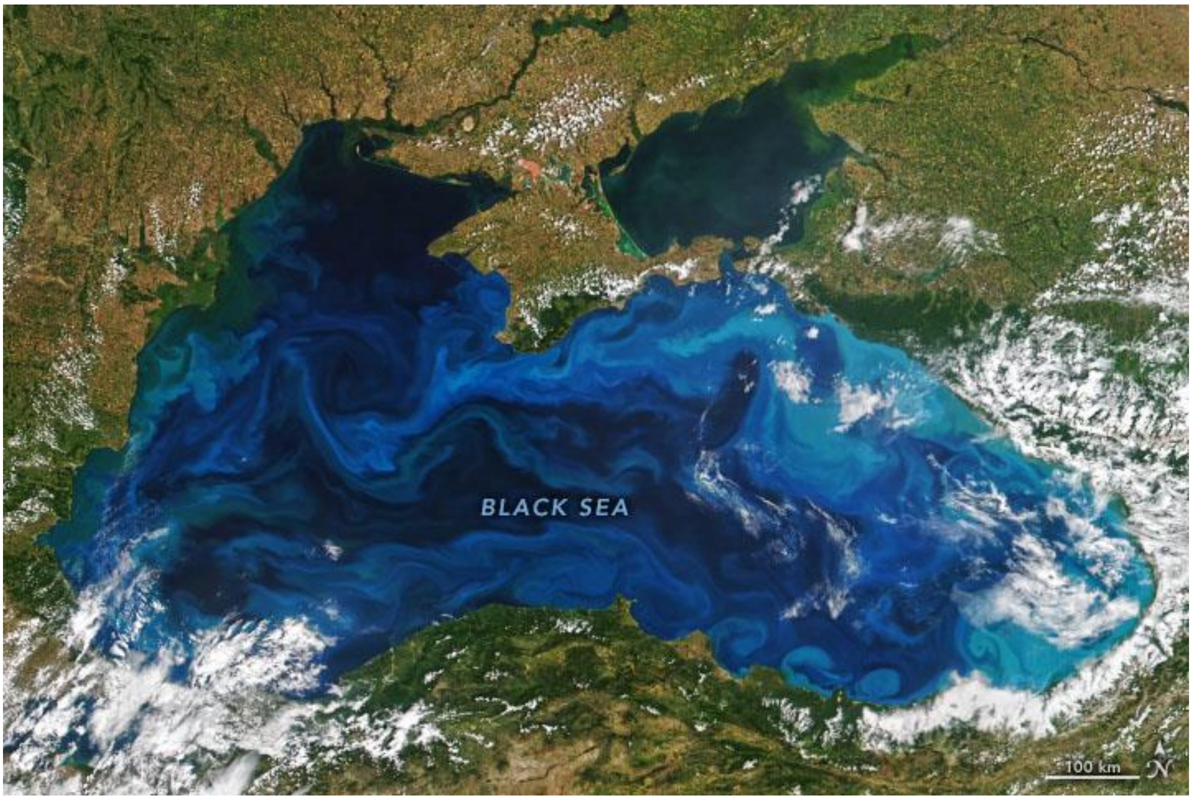


Figure 7.16 Satellite Photograph of the Black Sea

Source: https://earthobservatory.nasa.gov/images/

The main sources of marine pollution include river runoff, discharge of return and waste water from stationary coastal sources, diffuse pollution, and pollution from marine vessels.

Climatic changes occurring in the region of the Azov-Black Sea basin lead to changes in temperature regime, precipitation frequency and volumes, wind regime, sea level, as well as affect the hydrodynamic characteristics of sea waters and the structure of water masses. This affects the state of marine ecosystems, the characteristics of habitats and migration routes of biological species, and makes them more vulnerable to the harmful effects of economic and other activities on the environment.

As a result of pollution of the marine environment, unbalanced use of natural resources, as well as the lack of an integrated management system for the use of natural resources of the Azov and Black Seas, Ukraine loses (tentatively) up to 2 billion hryvnias annually.

Ukraine is located at the crossroads of trade routes of Eastern Europe and the Mediterranean basin, washed by the Black and Azov Seas which belong to the Atlantic Ocean basin.

The total length of Ukraine's sea coastline is more than 2,500 kilometres (Black Sea - 1,652.2 km, Sea of Azov - 874.8 km). The access from the Black Sea and the Sea of Azov through the Bosporus, Dardanelles, Gibraltar and Suez Canal to the World Ocean allows Ukraine to use the resources of the ocean for the needs of the economy and places it among the maritime states, which, according to the norms of international law, have the greatest benefits and privileges.

Since 2019, Ukraine has introduced European approaches to water monitoring in accordance with the requirements of the Water Framework Directive. The Decree of the Cabinet of Ministers of Ukraine No. 758 of 19 September 2018 approved a new procedure for state water monitoring, which, in particular, establishes the procedure for monitoring of marine waters.

Monitoring of marine waters is performed for the territorial sea and the exclusive maritime economic zone of Ukraine in order to:

- determination of the ecological status of marine waters;
- establishing reference conditions for marine waters;
- assessing progress towards the achievement of established environmental objectives;
- assessing trends in long-term natural and anthropogenic configurations of the status of marine waters.

On the basis of data and information obtained as a result of the state monitoring of marine waters, it determines their ecological state, develops a maritime strategy and assesses progress in achieving a good environmental status of marine waters within the exclusive maritime economic zone and territorial sea of Ukraine.

According to the Marine Strategy Framework Directive, "good environmental status (GES) means the environmental status of marine waters where these provide ecologically diverse and dynamic oceans and seas which are clean, healthy and productive within their intrinsic conditions, and the use of the marine environment is at a level that is sustainable, thus safeguarding the potential for uses and activities by current and future generations".

The components of the state monitoring of marine waters are monitoring of biological, hydromorphological, physical and chemical indicators, content of pollutants in bottom sediments and in tissues of hydrobionts, solid waste (litter) in the marine environment, and acoustic (noise) pollution of the marine environment.

The baseline assessment of the ecological condition of the marine environment made it possible to divide the Black Sea and the Sea of Azov into relatively homogeneous areas (marine water bodies), and to identify and describe descriptors for achieving good environmental status for each of the identified marine water bodies.

The subject of monitoring of coastal and marine waters of the Black and Azov Seas has been identified by the Ministry of Environment, whereas the executor of this monitoring is Ukrainian scientific center of Ecology of Sea (UkrSCES).

Within the framework of the Marine Conservation Strategy of Ukraine, approved by the Decree of the Cabinet of Ministers of Ukraine No. 1240-r dated 11 October 2021, 32 massifs of coastal marine waters (22 for the Black Sea and 10 for the Azov Sea), 10 marine shelf areas (9 for the Black Sea.) 1 for the Azov Sea) and 4 offshore areas (all in the Black Sea).

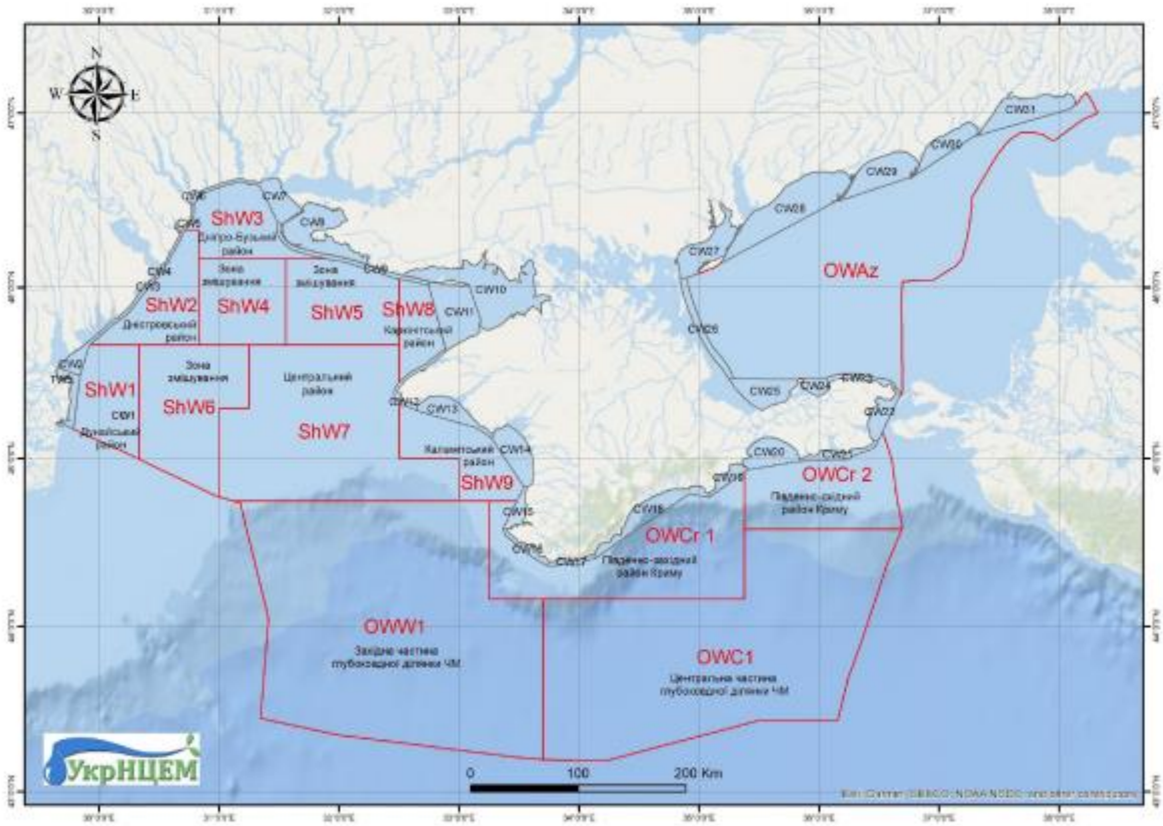


Figure 7.17 Zoning of the Black and Azov Seas, where marine water bodies of different typologies are represented for: 1) coastal waters; 2) offshore shelf areas and 3) open sea areas

Source: Ukrainian scientific center of Ecology of Sea, 2021

The procedure for state water monitoring assigns monitoring of marine waters only to the Ministry of Environment. However, the State Emergency Service also monitors the state of the marine environment covering the north-western part of the Black Sea and the Azov Sea water area, namely the delta and delta watercourses of the Danube, the Sukhyi Liman and the area of the entrance channel of the Chornomorsk city, the water area of the Odessa port, the gyres of the Southern Bug, the Dnipro-Bug Liman, the Taganrog and Berdyansk gulfs.

Observations are performed at 55 stations of the base network and 6 dumping stations (according to the plan at 67 stations of the base network and 9 dumping stations). Observation of marine water quality in the Azov-Black Sea basin is carried out by 6 laboratories with hydrochemical section of works.

The subsystem of water monitoring can use automatic, permanently installed, as well as mobile (in particular, on watercraft) sensors.

The Procedure for State Water Monitoring recommends the use of automatic continuous measurement systems for such indicators as:

- concentration and spatial distribution of chlorophyll;
- phytoplankton abundance, biomass and spatial distribution;
- biotesting of water quality;
- microbiota of water and bottom sediments;
- types and amount of litter;
- noise pollution of the marine environment.

Marine pollution monitoring consists of three components: 1) monitoring of abiotic indicators of the environment, 2) impact factors and 3) sources of impact.

When organising observations, certain tasks are defined, the main ones being:

1) organisation of systematic observations and assessment of the state of sea waters, pollution impact on natural physical-chemical and hydrobiological conditions;

2) study of pathways and parameters of spreading and natural disposal of pollutants for further determination of their possible discharge;

3) forecasting the dynamics of marine water pollution according to given values of discharges, hydrochemical and hydrobiological conditions;

4) development of recommendations on the optimal discharge regime in specific areas of the seas and oceans.

Observation points for marine and oceanic water quality are subdivided into 3 categories. The category is established depending on the location and capacity of pollution sources, regional and physiographic conditions.

Sites of I category are located in coastal areas of important economic importance:

- places of water use by the population;
- in ports and port water areas;
- in spawning areas and concentrations of valuable fish species;
- in areas of wastewater discharge;
- at the estuarial seashore of large rivers;
- in places of exploration, extraction, development, and transport of minerals.

Sites of the II category are established to study seasonal and annual variability of marine water pollution level and are located in places where pollutant input occurs due to migration processes.

The third category sites are established in the areas of the open sea and are intended for research of annual variability of marine water pollution and for calculation of pollutant balance. These stations are located in areas with lower concentration of pollutants.

The places of location of verticals and horizons, their number at each site are determined by the location and capacity of pollution sources, composition, concentration and type of pollutants. Observations are carried out according to one of two programmes - reduced or complete (Tables 7.4 and 7.5).

During visual observations, phenomena unusual for the given sea area are noted (floating impurities, slicks, oil stains; development and

Table 7.4 Observation programs of physical and chemical indicators of sea water quality

Indicators	Complete programme	Reduced programme
Petroleum hydrocarbons, mg/dm^3	+	+
Dissolved oxygen, mg/dm^3	+	+
Hydrogen index, pH units	+	+
Visual observations of the surface condition of a marine object	+	+
Chlorinated hydrocarbons, including pesticides, $\mu g/dm^3$	+	–
Heavy metals: mercury, lead, cadmium, copper, $\mu g/dm^3$	+	–
Phenols and synthetic surfactants, $\mu g/dm^3$	+	–
Additional area-specific pollutants: nitrite nitrogen, silicon, $\mu g/dm^3$	+	–
Salinity, %, water transparency, m	+	–
Wind speed, m/s, and wind direction	+	–
Water and air temperature, °C	+	–

Table 7.5 Observation programs of monitoring of hydrobiological indicators of sea water quality

Indicators	Complete programme	Reduced programme
1. Zooplankton:		
Total number of organisms ($specimens/m^3$)	+	+
Species composition, number and list of species	+	+
Total biomass (mg/m^3)	+	–
Numbers of major groups and species ($specimens/m^3$)	+	–
Biomass of major groups and species (mg/m^3)	+	–
2. Phytoplankton:		
Total cell count ($cells/dm^3$)	+	+
Species composition, number and list of species	+	–
Total biomass (mg/m^3)	+	–
Number of major systematic groups, number of groups	+	–
3. Microbial indicators:		
Total number of microorganisms ($cells/cm^3$)	+	+
Concentration of saprophytic bacteria ($cells/cm^3$)	+	+
Phytoplankton chlorophyll concentration ($\mu g/dm^3$)	+	+
Total biomass (mg/dm^3)	+	–
Quantitative distribution of indicator groups of marine microflorae (saprophytic, oil-oxidising, lipolytic bacteria) ($cells/cm^3$)	+	–
Intensity of phytoplankton photosynthesis	+	–

dying off of algae; mass ejection of molluscs to the shore; increase in turbidity; appearance of unusual colouring, etc.).

According to the European Water Framework Directive and the Marine Strategy Framework Directive, classes of environmental status of marine waters have been developed. Environmental status classes are classified into only 2 categories based on biological, chemical and physical indicators: "good environmental status achieved" and "good environmental status not achieved".

The characteristics (descriptors) of the "good" environmental status of the Black and Azov Seas according to quality descriptors (in accordance with Directive 2008/56/EC of the European Parliament and of the Council of 17 June 2008 establishing a framework for Community action in the field of marine environment policy) are given in Annex 2 to the Marine Environmental Strategy of Ukraine.

7.7 European policy in the field of sea water quality and monitoring

The marine environment is a precious heritage that needs to be protected, conserved and, where possible, restored to maintain biodiversity, ecosystem functioning and ensure clean, healthy and productive seas.

The marine ecosystem is threatened by a variety of factors, including pollution, eutrophication, overfishing, the introduction of exotic species, climate change and other human-related activities.

For this reason, in the July 2008, the Marine Strategy Framework Directive (2008/56/EC) (MSFD) entered into force. The Directive establishes a legal framework for the protection and management of European seas and ensures their long-term sustainable use. The main objective of the Directive is to achieve and/or maintain Good Environmental Status (GES) by 2020.

To this end, EU member states are obliged to develop a strategy for their marine waters by implementing appropriate measures and monitoring programs to protect, conserve and monitor the marine environment, preventing degradation or, if possible, restoring marine ecosystems in areas where it has been adversely affected.

To protect and conserve the marine environment and ecosystem functioning, Member States should also establish Marine Protected Areas (MPAs), within the framework of the program of measures of MSFD, in order to achieve and maintain GES.

This is also in line with the Habitats Directive (92/43/EEC) and other Regional and International Conventions.

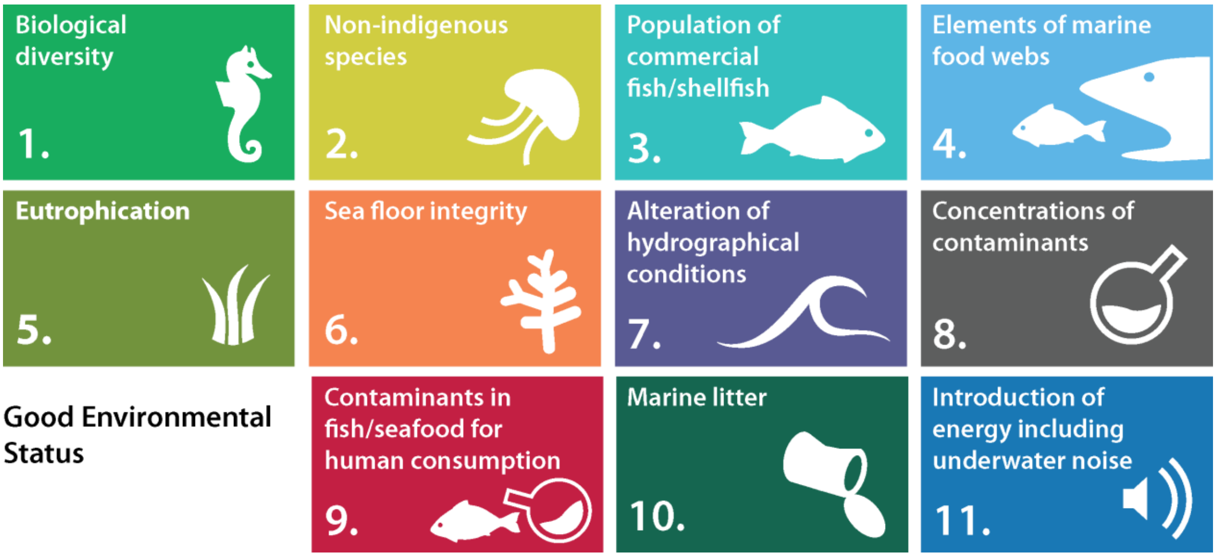


Figure 7.18 The 11 qualitative descriptors for determining good environmental status as presented in Directive 2008/56/EC of the European Parliament and the Council

Source: https://oap.ospar.org/en/ospar-assessments/intermediate-assessment-2017/introduction/policy-context/

Additionally, in September 2010, the EU adopted the Commission Decision on criteria and methodological standards on good environmental status of marine waters (2010/477/ EU). This Commission

Decision established a set of criteria and indicators for each of the 11 Descriptors of Annex I of the MSFD which assesses the extent to which they achieve Good Environmental Status in marine waters.

But by Commission Decision (EU) 2017/848 of 17 May 2017 there was repealed Decision 2010/477/EU and laid down new criteria and methodological standards on good environmental status of marine waters and specifications as well as standardized methods for monitoring and assessment.

Good Environmental Status (GES) according to the EU Marine Strategy Framework Directive is defined by the following conditions (11 Descriptors):

1. Biological diversity is maintained. The quality and occurrence of habitats and the distribution and abundance of species are in line with prevailing physiographic geographic and climatic conditions.

2. The non-indigenous species introduced by human activities are at levels that do not adversely alter the ecosystem.

3. Populations of all *commercially exploited fish and shellfish* are within safe biological limits, exhibiting a population age and size distribution that is indicative of a healthy stock.

4. All elements of the marine *food webs*, to the extent that they are known, are in a normal abundance and diversity and levels capable of ensuring the long-term abundance of the species and the retention of their full reproductive capacity.

5. Human-induced *eutrophication* is minimised, especially the adversely effects of it, such as loss in biodiversity, ecosystem degradation, harmful algae blooms and oxygen deficiency in bottom waters.

6. *Sea-floor integrity* is at a level that ensures that the structure and functions of the ecosystems are safeguarded and benthic ecosystems, in particular, are not adversely affected.

7. Permanent alteration of *hydrographical conditions* does not adversely affect marine ecosystems.

8. *Concentrations of contaminants* are at levels not giving rise to pollution effects.

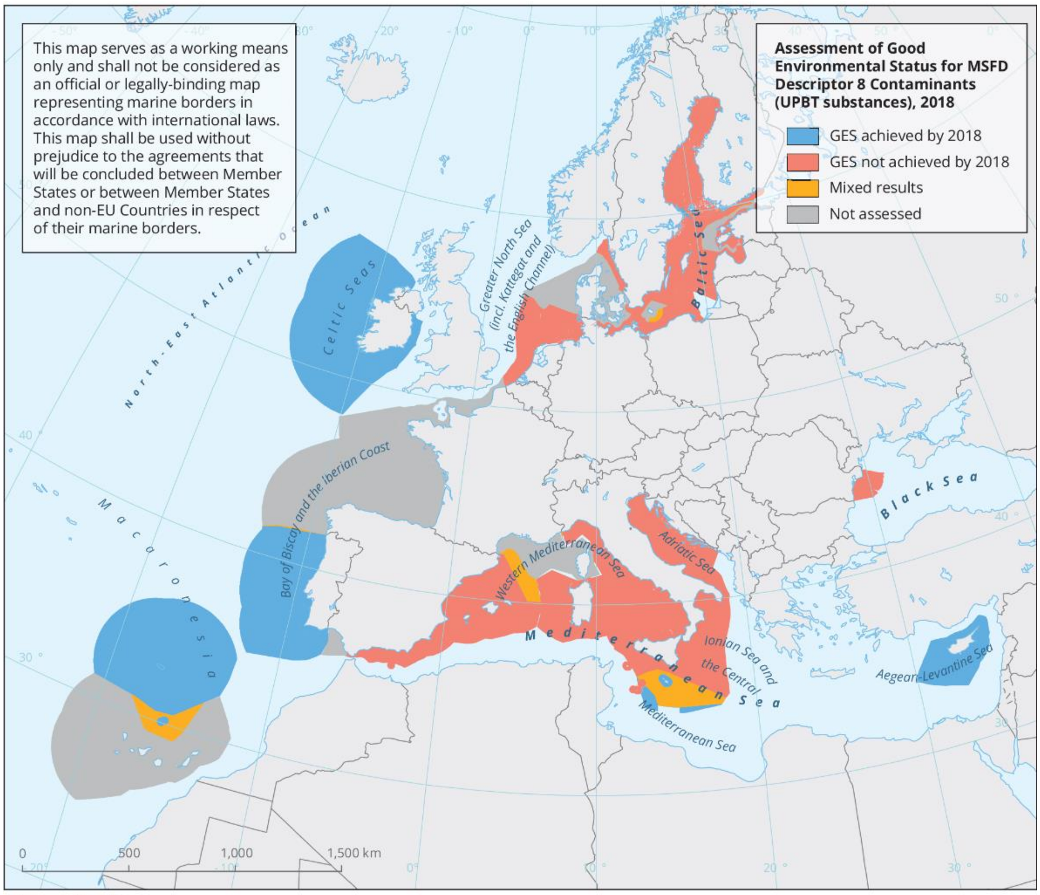


Figure 7.19 Assessment of Good Environmental Status for MSFD Descriptor 8 Contaminants (UPBT substances) by marine region, 2018
Source: https://www.eea.europa.eu/publications/zero-pollution/ecosystems/marine-pollution

9. *Contaminants in fish and other seafood* for human consumption do not exceed levels established by Community legislation or other relevant standards.

10. Properties and quantities of *marine litter* do not cause harm to the coastal and marine environment.

11. *Introduction of energy*, including underwater noise, is at levels that do not adversely affect the marine environment.

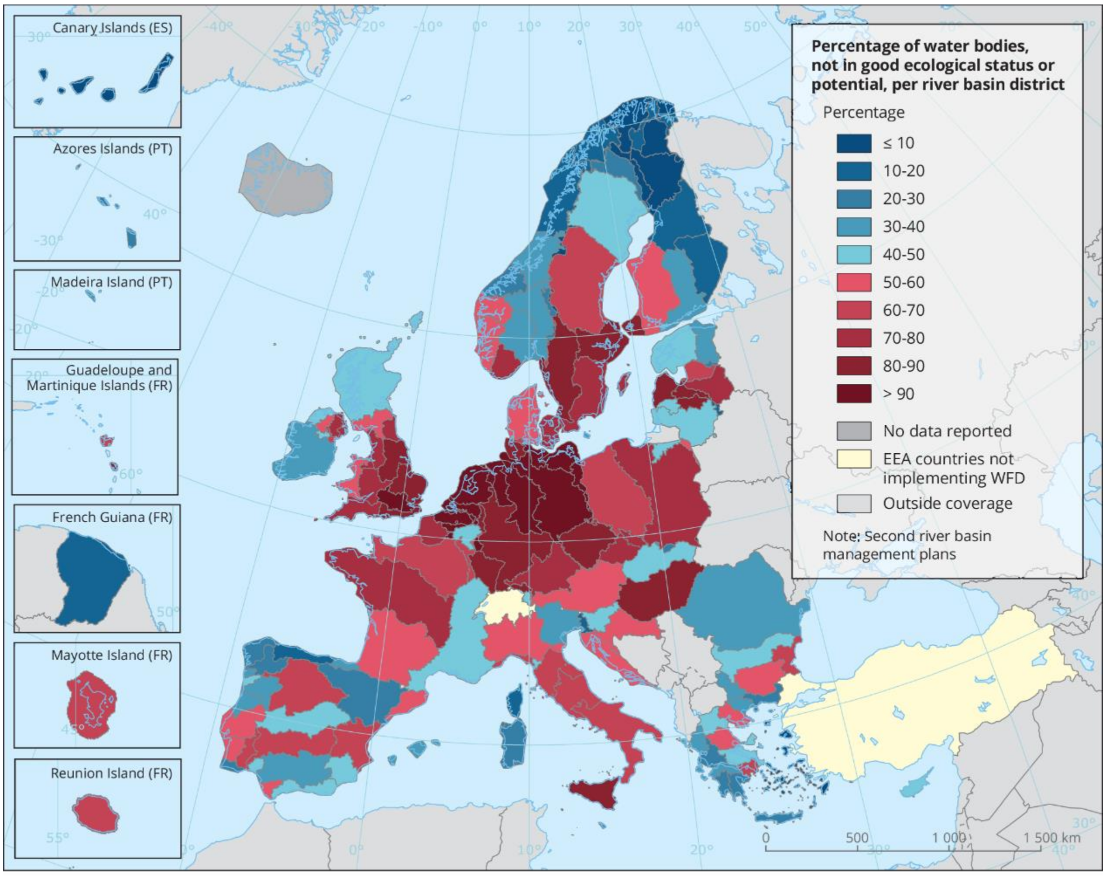


Figure 7.20 Percentage of water bodies, not in good ecological status or potential, per river basic district

Source: https://www.eea.europa.eu/ims/ecological-status-of-surface-waters

The most developed component of the programme is now the European Commission's Copernicus Marine Service (or Copernicus Marine Environment Monitoring Service (CMEMS)), which produces forecasts of the state of the world's oceans in general, the Arctic basin, and the marginal and inland seas of Europe.

The established forecast system distributes its products through a website (https://marine.copernicus.eu/). The products include direct data from contact observations as well as fields or parameters derived from the processing of remote sensing.

In addition, analyses and forecasts of selected surface wave parameters, three-dimensional fields of temperature, salinity, current velocity and ecosystem characteristics at any point in the world ocean are provided.

The Copernicus marine monitoring service uses a network of European marine data producers who provide state-of-the-art scientific knowledge to create a portfolio of ocean data products.

The Copernicus marine monitoring service includes two categories of marine data producers:

1. Thematic Data Assembly Centers (TAC), which process data received from satellites and observation platforms in situ.

2. Monitoring and Forecasting Centres (MFCs), which assimilate ocean numerical models from TAC data to generate reanalyses (20 years), analyses (today) and 10-day ocean forecasts.

There are seven monitoring and forecasting centres: World Ocean, Arctic Ocean, Baltic Sea, Northwest European Shelf, including the North and Irish Seas, Ibero-Biscay region, Mediterranean and Black Sea.

For example, Black Sea – Monitoring Forecasting Centre (BS MFC) provides regular and systematic information about the physical state of the ocean and marine ecosystems for the Black Sea.

The Black Sea physical analysis and forecasting product BLKSEA_ANALYSIS_FORECAST_PHYS_007_001 is a near real-time physical component of the Black Sea system based on a hydrodynamic model of the entire Black Sea basin.

A continuous archive of analyses for the last two years up to the present is available on the CMEMS server. It contains 11 datasets: 3D daily mean fields, 3D hourly mean fields of potential temperature, sea bottom temperature, salinity, zonal and meridional velocities, 2D sea surface levels, potential bottom temperature, mixed layer thickness information.

BLKSEA_REANALYSIS_PHYS_007_004 is the nominal product for the physical reanalysis of the Black Sea state. It consists of three-dimensional, daily and monthly mean fields of potential temperature, salinity (Fig.7.21), zonal and meridional velocities, and two-dimensional daily and monthly mean fields of sea surface height and mixed layer depth.

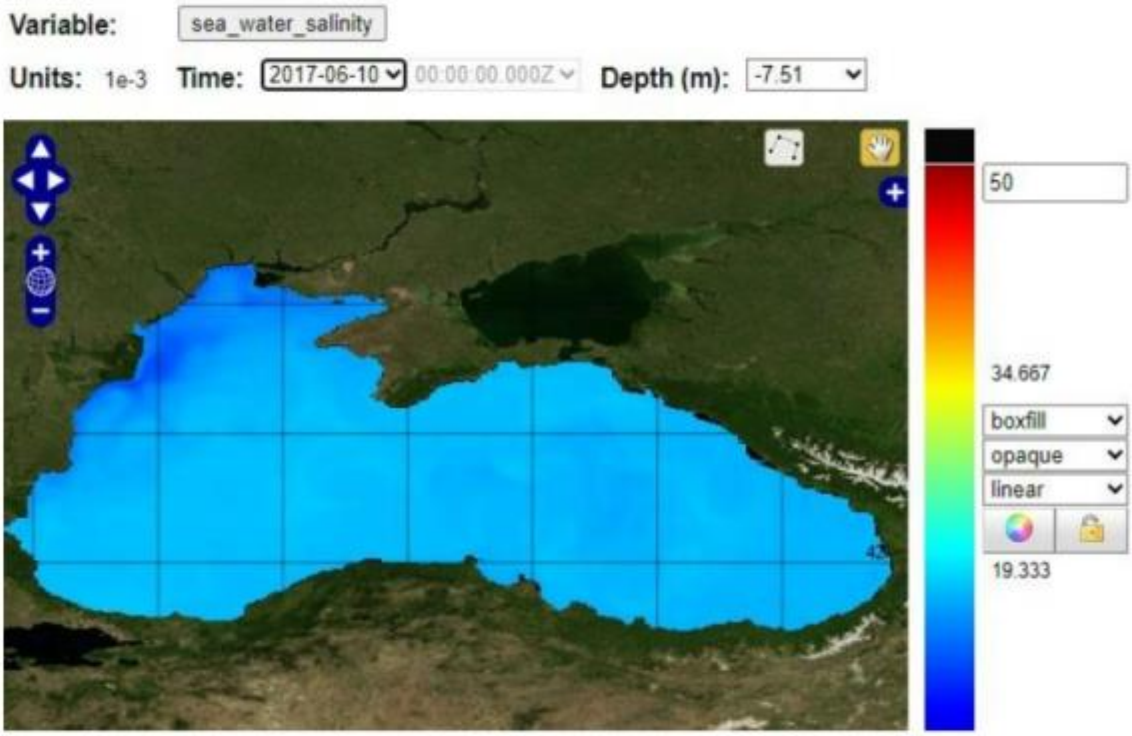


Figure 7.21 Example of visualisation of salinity calculation data for the Black Sea physical reanalysis (as of 06 October 2017, depth 7.51 m)

There are also 26 types of satellite observations for the Black Sea (8 products for measuring sea surface level, 5 for chlorophyll content, 3 for optics, 5 for temperature, 2 for wind, and 3 for wave height). Information about the sea surface level is provided by the Toulouse Centre for the Preparation and Processing of Satellite Altimetry Measurements (France).

Products for the Black Sea exist both separately and as part of the European region. They process data from almost all satellites: Jason-3, Sentinel-3A, HY-2A, Saral/AltiKa, Cryosat-2, Jason-2, Jason-1, T/P, ENVISAT, GFO, ERS1/2.

7.8 Water quality index

Due to spatial and temporal variations in water quality, which often are difficult to interpret, monitoring of the composition of waters is necessary.

The assessment of water quality is a prerequisite for the implementation of water protection policies and optimal allocation of different water sources according to their uses. Indeed, surface water has often been evaluated using norms. However, sources of pollution are diverse: urban, industrial and agricultural pollution (diffuse or point source).

The frequency of monitoring and assessment of water quality helps to develop management strategies to control surface water pollution facing to increasing urbanization and anthropogenic pressure on water resources.

According to the European Environment Agency (EEA) water quality variables can be grouped into the following broad categories:

- Basic variables (e.g., water temperature, pH, conductivity, dissolved oxygen, and discharge) used for a general characterization of water quality.

- Suspended particulate matter (e.g., suspended solids, turbidity and organic matter (TOC, BOD and COD)).

- Organic pollution indicators (e.g., dissolved oxygen, Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), ammonium).

- Indicators of eutrophication: nutrients (e.g., nitrogen and phosphorus), and various biological effect variables (e.g., chlorophyll a, Secchi disc transparency, phytoplankton, zoobenthos).

- Indicators of acidification (e.g., pH, alkalinity, conductivity, sulphate, nitrate, aluminium, phytoplankton and diatom sampling).

- Specific major ions (e.g., chloride, sulphate, sodium, potassium, calcium and magnesium) as essential factors in determining the suitability of water for most uses (e.g., public water supply, livestock watering and crop irrigation).

- Metals (e.g., cadmium, mercury, copper and zinc).

- Organic micropollutants such as pesticides and the numerous chemical substances used in industrial processes (e.g., PCB, HCH, PAH).

- Indicators of radioactivity (e.g., total alpha and beta activity, ^{137}Cs, ^{90}Sr).

- Microbiological indicator organism (e.g., total coliforms, faecal coliforms and faecal streptococci bacteria).

- Biological indicators of the environmental state of the ecosystem (e.g., phytoplankton, zooplankton, zoobenthos, fish, macrophytes and birds and animals related to surface waters).

Water quality index (WQI) is valuable and unique rating to depict the overall water quality status in a single term that is helpful for the selection of appropriate treatment technique to meet the concerned issues.

Initially, WQI was developed by Horton (1965) in United States by selecting 10 most commonly used water quality variables like dissolved oxygen (DO), pH, coliforms, specific conductance, alkalinity and chloride etc. and has been widely applied and accepted in European, African and Asian countries.

The assigned weight reflected significance of a parameter for a particular use and has considerable impact on the index.

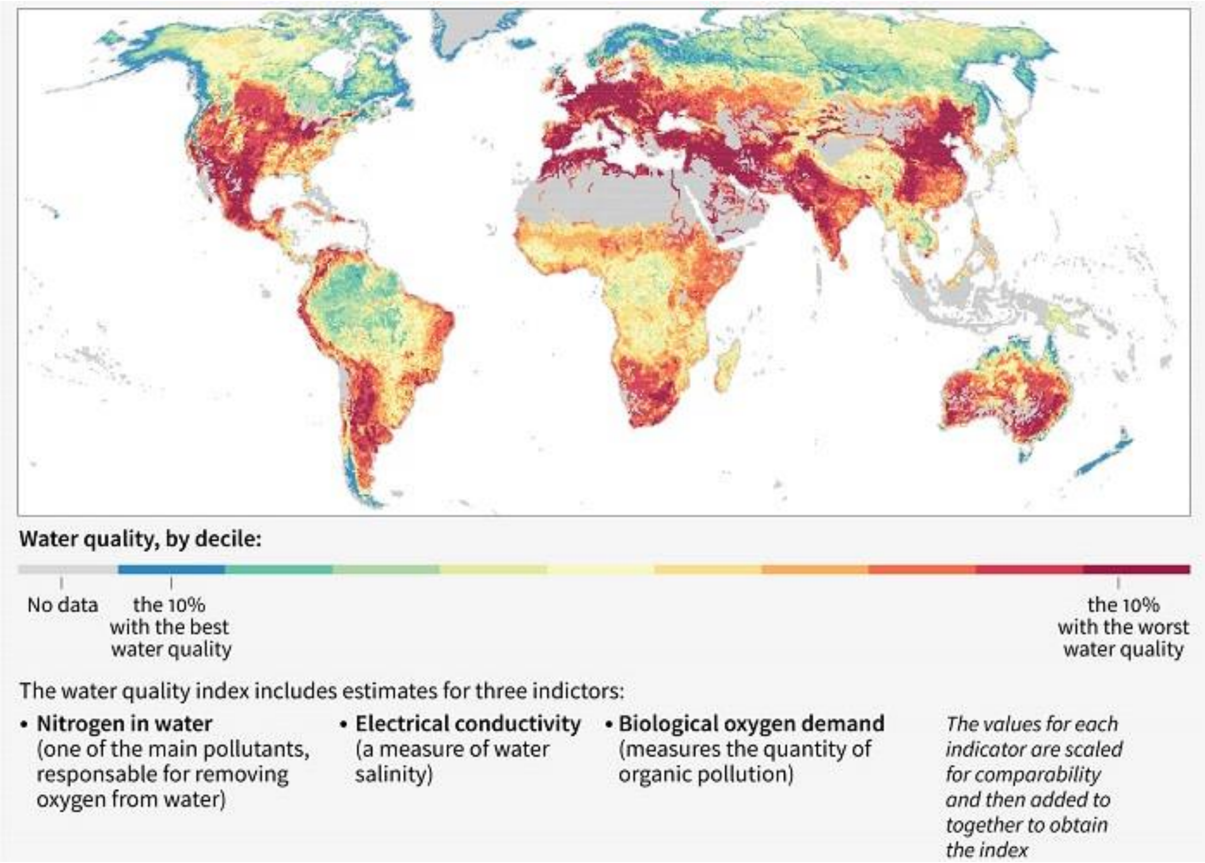


Figure 7.22 Map of water quality in the world based on an index of key indicators from 2000 to 2010, based on a World Bank research study

Furthermore, a new WQI similar to Horton’s index has also been developed by the group of Brown in 1970, which was based on weights to individual parameter. Recently, many modifications have been considered for WQI concept through various scientists and experts.

Today there are about 30 WQIs developed and used in different regions of the world.

The WQI is a useful and simple method used to present water quality data. It has found to be an effective technique for assessing temporal and spatial changes in water in any region of the world. Indices of water quality make it possible to convert vast amounts of complex data on water quality into a unified value in a simple and repeatable manner.

Questions for self-control

1. Does Ukraine belong to the least provided with water resources European countries?

2. What is the peculiarity of distribution of water resources in Ukraine?

3. The basic priorities of water use in Ukraine are:

a. population;

b. forests;

c. agriculture;

d. industry;

e. nature reserves.

4. What is water security according to UN-Water? What are the causes of the problems with water availability in Ukraine?

5. What are the objects of state water monitoring?

6. What procedures are established for state water monitoring?

7. What is the principle of the new monitoring of surface water bodies?

8. In what cases is diagnostic monitoring carried out?

9. When is operational monitoring performed?

10. Which institution is responsible for monitoring of groundwater bodies?

11. What are the classes of hazard for pollutants in the aquatic environment?

12. What is a MAC for the aquatic environment?

13. Name the main methods of assessing the quality of natural waters.

14. What is an observation site? What categories of observation sites for surface water quality are distinguished?

15. Physical parameters of water quality:

a. color;

b. salinity;

c. temperature;

d. turbidity;

e. pH.

16. To classify the ecological status of a surface water body, … classes are used to (fill in the missing word).

17. Name the main sources of marine pollution.

18. What are the requirements for the new procedure of monitoring of marine waters?

19. What is "good environmental status" according to the European approach?

20. Name the descriptors that are used to recognise the good environmental status of marine waters.

8. SOIL AND LAND MONITORING

Land is an essential building block of civilization. Land, literally the ground beneath our feet, is a finite resource composed of soil, water, minerals, plants, and animals. It is an essential part of our life support system and the key building block of our societies and economies.

The United Nations Convention to Combat Desertification (UNCCD) defines land as "the terrestrial bioproductive system that comprises soil, vegetation, other biota, and the ecological and hydrological processes that operate within the system."

Healthy and productive land resources – soil, water, and biodiversity – are the foundation of societies and economies. But in recent decades, land resources have been subject to persistent degradation and loss due to global patterns of human domination.

8.1 General concepts of land degradation

Land degradation is the reduction or loss of the biological or economic productivity and complexity of rainfed cropland, irrigated cropland, or range, pasture, forest, and woodlands resulting from land uses or from a process or combination of processes arising from human activities.

The drivers of land degradation are mainly external factors that directly or indirectly impact the health and productivity of land and its associated resources, such as soil, water, and biodiversity.

Direct drivers are either natural (e.g., earthquakes, landslides, drought, floods) or anthropogenic (i.e., human-induced); some of the latter influence what would formerly be thought of as natural climatic events.

Human-induced drivers such as deforestation, wetland drainage, overgrazing, unsustainable land use practices, and the expansion of agricultural, industrial, and urban areas (i.e., land use change) continue to be the most significant proximate cause of land degradation.

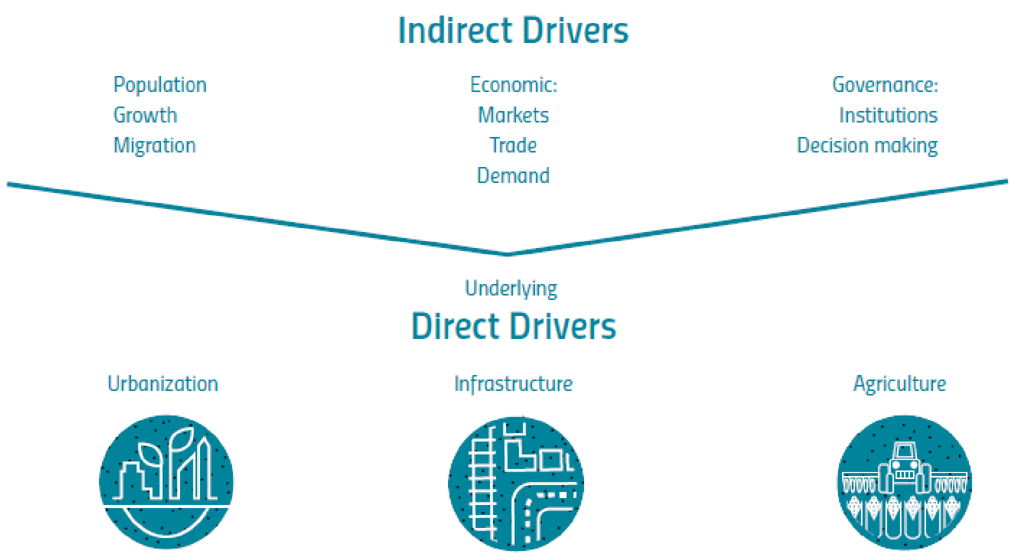


Figure 8.1 Indirect drivers underlying direct drivers

Source: Global Land Outlook, 2017

The indirect or underlying causes of land degradation (indirect drivers) are linked to lifestyles, economies, and consumption patterns, a complex mixture of demographic, technological, institutional, and sociocultural factors. Indirect drivers are far more complex and operate at larger and longer scales and farther from the area of degradation.

Direct and indirect drivers interact, mutually reinforcing each other and together drive land degradation in many parts of the world.

Soil degradation is a key factor undermining food security. Soils can be degraded over time either qualitatively (e.g., salinization) and quantitatively (e.g., erosion).

There are several major types of soil degradation processes.

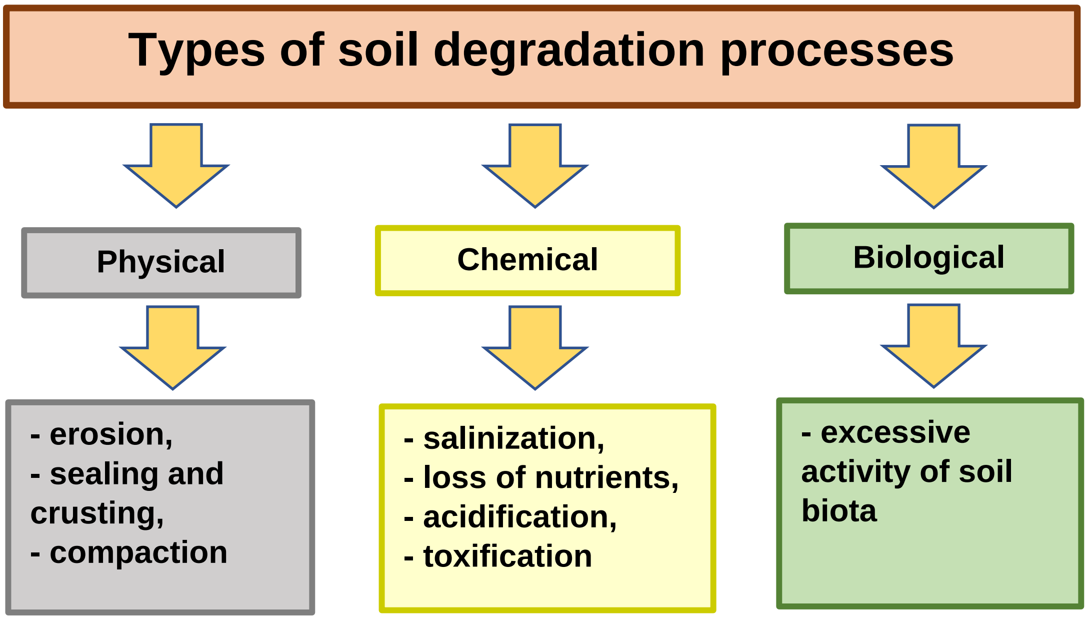


Figure 8.2 The major types of soil degradation processes

1) Physical degradation: the structural breakdown of the soil through the disruption of aggregates. This results in the loss of pore function, which in turn leads to a reduction in surface infiltration, increased water run-off, and decreased drainage. In time, this leads to a decrease in the availability of gases for plants and biota. Physical degradation processes include erosion, sealing and crusting, and compaction.

2) Chemical degradation: processes leading to soil chemical imbalances, including salinization, loss of nutrients, acidification, and toxification.

3) Biological degradation: the artificial disruption of soil structure (for example, through tillage) can lead to excessive activity of soil biota due to oxygenation and excessive mineralization of organic matter leading to the loss of structure and nutrients.

All these processes can be influenced by a number of direct drivers, natural and anthropogenic, influencing soil processes in different ways, including the nature and speed of the processes.

Direct natural drivers include climate, natural hazards, geology and geomorphology, and biodiversity.

Climate has a significant impact on soil processes and the provision of ecosystem services. Local climate (such as rainfall intensity, temperature, sunshine) influences supporting processes and biodiversity by driving soil moisture and temperature.

Natural hazards, like earthquakes or volcanic eruptions for example, can change the soil environment and the geological origin of parent material determines the initial minerals that drive soil development and properties as will the type and variety of species present.

Anthropogenic drivers, such as land use, farming practices and technologies, also greatly influence soil processes (Fig. 8.3). The type of land use (such as cropping, livestock) determines the type of disturbance (for instance, tillage, treading, use of agrochemicals) as well as applied inputs (for example, excrements, synthetic fertilizers).

Farming practices determine the intensity of disturbances (such as organic versus conventional cropping) and the amount of inputs (for example quantity and timing of fertilization).

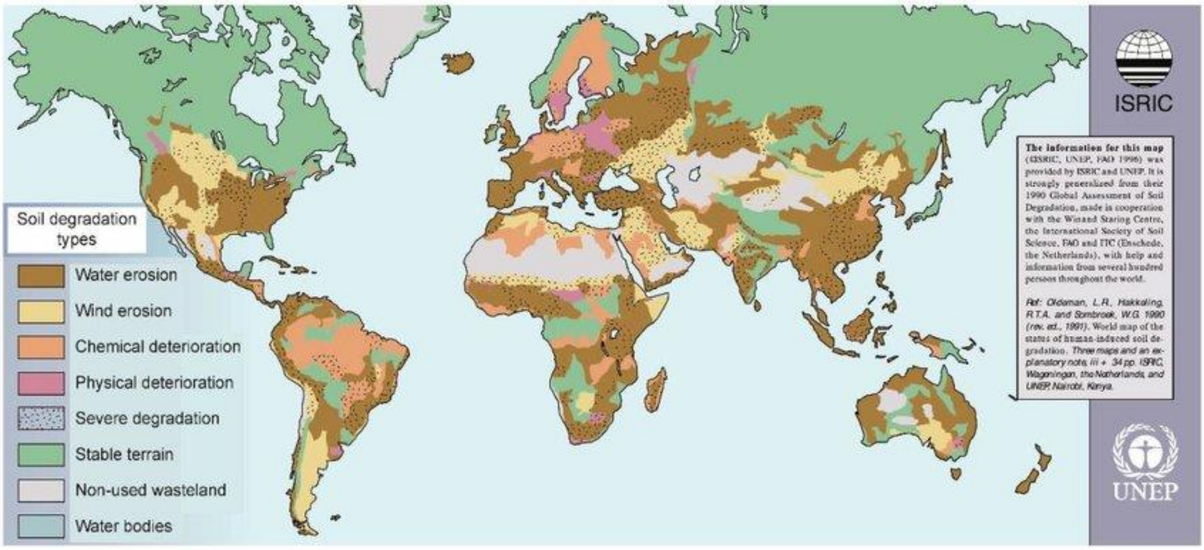


Figure 8.3 World Map Showing Human Induced Soil Degradation

Source: International Soil Reference and Information Centre, 2017

8.2 Overview of the land fund of Ukraine

The land fund of Ukraine is one of the biggest in Europe. If, for instance, cultivated land in developed European countries occupies from 30 to 32 per cent of the total area, in Ukraine this parameter extends to 56.1 per cent.

The lands of Ukraine include all lands within its territory, as well as islands and lands occupied by water bodies, which are divided into 9 categories according to their intended purpose:

1) Lands for agricultural use;

2) Lands for housing and civil building use;

3) Lands for natural reserve and other environmental protection use;

4) Lands for health-improving purpose;

5) Lands for recreational use;

6) Lands for historic and cultural use;

7) Forest fund lands;

8) Water fund lands; and

9) Lands for industrial, transportation, communications, energy, defense and other purposes.

Within the category of land of agricultural purpose, there are agricultural lands - lands that are systematically used or are suitable for use for specific economic purposes and are distinguished by natural and historical features (arable land, hayfields, pastures, perennial plantations and fallow lands).

Ukraine has a significant land and resource potential. As of 1 January 2021, according to the State Geocadastre of Ukraine, the land fund of Ukraine is 60.3 million hectares, of which agricultural land is 17.6 million hectares, including arable land - 14.83 million hectares.

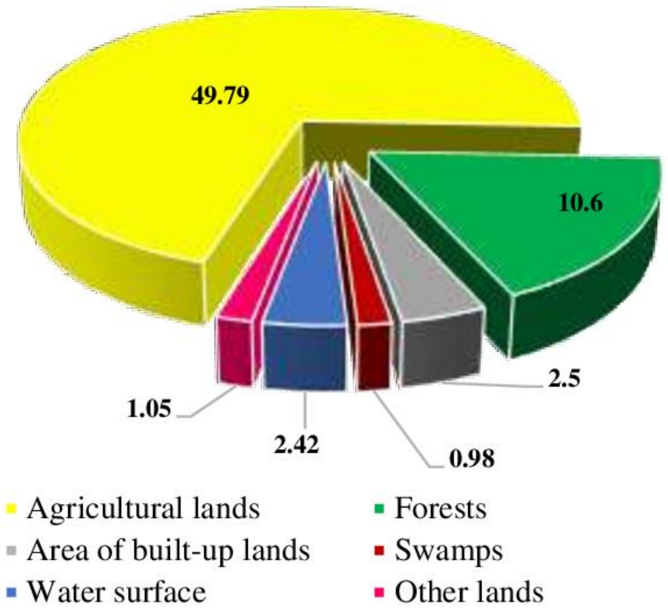


Figure 8.4 The land fund of Ukraine structure as of January 1, 2020, million hectares [48]

The country's agricultural production resources are: 78.4 per cent arable land; 13.1 per cent pastures; 5.8 per cent hayfields; 2.1 per cent perennial plantations; 0.6 per cent fallow lands.

Forests and other areas covered by forests account for 17.6% of the country's territory; built-up land accounts for 4.2%; areas with water 4.2%; marshes 1.6%; and other 3.5%.

The peculiarity of the soil cover of Ukraine is its diversity (about 40 types and more than 800 subtypes) and heterogeneity, with low-productive, technogenically polluted and degraded soil areas spread up to 10-15 million ha.

Table 8.1 Ukraine: soil distribution [49]

Soils (based on Ukrainian classification)	Agricultural lands (thousands ha)	Arable (%)
Chernozem podzolic	3 418.7	91.6
Chernozem typical	5 779.6	91.8
Chernozem ordinary	10 488.6	88.3
Chernozem southern	3 639.9	88.8
Meadow chernozem and chernozem-meadow	2 038.9	60.0
Light-grey forest, forest grey, dark grey podzolic	4 333.4	80.5
Sod-podzolic, podzolic, grey	3 850.2	74.1
Dark brown, chestnut saline, saline meadow-chestnut, chestnut salt	1 382.9	80.0
Brown (podzolic, podzolic, meadow brownsoil-podzolic gley)	1 110.0	43.9
Brown	48.5	26.2
Meadow and marsh and swamp	975.3	7.9
Alluvial meadow and meadow-swamp	781.9	18.8
Peat from lowland	559.4	14.9
Sod-sandy and sandy-coherently and sand	505.5	24.2

More than 60% of the country's land resource structure is made up of chernozem-type soils which are characterised by: 1) excellent fertility potential, 2) abundant humus and nutrient reserves, 3) favourable structure and water regime for plants; and 4) high biological activity.

According to the estimates of Ukrainian scientists, Ukrainian croplands are mostly located in favourable natural climatic conditions for the growing of most agricultural crops.

About 1/10 of all arable land areas are located in the Polissya, about 2/5 - in the Forest-steppe, and half of it is concentrated in the Steppe zone. Cropland in the mountainous region of Crimea and the region of brown forest soils in the Carpathians occupy an insignificant proportion of the soil pool, but are important because they can be used to grow tobacco, grapes, aromatic oil plants, vegetables and fodder crops.

Figure 8.5 Ukraine's valuable farmlands

Source: https://www.gisreportsonline.com/r/ukraine-agricultural-production/

8.3 Specific features of land monitoring in Ukraine

Land monitoring (monitoring of lands and soils) is one of the subsystems of the state environmental monitoring system. Legislative and regulatory tools for the organisation and implementation of land and soil monitoring are 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 20 August 1993 No. 661 "On Approval of the Regulations on Land Monitoring".

Land monitoring is a system of observation of the state of the land fund, including lands located in the zone of radioactive contamination for the purpose of timely identification of changes, their assessment, prevention and elimination of consequences of negative processes.

The land monitoring system collects, processes, transmits, stores and analyses information on the state of the land fund, forecasts their changes and develops scientifically based recommendations for decision-making on prevention of negative changes in lands and compliance with environmental safety requirements.

The object of land monitoring is all lands irrespective of their form of ownership. Soil monitoring is an integral part of land monitoring, particularly on agricultural lands.

The Regulation on Land Monitoring provides for the following types of monitoring:

1) national;

2) regional;

3) local.

Observations on the condition of land, depending on the term and periodicity of their implementation, are divided into:

● basic (baseline, registering the state of the object of observation at the time of the beginning of land monitoring);

● periodic (conducted after a year or more);

● operational (capturing current changes).

The basic tasks of land monitoring are to forecast the ecological and economic impact of degradation of land plots, to provide information for the State land cadaster, to organize land use and land engineering, to effect state oversight of land use and protection in order to avoid or eliminate the action of negative processes.

The Provision on soil monitoring on agricultural lands (approved by the Order of the Ministry of Agrarian Policy No. 51 dated 26.02.2004) refers soil monitoring on agricultural lands to the integral part of the SEMS. Among the executing agencies of such monitoring, apart from the Ministry of Agrarian Policy, are: The Ministry of Environment, State

Geocadastre, State Water Agency and research institutions of the National Academy of Sciences in the field of land protection.

From the list of the mentioned entities, only the State Water Agency approved the Instruction on organisation and implementation of monitoring on irrigated and drained lands, which defines the powers and functions of the State Water Agency and its territorial bodies on implementation of monitoring of irrigated and drained lands.

Probably, in the process of implementation of the land market in Ukraine, the Regulations on Land Monitoring will undergo fundamental changes, because the purpose of this document, in addition to the issues of assessing the condition of agricultural land, will acquire a broader context in the direction of introducing approaches to assessing the market value of all lands.

Chapter 34 of the Land Code of Ukraine introduces the State Land Cadastre. The State Land Cadastre is the only state geoinformation system of data on lands located within the borders of Ukraine, their intended purpose, restrictions on their use, as well as data on the quantitative and qualitative characteristics of lands, their assessment, and on the distribution of lands between owners and users. The State Land Cadastre is the basis for maintaining cadastres of other natural resources.

According to the Law of Ukraine "On Land Management", one of the sources of initial information for land monitoring is defined as land management works, namely, soil, geobotanical and other land observations conducted by state authorities, local self-government bodies, legal entities and individuals in the process of land management.

The materials of such studies provide information on the qualitative condition of lands, detection of self-deforested areas, lands affected by water and wind erosion, waterlogging, radioactive and chemical pollution, and other negative phenomena. At the same time, the Law establishes the principle of openness and accessibility of land management documentation, as well as determines the procedure for access and use of land management and land evaluation documentation by the State Fund.

The Ministry of Agrarian Policy and Food of Ukraine (Ministry of Agrarian Policy), among other things, monitors soils of agricultural purposes (radiological, agrochemical and toxicological determinations, residues of pesticides, agrochemicals and heavy metals).

The Regulation on the Ministry of Agrarian Policy refers to the main tasks of the Ministry as ensuring the formation and implementation:

● state agrarian policy, in particular on soil monitoring and soil fertility on the lands of agricultural purpose,

● state policy of state supervision (control) in the agro-industrial complex in terms of compliance with land legislation, use and protection of land of all categories and forms of ownership, as well as soil fertility,

● state policy in the sphere of land reclamation and operation of state water management facilities of complex purpose, and inter-farm irrigation and drainage systems.

The State Service of Ukraine for Geodesy, Cartography and Cadastre of Ukraine (State Geocadastre) in accordance with the tasks assigned to it:

● conducts cartographic monitoring of the territory of Ukraine, including the shelf zone and settlements;

● conducts land monitoring and land protection in accordance with legislation.

However, today the State Geocadastre does not participate in the SEMS, as no budgetary funds are allocated for such purposes. According to the Procedure for the Use of Funds Provided for in the State Budget for the Implementation of Land Reform Measures, no funds are provided for environmental monitoring activities for the State

Geocadastre. There are no environmental observation posts (points, stations) in the State Geocadastre.

In fact, the State Geocadastre delegated its land monitoring powers to ***the State Institution "Soil Protection Institute of Ukraine"*** (subordinate to the Ministry of Agrarian Policy). The State Institution " Soil Protection Institute of Ukraine" today includes 24 branches and implements scientific and technical policy in the field of protection of soils and their fertility, rational use and environmental safety of lands of agricultural purpose, environmental objects, determining the quality of products, raw materials, and agrochemicals. In total, this State Institution supervises 754 fixed soil monitoring sites throughout the oblasts of Ukraine, see Figure below.

Figure 8.6 Soil monitoring sites of the State Institution "Soil Protection Institute of Ukraine"

The monitoring performed by this Institute is called Agrochemical certification of fields and land plots. This certification has been carried out since 1965 at five-year intervals. Data of agrochemical certification of land plots are provided in the form of agrochemical passport, the form and the order of which is established by the Ministry of Agrarian Policy and Food of Ukraine.

Agrochemical certification is probably the most relevant for monitoring. However, it is not exactly monitoring, because observations are not made on fixed plots and are made for a limited list of indicators. In addition, certification does not even give a complete picture of changes in soil fertility, as it does not determine physical, numerous chemical and biological indicators.

For example, Ukrainian soils are the most vulnerable to erosion and compaction, but agrochemical passportisation does not involve the collection of systematic spatial and temporal information on their dynamics. It only aims to assess the nutrient regime of the land, the reaction of soil solution and certain pollutants.

As the current EU legislation on land (soil) protection is still developing, there are currently no pan-European approaches to define a mandatory list of pollutants that are priorities for the state land protection management. Within the framework of national land monitoring, the State Institution "Institute of Soil Protection of Ukraine" conducts research:

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● general and agro-physical indicators (7 parameters),

● agrochemical, physical-chemical indicators, content of firmly fixed forms of heavy metals and trace elements, residues of persistent pesticides (14 parameters),

● content of mobile forms of microelements and heavy metals (8 parameters),

● gamma background and specific activity of caesium - 137 and strontium - 90.

The State Agency of Water Resources of Ukraine, as previously noted, monitors irrigated and drained lands (depth and salinity of groundwater, degree of salinity and salinity of soils); waterlogging of rural and settlement communities and coastal zones of reservoirs (overforming of banks and waterlogging of territories).

Observations of groundwater levels on reclaimed lands and in rural settlements are carried out using about 32,000 observation wells on the area of 2.26 million ha of irrigated and 2.96 million ha of drained agricultural lands.

Within the framework of soil monitoring in the regions of hydrotechnical reclamation, subdivisions of the State Water Agency monitor 17 parameters, including general and agrophysical parameters (5 indicators), physical and chemical parameters (9 indicators) and analise the content of heavy metals and their water-soluble forms (3 indicators).

The State Geological Survey. Enterprises of the geological industry also conduct systematic observations of the development of dangerous exogenous geological processes (landslides, karst, abrasion, erosion). According to the information of the state enterprises under the authority of the State Geological Survey, their laboratories also analyse rocks, soil, etc.

The Regulation on land monitoring does not define ***the State Emergency Service*** as the subject of monitoring, but SES carries it out on 13 parameters at 41 sampling stations. The mentioned monitoring includes determination of: toxicants of industrial origin (heavy metals - cadmium, manganese, copper, nickel, lead, zinc), acidity (pH) and mechanical composition of soil, as well as observations of contamination of agricultural soils with residual amounts of pesticides (n, n - DDE, n, n - DDT, ά - HCCH, γ - HCCH) and nitrates.

The objects of observations are soils of settlements and agricultural lands (fields, orchards). To determine residues of pesticides, for example, in 2017 a sample of farmland was surveyed in 27 administrative districts in 13 regions of Ukraine. The content of toxicants of industrial origin was determined selectively in soils of 21 settlements of 13 regions of Ukraine.

The Ministry of Health monitors soil quality to determine compliance with sanitary and epidemiological standards (in places of residence and recreation of the population, crop production, in sanitary zones of industrial enterprises, in places of storage of toxic waste, etc.). Observations made for soils include pesticide content, heavy metals, bacteriological, virological characteristics, presence of helminth eggs. Laboratory centres of the Ministry of Health perform instrumental quantitative measurements of 57 soil parameters.

8.4 Special aspects of legal support for land and soil monitoring in European and international legislation

Soil monitoring is conditionally divided into:

● monitoring of soil contamination;

● monitoring of soil erosion;

● monitoring of soil salinity.

All these types of soil monitoring make it possible to assess both the possibility of using soils for certain purposes and to determine their market value.

In 1982, the Food and Agriculture Organisation (FAO) adopted the World Soil Charter, which called on all governments to consider soil as a world heritage of humanity, and in 1983 UNEP adopted the World Soil Policy Framework.

Soil monitoring in Europe operates on the one hand within several programmes (i.e., the International Cooperative Programme for the Assessment and Monitoring of Aerial Pollution of Forests, the International Integrated Monitoring Programme covering 31 European countries, the European Geological Forum) and on the other hand as independent networks of points in some countries.

The development of soil monitoring networks in Europe has been heavily influenced by various EU Directives, notably the "Nitrate" Directive 91/676/EEC, the Directive on the Continuous Use of Pesticides (Directive 2009/128/EC), Directive 86/278/EEC on the protection of the environment and, in particular, soil in cases where sewage sludge is used in agriculture, the Fertilisers Regulation (EU Regulation 2019/1009), the Mercury Regulation (EU Regulation 2017/852) and the Plant Protection Products Regulation (EU Regulation 1107/2009), on permissible concentrations of heavy metals, control of enterprise emissions, application of effluents and industrial waste on agricultural land, and others.

The outcome documents focus on the need to address (harmonise and standardise) a number of methodological issues: soil indicators, formation of EuroSoilMonitoringNet networks, selection and description of objects (sampling techniques, depth and time intervals of sampling), study methods, databases and information systems.

Important aspects of soil pollution regulation include legislation on environmental impact assessment. In order to determine the scope of compensation for environmental damage, it is important to take into account the provisions of EU and CE Directive No. 2004/35/EC of 21 April 2004 on environmental liability for the prevention and remediation of environmental damage.

In recent years, soil monitoring activities have been intensified in many EU countries due to the adoption of the new EU Soil Strategy for

2030 on 17 November 2021 (Communication from the Commission "EU Soil Strategy for 2030 Reaping the benefits of healthy soils for people, food, nature and climate"), which proclaims the creation of a global soil monitoring network.

Such a system involves the use of various sensors (working in real time) to monitor soil contamination, its bio-geophysical characteristics with the involvement of remote sensing data of the earth's surface, and so on.

According to the view of the experts, the newly created EU Soil Observatory will play a central role in the implementation of the Soil Strategy, as it will provide the required data and the necessary indicators for regular evaluation of the state of soils in the EU.

Figure 8.7 The five main functions of the EU Soil Observatory

Source: Concept Note for the EU Soil Observatory, Ispra, September 2021

One of the instruments, the EU-wide Soil Monitoring System (EUSO), is expected to support developing a harmonised monitoring system of soils for the EU by integration of the existing LUCAS Soil programme with national or regional activities in the field of soil monitoring.

The final monitoring system should help to produce indicators that reflect the policy objectives (for example, erosion, SOC MVR, biodiversity, Soil Pollution Watch List, and others).

Besides practical sample planning considerations for the monitoring network (geographical location, parameters to be measured both qualitatively and quantitatively), a common data infrastructure (for collection, transmission, sharing, dissemination) based on INSPIRE principles will be developed. The results of soil monitoring will be submitted to the European Soil Data Centre (ESDAC).

The UN Convention to Combat Desertification (UNCCD), which Ukraine acceded to on 04 July 2002, encourages Parties of the Convention to strengthen assessment and monitoring capacities, including hydrological and meteorological services.

Parties' National Action Plans should include measures for monitoring and assessing the impacts of drought, including monitoring and assessment of environmental degradation to provide reliable, timely information on the processes and dynamics of resource degradation to inform and facilitate the development of more effective policies and measures.

In the EU, land and soil monitoring is carried out by:

● The European Environment Agency, in particular, its European Topic Centre on Urban Land and Soil Systems (ETC/ULS), which is part of the Eionet network;

● European Statistical Office (Eurostat);

● within the Eionet network, thematic groups of experts known as National Reference Centres Soil, or NRC Soil.

In particular, Eurostat has organised the LUCAS land monitoring platform (the EU's land use and land cover survey) and maintains the LUCAS topsoil database. Scientific and technical support for these activities is provided by the Joint Research Centre at the European Commission.

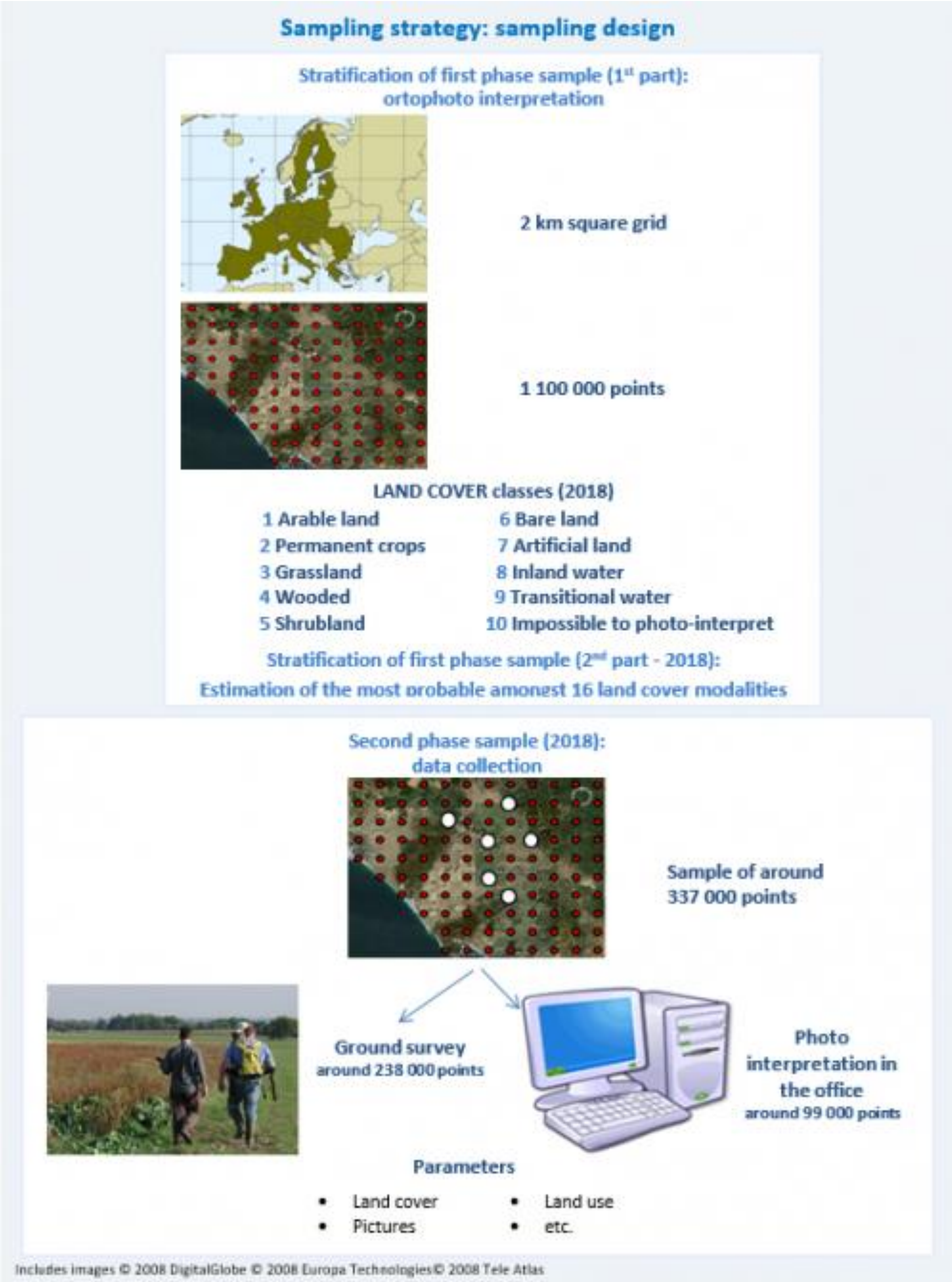


Figure 8.8 LUCAS - schema for data collection exercise

Source: https://ec.europa.eu/eurostat/statistics-explained/index.php?title=LUCAS_-_Land_use_and_land_cover_survey

All institutions and agencies work closely together to coordinate efforts and exchange relevant information.

The methodological basis of land and soil monitoring at LUCAS is that monitoring is conducted by means of spot statistical observations, at more than 250,000 points across the EU. Observations cover different types of land use and types of land cover. Observations are repeated every few years, which allows for the detection of changes in land use.

The methodological basis for the EU land cover identification is 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 monitoring of soil condition have been identified:

● their physical degradation (as a result of erosion, soil sealing, compaction);

● chemical degradation (pollution, acidification, eutrophication);

● biological degradation of soils, loss of organic matter and their multifunctional properties (in other words, their ecosystem functions).

In general, the organisational and methodological framework for land monitoring in the EU is quite well developed. In 2021, the European Topic Centre 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, there are still some issues in the organisation of soil monitoring system in the EU, in particular regarding target parameters, sampling schemes and their analysis, criteria for spatial and temporal representativeness, requirements for statistical processing to assess uncertainties and trends, levels of intensity (detail) of measurements, integration with other types of environmental monitoring (climate, air, biodiversity, water quality).

8.5 Organisation of land monitoring based on remote sensing technologies: European experience

The Copernicus Land Monitoring Service (CLMS) provides geographical data on land cover and its changes, land use, vegetation status, water cycle and variable energies of the Earth's surface to a wide range of users in Europe and worldwide in environmental terrestrial applications.

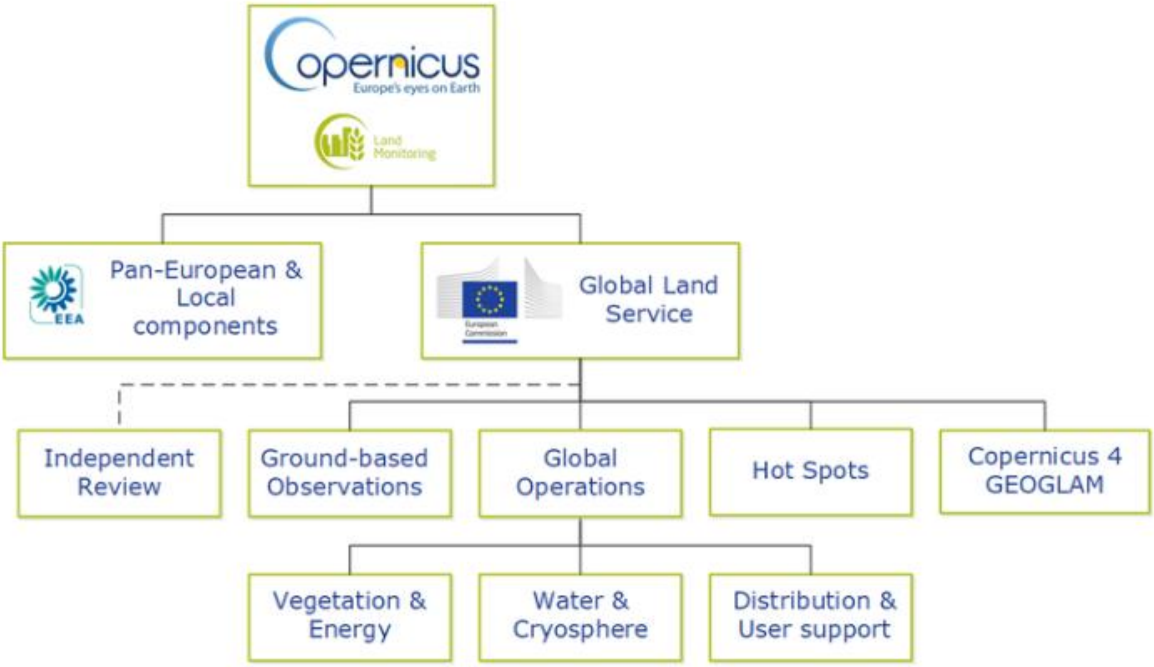


Figure 8.9 Organisational network of the Copernicus Global Land Service

Source: https://land.copernicus.eu/global/about

It supports programmes in various areas such as water management, spatial and urban planning, forest management, agriculture and food security, rural development, nature conservation and restoration, ecosystem accounting and climate change mitigation/adaptation.

CLMS is implemented together by the European Environment Agency and the European Commission's Joint Research Centre (JRC) and has been functioning since 2012.

CLMS consists of five main components:

Systematic biophysical monitoring yields mainly a number of qualified biogeophysical products on the state and evolution of the land surface. These are produced globally every ten days at medium spatial resolution and supplemented with long-term time series. Products are used for monitoring vegetation, crops, energy budget, water cycle and terrestrial cryosphere variables.

Land cover and land use mapping generates land cover classifications at different levels of detail in both pan-European and global contexts. At a pan-European level, these are complemented by detailed layers of land cover characteristics such as waterproofing, forests, grasslands, water and humidity, and small tree elements. At the global level, land cover mapping follows FAO's modular-hierarchical land cover classification system.

Thematic hotspot mapping aims to provide tailored and more detailed information on specific areas of interest, known as hotspots. Hotspots in the context of CLMS are prone to certain environmental problems.

Satellite images and Reference Data provides a mosaic of high and very high resolution satellite imagery and reference datasets. This includes, on the one hand, a series of satellite images from contributing missions covering Europe, as well as the creation of a mosaic of Sentinel-2 images at the worldwide level. On the other hand, it consists of reference datasets providing homogeneous pan-European coverage of some key geospatial topics such as hydrography and height.

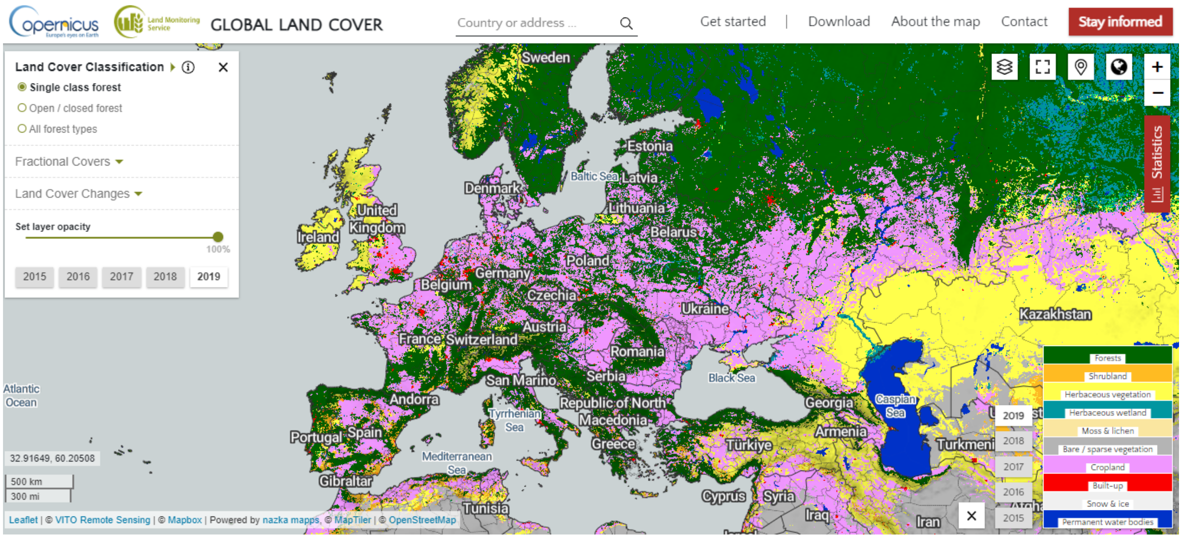


Figure 8.10 One of the CLMS products: Global Land Cover viewer for maps and area statistics

Source: https://lcviewer.vito.be/2019

The European *Ground Motion Service* (EGMS) provides a unique opportunity to study geological hazards and anthropogenic deformations such as slow landslides, surface subsided due to the exploitation of groundwater or underground mining, volcanic eruptions and much more.

8.6 Specificities of land degradation and desertification monitoring processes. The concept of Land Degradation Neutrality

As previously noted, land degradation is any change in the condition of the land which reduces its productive potential. It is the deterioration in the quality of land, its topsoil, vegetation, and/or water resources, caused usually by excessive or inappropriate exploitation.

Desertification means land degradation in arid, semi-arid and dry sub-humid areas resulting from various factors, including climatic variations and human activities.

The current use of Ukraine's land resources does not meet the requirements of rational environmental management. The state of Ukraine's land resources is close to critical.

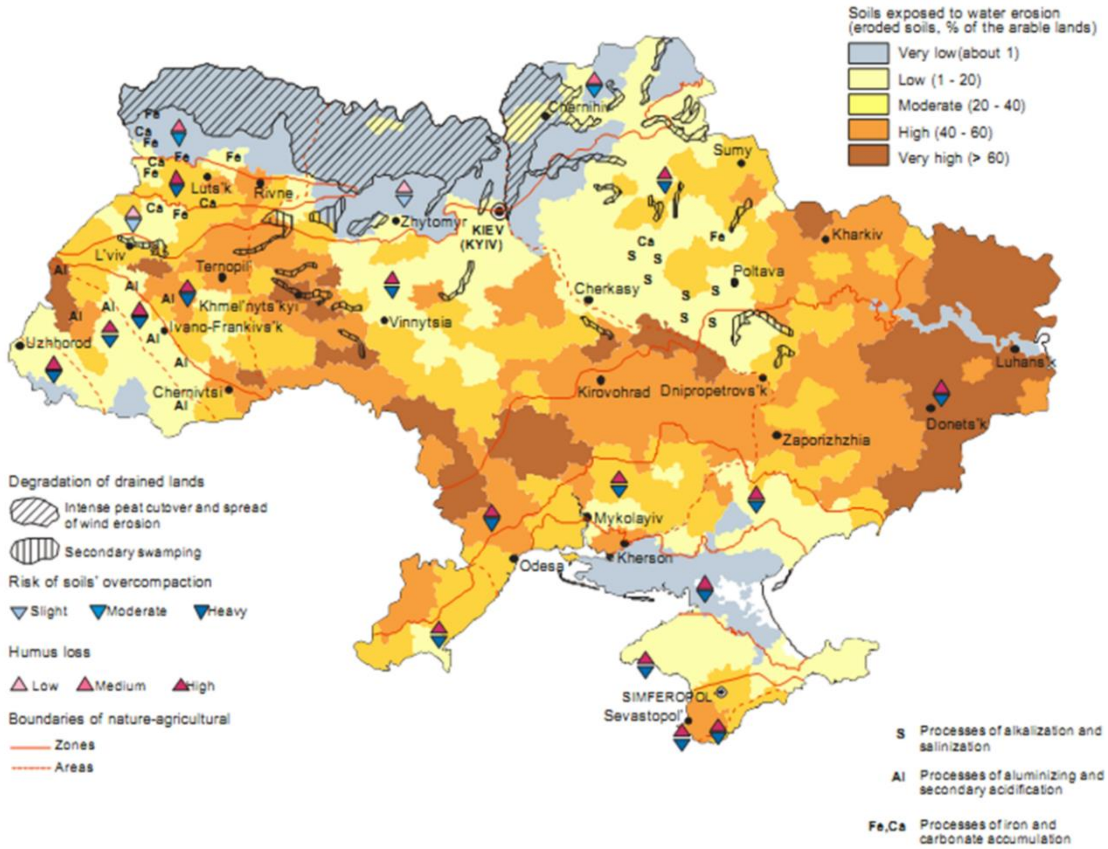


Figure 8.11 Distribution of soil and land degradation processes in Ukraine

Source: http://www.fao.org/3/a-i3905e.pdf

About 57 per cent of Ukraine's territory is affected by water and wind erosion, and more than 12 per cent of the state's territory is subject to waterlogging.

According to different criteria, about 20 per cent of Ukraine's land is contaminated. About 23,000 cases of landslides are recorded annually. As a result of abrasion, up to 60 per cent of the coastline of the Azov and Black Seas and 41 per cent of the shoreline of the Dnipro reservoirs are destroyed. More than 150 thousand hectares of land are disturbed as a result of mining and other activities. The number of underground and surface sinkholes is about 27 thousand.

The reasons for this situation are complex and have historical backgrounds. It should be especially noted the violation of the ecologically balanced ratio between land categories, the reduction of the territory of unique steppe areas, excessive ploughing of the territory and violation of the natural process of soil formation, the use of imperfect technologies in agriculture, industry, energy, transport and other sectors of economy, the focus on achieving short- and medium-term economic benefits, while ignoring the environmental component and negative consequences in the long term.

Table 8.2 Types and subtypes of soil degradation according to DSTU 7874:2015

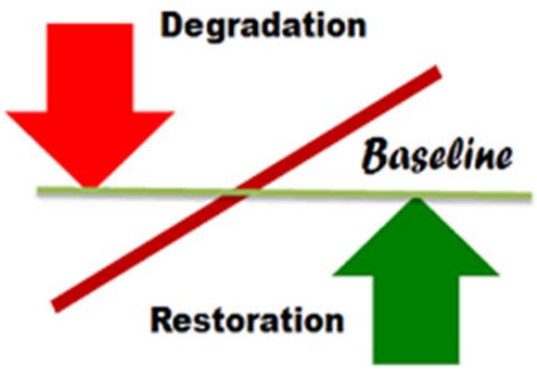
Type of Degradation	Degradation Subtype	Type of Degradation	Degradation Subtype
Mechanical	Water erosion	**Physico-chemical**	Acidification
	Deflation		Secondary salinization
	Mechanical disturbances		Decalcification
	Drifted debris		Reduction of oxidation-reducing potential and loss of buffer functions
Physical	Deterioration of physical properties in soil	**Biological**	Reduced biodiversity
	Perpetual changes in granulometric and aggregate composition		Reduced biological activity of soil
	Perpetual changes in water and thermal regime		Deterioration of sanitary conditions
Chemical	Deterioration of soil-humus conditions		Toxicity of soil
	Trophic depletion of the soil	**Radiation**	Radioactive contamination
	Salinity		
	Pollution/ contamination		

Today, given that most of the military activities taking place in the area of distribution of the most fertile soils of Ukraine and Europe, it can be assumed that the impact of pollution and the effects of erosion on agriculture will be very significant and probably more significant than the impact on wildlife.

Hundreds of hectares of agricultural land have been damaged as a result of fighting, the location of military and auxiliary units, and mine contamination, which will require special reclamation to return the farmland to use again.

According to State Standard ‘DSTU 7874:2015’, soil-degradations feature 6 types and over 20 subtypes (see Table 8.2 above).

Currently, information on the condition of lands and distribution of particular types of degradation processes in Ukraine is collected by different subjects of monitoring according to different methodologies. That is why it is very difficult to compare them, to spatially identify the affected areas and the proportion of degraded land in the country.



Land Degradation Neutrality (LDN) is a new approach to land degradation management introduced to stop the ongoing loss of healthy land as a result of unsustainable land management and conversion.

The LDN is one of the main pillars of the global 2030 Agenda for Sustainable Development: The LDN underpins the achievement of several Sustainable Development Goals (SDGs) connected with food security, reduction of poverty, environmental protection and efficient use of natural resources.

The indicator selected to measure the achievement of SDG target 15.3 is the " share of degraded land in total land area".

The monitoring of this index, as well as the LDN monitoring, is founded on the joint use of three sub-indicators, specifically 1) land cover, 2) land productivity and 3) above and below ground carbon stocks. These indicators should be reinforced and extended with other nationally relevant indicators and relevant information at the national and regional levels.

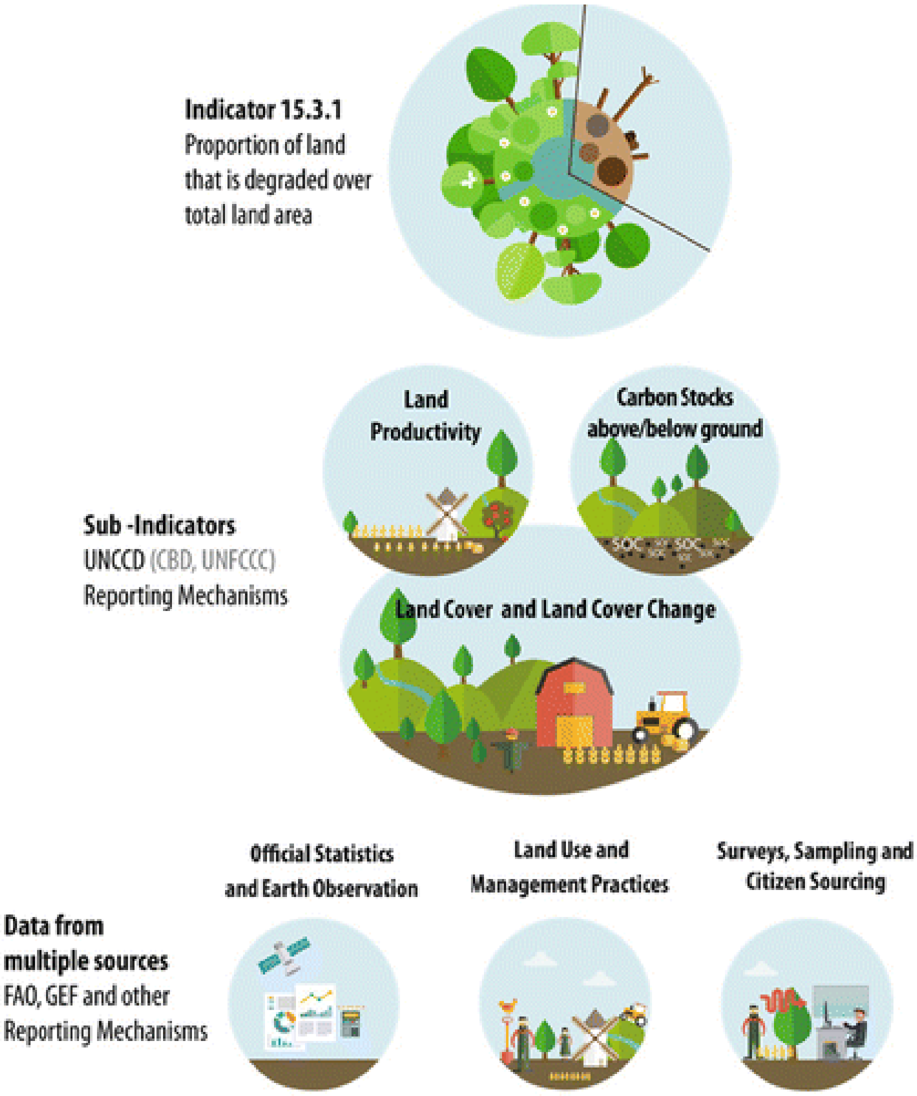


Figure 8.12 Indicator framework for monitoring and reporting on Sustainable Development Goal target 15.3.
Source: UNCCD et al., 2016

For LDN purposes, it is important to point out that these three indices provide good capture of the ecosystem services on land underlying LDN, and in combination can be used to monitor the quantity and quality of natural capital on land and the ecosystem services derived from this land basis.

Additionally, these indicators reflect changes in the system in different ways, but at the same time in a very relevant way.

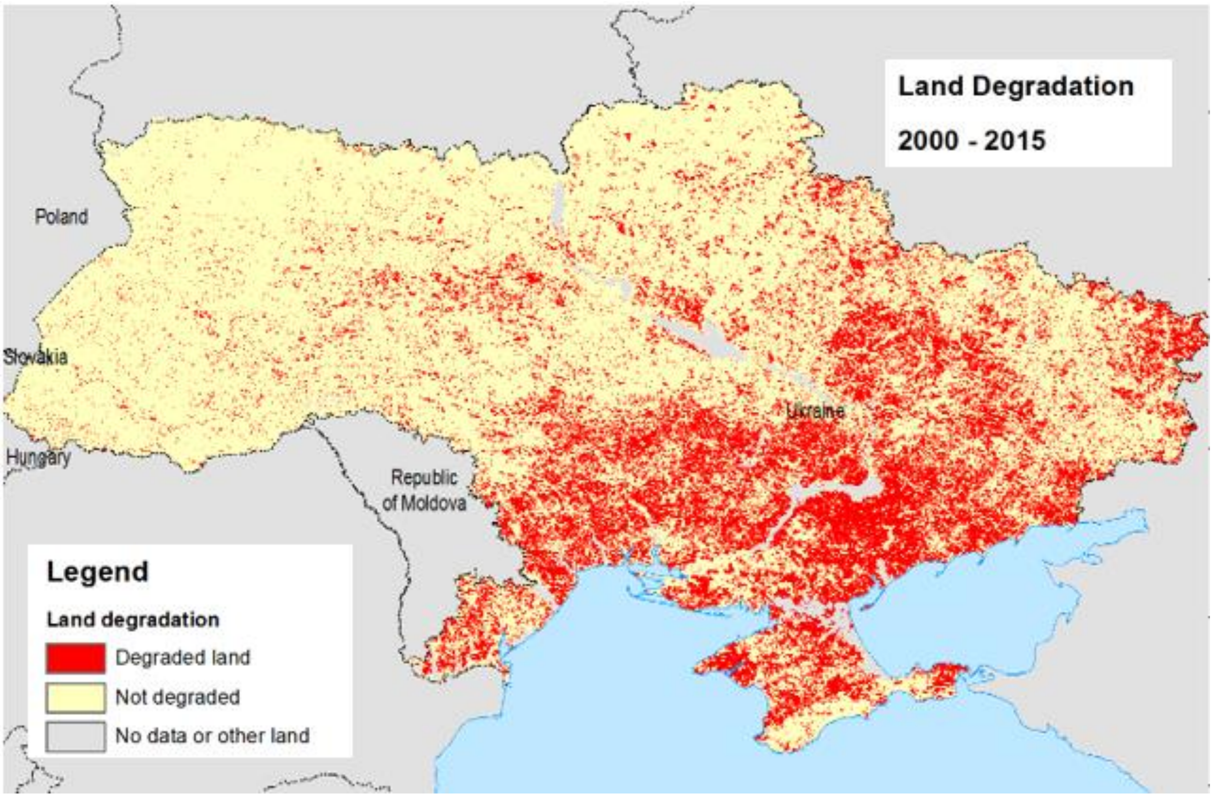


Figure 8.13 Proportion of land that is degraded over total land area (Sustainable Development Goal indicator 15.3.1)

Land cover provides a first understanding about vegetation decline or increase, environmental fragmentation and land conversion, land productivity reflects relatively rapid changes, whereas SOC shows slower changes that indicate the direction and closeness to thresholds. A map of land degradation in Ukraine (2000-2015) using global default data and based on the above indicators is presented in Figure 8.13.

To achieve the SDG goal of a land degradation-free world, countries were invited to take voluntary commitments to LDN at the national level.

Ukraine participated in the LDN TSP and developed with the participation of the National Academy of Agrarian Sciences proposals for possible national voluntary LDN targets. These proposals were discussed and then approved by the Coordination Council for Combating Land Degradation and Desertification of Ukraine at its meeting on 4 May 2018.

The following LDN voluntary targets were set:

- Stabilisation of the content of soil organic carbon in agricultural land:

- by 2020, achieve a stable level of soil organic carbon (humus) content in agricultural land (not lower than the baseline).

- by 2030, increase the content of soil organic carbon (humus) in agricultural land by at least 0.1%, including by zone:

- Polissya - by 0.10-0.16%;

- Forest-steppe and Steppe - by 0.08-0.10%.

As additional tasks, it was adopted:

- rehabilitation and rational use of peatlands;

- restoration of irrigation and enhancement of ecological and reclamation conditions of irrigated lands.

8.7 Improvement of soil monitoring

Recently, many steps have been taken to form a modern system of land montitoring in our country. It is obvious that such a system should be created on the basis of existing institutions and organisations related to soil monitoring, as considerable funds are needed to organise this mission. This system should be single, unified for the whole country, with clear hierarchical levels, interconnected and well-coordinated management and execution system.

In accordance with the existing legislation, the land monitoring system is being improved by determining and elaborating standards and normative acts in the field of land use and land protection, in particular, protection and reproduction of soil fertility.

Improvement of the procedure of land monitoring in Ukraine needs to develop and introduce a number of mechanisms for coordination of interaction and all monitoring subjects using a unified system of methods and technologies for planning, organising and implementing observations and common activities, which will contribute to prompt response of local executive bodies and authorities to the emergence or risk of emergencies and adequate control over their development and mitigation of consequences.

The key objectives of the development of the land monitoring system are: strengthening the organisational and legal provisions for monitoring; creating a unified integrated monitoring system; optimising methods of land monitoring; defining and preparing standards and normative acts in the area of land use and protection; providing for more complete integration of information resources; enhancing coordination of subjects of monitoring and data management in the framework of the state land monitoring system in Ukraine; participation in international land monitoring research and harmonisation of Ukrainian standards with international requirements for integration of the national land monitoring system into international systems.

By Presidential Decree No. 111 of 23 March 2021, the task of preparing a draft law on soil conservation and protection of soil fertility was defined.

To implement this Decree, the Ministry of Agrarian Policy and Food of Ukraine has developed a draft concept of the National Programme for Land Use and Protection until 2030, where the task of land monitoring is a priority. The Cabinet of Ministers of Ukraine approved this concept by its Resolution No. 70-r dated 19 January 2022.

It is emphasised that changes in land tenure in Ukraine, the development and widespread introduction of information technologies, as well as the need to ensure food security of the state in the context of global climate change and new economic challenges, require the improvement of the system of information support for monitoring the land condition. Despite the large amount of accumulated information, its dispersion between different data sources hinders objective assessment of the land and soil conditions, as well as planning and measures for their protection.

The development of criteria for monitoring, the basics of monitoring based on automated information-analytical systems and remote sensing of the Earth are among the pressing problems that need to be solved first of all. And ensuring public monitoring will give everyone an understanding of what site is in what condition in terms of soil quality indicators.

Questions for self-control

1. How many percent do arable lands occupy in developed European countries?

2. What does land degradation mean?

3. How many categories have the land fund according to Land Code of Ukraine?

4. The structure of agricultural lands is as follows:

1. 78,0 % *A pasture*

2. 13,2 % *B multi-annual plantings*

3. 5.8% *C fallow lands*

4. 2.1% *D arable lands*

5. 1% *E hayfields*

5. How many types of monitoring are envisaged by the Regulation on Land Monitoring?

6. What are the main objectives of land monitoring?

7. What parameters are monitored by State institution "Soil Protection Institute of Ukraine"?

8. How frequently eco- agrochemical passportization of fields and land areas is carried out?

9. What types of land does the State Agency of Water Resources of Ukraine monitor?

10. What types of soil monitoring can be divided into in the EU?

11. What issues still remain in the EU soil monitoring system?

12. Degraded soils can be damaged in several ways:

a. by physical compaction and loss of aggregate stability;

b. in lower agricultural yields;

c.) through soil acidification, salinity, erosion and desertification;

d. through higher production costs.

13. How can we describe depleted soils?

14. Give a brief description of the current state of land use in Ukraine. What problems prevail in the current land use system in Ukraine?

15. What indicator is traditionally considered an integral soil fertility indicator?

a. level of plant nutrients;

b. ecological balance;

c. humus level;

d. overgrazing.

16. What kind of soil contamination do you know?

17. The monitoring of indicator SDG 15.3 is based on the combined use of sub-indicators:

a. Land cover;

b. Carbon stocks and stock changes in livestock production systems;

c. Land productivity;

d. Carbon stocks above and below ground.

18. Changes in what indicator of LDN provide a first indication of a reduction or increase in vegetation, habitat fragmentation and land conversion?

19. What are the priority actions to improve land and soil monitoring?

20. What innovative principles are envisaged to be implemented in monitoring in accordance with the concept of the National Programme of Land Use and Protection until 2030?

9. MONITORING OF BIODIVERSITY

9.1 The importance of biodiversity for sustaining life on earth;

9.2 General characteristics of Ukraine's forests;

9.3 The main approaches to conducting forest monitoring;

9.4 Experience in forest monitoring in the European Union;

9.5 Monitoring of fauna and flora: basic provisions;

9.6 Monitoring of biodiversity in international and EU legislation;

9.7 Monitoring of landscapes;

9.8 Background environmental monitoring in Ukraine.

9.1 The importance of biodiversity for sustaining life on earth

Biological diversity - or biodiversity - is the term given to the variety of life on Earth and the natural patterns it forms.

The biodiversity we see today is the fruit of billions of years of evolution, shaped by natural processes and, increasingly, by the influence of humans. It forms the web of life of which we are an integral part and upon which we so fully depend.

This diversity is often understood in terms of the wide variety of plants, animals and microorganisms. So far, about 1.75 million species have been identified, mostly small creatures such as insects. Scientists reckon that there are actually about 13 million species, though estimates range from three to 100 million (Figure 9.1).

Biodiversity also includes genetic differences within each species - for example, between varieties of crops and breeds of livestock. Chromosomes, genes, and DNA-the building blocks of life-determine the uniqueness of each individual and each species.

Yet another aspect of biodiversity is the variety of ecosystems such as those that occur in deserts, forests, wetlands, mountains, lakes, rivers, and agricultural landscapes. In each ecosystem, living creatures, including humans, form a community, interacting with one another and with the air, water, and soil around them.

Figure 9.1 Biologists estimate that we share the planet with 3.6 million to 100 million species, with a best estimate of 10–14 million species

It is the combination of life forms and their interactions with each other and with the rest of the environment that has made Earth a uniquely habitable place for humans. Biodiversity provides a large number of goods and services that sustain our lives.

The preservation of biodiversity is one of the global environmental challenges. Human impact on the environment has led to the decline of thousands of species of plants and animals, extinction rates have increased by a thousand compared to natural rates.

This is a challenge to Ukraine as well. The third edition of the Red Data Book of Ukraine (2009) includes 839 species of plants and 542 animal species, much more than was in the previous edition (the 1980 edition included only 85 species of animals). If the Red Data Book were published now, this list would be much longer.

Strong efforts should be applied and a complex approach implemented to preserve biodiversity in modern Ukraine. The methods to be used include the development of the network of protected areas, building the ecological network, designing and implementing action plans for protecting and restoring numbers of certain rare and declining species, finding environmentally friendly technologies to be applied in farming, transportation etc.

9.2 General characteristics of Ukraine's forests

The total area of forest lands belonging to the forest fund of Ukraine is 10.4 million hectares, including 9.6 million hectares covered with forest vegetation.

Forests by their purpose and location fulfil mainly ecological (water conservation, protective, sanitary-hygienic, health-improving and other) functions with limited operational significance.

The forest cover of Ukraine is 15.9%, but the forests are very unevenly distributed. They are concentrated mainly in Polissya and the Ukrainian Carpathians. The forest cover in different natural zones has significant differences and does not reach the optimal level, at which land resources are used most efficiently, an ecologically stable environment is formed and the whole complex of useful properties of the forest is most fully expressed.

However, despite its rather small forest cover, Ukraine ranks 9th in Europe in terms of forest area and 6th in terms of timber reserves. Over the last 50 years, the country's forest cover has grown by almost 1.5 times and timber reserves by 2.5 times.

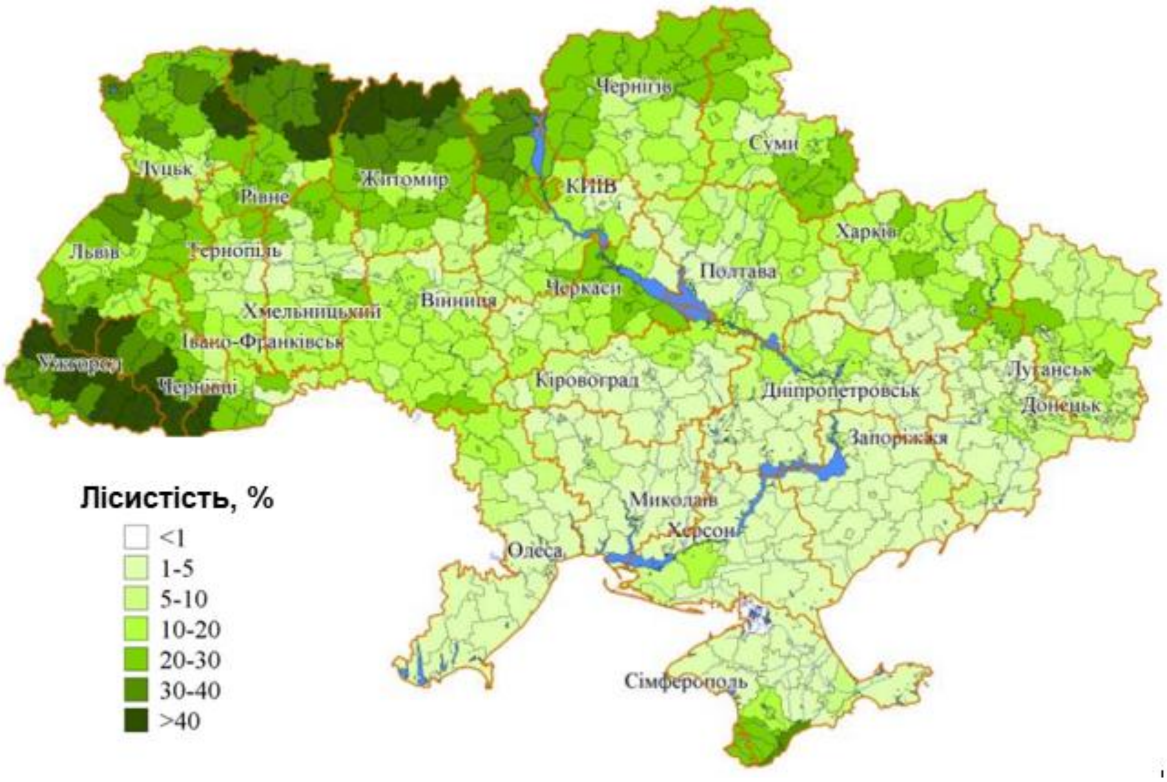


Figure 9.2 Forest cover of Ukraine by administrative-territorial units, %
Source: State Forest Resources Agency of Ukraine

The timber reserve in forests is estimated at 2.1 billion cubic metres. There is a gradual increase in the reserve, which confirms the significant economic and environmental potential of Ukraine's forests.

The highest specific weight is given to middle-aged forest stands - 45%, while mature and over-mature one’s account for about 17%. The average age of forest stands is about 60 years, and forests are gradually becoming old, which affects their sanitary condition.

The forests of Ukraine are formed by more than 30 species of wood species, among which dominate pine (*Pinus silvestris*), oak (*Quercus robur*), beech (*Fagus silvatica*), spruce (*Picea abies*), birch (*Betula pendula*), alder (*Alnus glutinosa*), ash (*Fraxinus excelsior*), hornbeam (*Carpinus betulus*), fir (*Abies alba*). Coniferous plantations account for 43% of the total area, of which pine account for 35% and hard-leaved plantations - 43%.

Figure 9.3 Distribution of forest area by predominant species, %.
Source: Society of Foresters of Ukraine

9.3 The main approaches to conducting forest monitoring

The legislative basis for forest monitoring is the Forest Code of Ukraine (Articles 35, 55) and the Resolution of the Cabinet of Ministers of Ukraine No. 391 of 30 March 1998 "On Approval of the Regulation on the State Environmental Monitoring System".

On 25 June 2020, the Law of Ukraine "On Amendments to the Forest Code of Ukraine regarding National Forest Inventory" that regulates the core principles of national forest inventory came into force.

On 21 April 2021, the Cabinet of Ministers of Ukraine approved the Procedure for National Forest Inventory. The Procedure defines the requirements for the organisation, procedure of the national forest inventory, control over forest inventory work and reporting on its results.

The national forest inventory of Ukraine will provide an opportunity to obtain statistically justified information on quantitative and qualitative indicators of the state and dynamics of the national forests, their resource potential for the needs of state management, strategic planning of forestry, state forest cadastre, environmental monitoring, as well as international reporting on forests.

According to this Resolution, forest monitoring is an integral part of the state environmental monitoring system and its implementation is entrusted to the State Agency of Forest Resources of Ukraine, which is responsible for monitoring:

1) soils of forest land fund (radiological determinations, residual amounts of pesticides, agrochemicals and heavy metals);

2) forest vegetation (damage by biotic and abiotic factors, biomass, biodiversity, radiological determinations, pollutant content);

3) hunting fauna (species, quantitative and spatial characteristics, radiological determinations).

Enterprises of the State Forest Resources Agency conduct forest vegetation monitoring in 24 regions of the country. Forest vegetation monitoring includes assessment of biomass, its damage by biotic and abiotic factors; hunting fauna, biodiversity; radiological determinations.

The data on monitoring of the number, dispersal and harvesting of game species are based on the materials of the statistical bulletin "On Hunting Management". Thus, it can be concluded that monitoring of forests and game management is better developed than other areas of biodiversity monitoring.

From the very beginning, forest monitoring activities in Ukraine have been based on methods harmonised with the Level I monitoring methodology of the UN ECE ICP Forest (Manual on methods, 2010), an international joint programme for the assessment and monitoring of air pollution on forests in the United Nations Economic Commission for Europe.

Since 2000, forest monitoring has been carried out jointly by forest research and design institutions (Ukrainian Research Institute of Forestry and Agroforestry named after G.M. Vysotsky (UkrNIILGA) and Ukrainian State Forestry Design Production Association (PA "UkrDerzhliproekt").

In 2011, according to the Order of the State Forestry Agency, field observations at the sites of monitoring of Level I forests were entrusted to specialists of state forestry enterprises.

Formation of the forest monitoring database was assigned to PA "UkrDerzhliproekt", and scientific and methodological support, data analysis and reporting on the results of monitoring of Level I forests - to UkrNIILGA.

UkrNIILGA served as the national focal point for the international joint programme on assessment and monitoring of air pollution impact on forests (UN ECE ICP Forest). According to the established international requirements, the Institute annually submitted national reporting to the International Coordination Centre of the UN ECE ICP Forest Programme with information on the dynamics of the state of Ukraine's forests at the monitoring sites of Level I.

The Institute's specialists regularly participated in international calibration events to ensure the quality of forest monitoring data, harmonised methods for determining forest monitoring indicators in accordance with the requirements of the UN ECE ICP Forest programme, and trained Ukrainian specialists who performed field data collection at forest monitoring sites.

After the expiry of the State Programme "Forests of Ukraine 2010-2015", which provided for the implementation of forest monitoring works, starting from 2016 PA "UkrDerzhliproekt" ceased activities on the formation of Ukrainian 1st level forest monitoring databases. Therefore, since 2016, national and international reporting on forest monitoring of Ukraine is not provided.

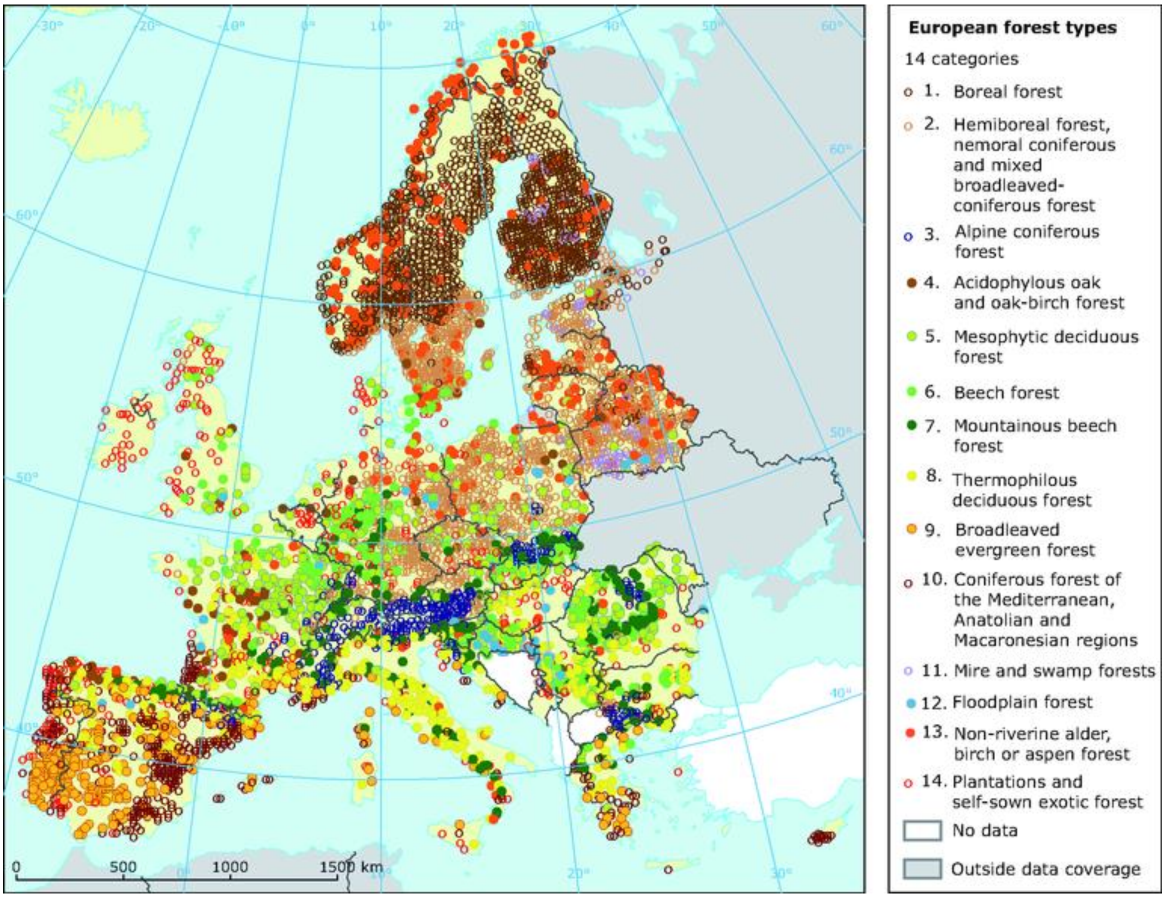


Figure 9.4 Classification of the ICP Forests Level 1 plots with respect to main categories of the European Forest Types
Source: European Environment Agency (EEA)

Forests, plants and animals are also monitored for the following indicators:

1. Red Book Species (national protection status) - number of species in the forest management district (units),

2. Regionally rare species - number of species (with regional protection status, which are included in the Red Lists of the regions) in the forest management district (units).

3. Rare species - number of species in the forest management district (units).

As for soil monitoring of lands of the forest fund, it is carried out on a limited number of forest monitoring plots within the framework of fulfilment of the sectoral thematic plan of research works.

Monitoring of hunting fauna has been and continues to be carried out annually by legal entities that have been granted hunting grounds for use - such activity is carried out by means of state statistical observation No. 2-tp (hunting) "Hunting management".

9.4 Experience in forest monitoring in the European Union

Currently, there is no common forest policy in the EU, and therefore each member state defines it within its national competence, guided by the Forest Strategy 2015 and a number of European directives on forest management directions.

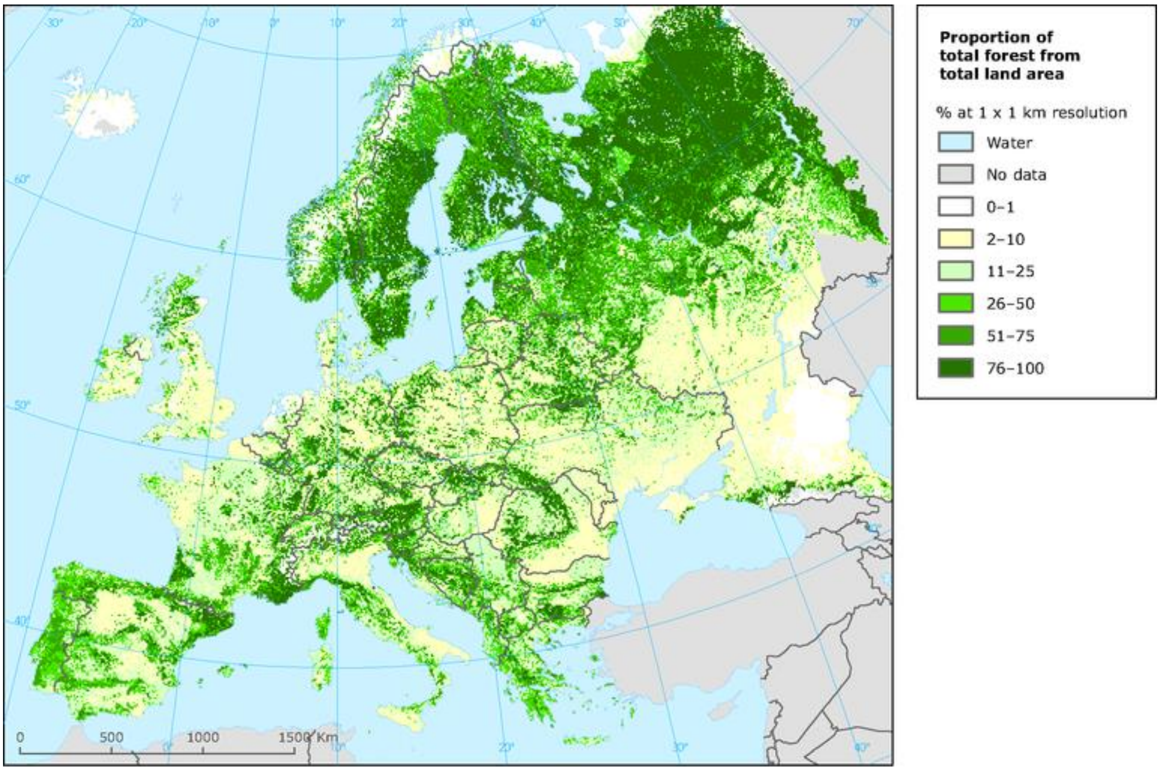


Figure 9.5 Forest map of Europe based on remote sensing technologies and forest inventory statistics

Source: European Forest Institute (EFI), European Environment Agency

Forest monitoring in almost all countries of the world, including the EU, is developing as a multilevel system. The first level of monitoring (extensive) is harmonised with the International Joint Programme for

Assessment and Monitoring of the Impact of Air Pollution on Forests in the UN Economic Commission for Europe (ICPForests). The information obtained at the first level of monitoring makes it possible to assess the temporal and spatial dynamics of forest conditions, but it is not sufficient to determine the cause and effect of such changes.

These tasks are performed at the second level (intensive) of monitoring, carried out using both the ICPForests forest monitoring methodology and the American ForestHealthMonitoring (FHM) forest health monitoring technology. In addition to indicators of the impact of stress factors on forests, the second level defines the main parameters of forest ecosystems necessary for assessing plant species biodiversity, determining the balance of carbon in forests, and introducing technologies for their remote sensing.

Multilevel allows to balance the costs of monitoring and the level of its informativeness.

To ensure transnational use of data in a rapidly changing situation, the EU is constantly working to improve and harmonise the forest monitoring system.

The first steps towards a common forest monitoring system were taken in the EU with the adoption of Council Regulations (EEC) No 3528/86 of 17 November 1986 on the protection of Community forests against atmospheric pollution and No 2158/92 of 23 July 1992 on the protection of forests against fire.

These Regulations laid the foundation for collecting information on the state of forests, the impact of atmospheric air pollution on forest ecosystems, and forest fires. Later in the EU, Regulation (EC) No 2152/2003 of the European Parliament and of the Council on forest monitoring and interaction in the field of environmental protection in the Community was approved.

The monitoring proposed by the Regulation was carried out until 2006, and the monitoring system in the Community consisted of:

● monitoring of air pollution, biotic, abiotic and anthropogenic factors that affect forests,

● monitoring of forest fires and their causes and consequences,

● monitoring of soils, carbon sequestration, climate change and biodiversity impacts, and the protective functions of forests.

All the above-mentioned acts of EU legislation defined the obligation of the authorised bodies of the member states to cooperate in the process of collection, exchange and dissemination of information on the state of forests.

The new EU Forest Strategy 2030 notes the need for further coordinated monitoring of forests at EU level and tasks the European Commission to develop a legislative proposal for a forest surveillance, reporting and data collection system.

As envisaged in the EU Forest Strategy 2030, this legislative proposal is intended to create a pan-European integrated forest monitoring framework using remote sensing and geospatial data technologies integrated with ground-based monitoring, which will improve the accuracy of monitoring.

The need for forest monitoring also stems from the need to fulfil a number of other international instruments to which Ukraine is a party, such as the UN Convention on Large-Scale Transboundary Air Pollution, the UN Convention on Biological Diversity, the UN Framework Convention on Climate Change and its protocols.

9.5 Monitoring of fauna and flora: basic provisions

Monitoring of flora and fauna is an important part of the state monitoring of the environment under the current legislation, in particular the Laws of Ukraine "On the Plants" and "On Wildlife", as well as forest monitoring.

According to the Law of Ukraine "On the Protection of the Environment", one of the main sources of information on the state of the natural environment, including biodiversity, is monitoring data, the maintenance of which is regulated by a resolution of the Cabinet of Ministers of Ukraine.

The Regulation on the State Environmental Monitoring System defines biodiversity monitoring in the following aspects:

- in part of the authority of the Ministry of Environment - on endangered species of flora and fauna and species under special protection;

- in part of the authority of the State Forest Resources Agency - on forest vegetation and hunting fauna.

One of the information sources of the monitoring of wildlife is the data of primary records of wild animals, which are obliged to be collected and submitted by users of wildlife (enterprises, institutions, organisations and citizens engaged in hunting and fishing, etc.) in accordance with the procedure established by law.

The Law of Ukraine "On the Red Data Book of Ukraine" stipulates that the protection of the objects of the Red Data Book of Ukraine (rare and endangered species of permanent or temporarily resident (growing) species of fauna and flora in natural or artificially created conditions within the territory of Ukraine, its continental shelf and exclusive (maritime) economic zone) is ensured through continuous observation (monitoring) of the state of their populations. However, the organisational and other bases of such monitoring are not specifically defined.

The Law of Ukraine "On Wildlife" in a number of its provisions provides for the maintenance of a state record and cadastre of wildlife, and the Law of Ukraine "On the Plants" provides for the maintenance of a state record and cadastre of the plant world.

The state cadastre of wildlife is a systematised set of data on the geographical distribution of species (groups of species) of animals, their number and condition, characteristics of their habitat and current economic use, as well as other data necessary to ensure the protection and rational use of wildlife.

The Ministry of Environment, the Council of Ministers of the Autonomous Republic of Crimea, oblast, Kyiv and Sevastopol city state administrations organize the state wildlife cadastre and coordinate activities related to cadastral work.

Governmental control over the quality and reliability of data included in the said cadastre is exercised by the State Environmental Inspectorate and its territorial bodies.

The Department of Monitoring and Protection of Wildlife of the I.I. Schmalhausen Institute of Zoology of the National Academy of Sciences of Ukraine is responsible for the direct management of the Wildlife Cadastre.

The purpose of keeping records and cadastre of plant life is to record quantitative, qualitative and other characteristics of natural plant resources, the volume, nature and regime of their use, as well as to exercise systematic control over qualitative and quantitative changes in plant life and to provide executive authorities and local self-government bodies, as well as owners and users of land plots on which plant life objects are located, with information on the state of plant life.

The Ministry of Environment is responsible for maintaining state records and cadastre of plant life, coordinating activities related to these works, determining forms of cadastral reporting and storage of cadastral information and its publication.

The Green Book is the basis for the development of protection measures for the conservation, reproduction and utilisation of natural plant communities listed in it. Protection of these communities is aimed at preserving their cenotic structure, populations of rare plant species and their growing conditions. The publication of the Green Book of Ukraine in 1987 as an official state document was devoted to the description of the current state of rare plant communities and measures for their conservation and scientifically based reproduction.

The Order of the Ministry of Environment of 17.12.2020 No. 368 approved 1) the List of rare and endangered and typical natural plant communities to be protected and included in the Green Book of Ukraine (a total of 159 communities in all natural zones); 2) the List of natural plant communities withdrawn from the Green Book of Ukraine.

In 2021, the Ministry of Environment started work on the draft Strategy for Biodiversity Protection until 2030. Its structure includes, among other objectives, monitoring of the state of biodiversity in Ukraine, which will help to make management decisions.

According to the UN Convention on Biological Diversity of 1992 (hereinafter - CBD), biological diversity means the diversity of living organisms from all sources, including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; it includes diversity within, between and among species and ecosystem diversity.

In the CBD, to which Ukraine has acceded, one of the main ways to conserve biodiversity is to obtain reliable information, assessment and monitoring of biodiversity. Biodiversity monitoring includes genetic, species and ecosystem levels of biodiversity.

The sphere of biodiversity monitoring is very specific and complex due to the large number of objects to be monitored: the biota of Ukraine counts more than 74 thousand species. The flora comprises more than

27,000 species (including 5,100 vascular plants), the fungi more than 12,000 species, and the fauna about 45,000 (including more than 35,000 insects).

At the same time, each specific group of animals and plants requires a specific methodological basis for monitoring, as well as special qualifications of experts carrying out monitoring.

In view of the high biodiversity of Ukraine, various alternatives for identifying target sites for monitoring are being considered.

For example, biodiversity monitoring could be limited to:

1) species and ecosystems (natural habitats) under special protection;

2) objects of hunting and fishing;

3) animals and plants that negatively affect natural ecosystems.

However, even in such a volume, the number of objects to be monitored remains very high. In particular, the Red Data Book of Ukraine (2009) includes 826 species of flora and 543 species of fauna. If we add animal and plant species whose protection and use are regulated by international agreements to which Ukraine has acceded, this list will grow even more.

According to the Sixth National Report on Ukraine's implementation of the CBD, some natural reserve institutions and other scientific institutions have organised local scientific monitoring programmes for selected species (for example, European beaver, black stork, cetaceans, aquatic bioresources in the Azov-Black Sea basin, birds of wetland natural complexes). The scientific monitoring programmes are supported by international technical assistance and grants for temporary projects.

Animals and plants that negatively affect natural ecosystems are not monitored at the national level.

Insufficient levels of funding for monitoring, as well as the involvement of experts and the public in its implementation at the state level, are among the obstacles to achieving national biodiversity targets.

A review of the current situation with biodiversity monitoring in Ukraine shows that, in general, such monitoring is at an early stage of development, although some orientations in this area have been quite well developed and have a long history.

Among these is the Chronicles of Nature programme. This programme has been supported for decades by authorised staff of protected territories.

"Chronicle of Nature" is an annual synthesis of data on the state of protected forest reserve areas, plant and animal populations, as well as interesting natural objects. In some forest nature reserves, such "Chronicles" are kept for decades and contain a continuous series of data on animal numbers, biological diversity, and ecosystem dynamics.

With the developed network of biological stations (nature reserves), it is possible to get reliable information on biodiversity trends in model areas in all natural zones and physiographic regions.

9.6 Monitoring of biodiversity in international and EU legislation

In the EU, framework conditions for the organisation and implementation of biodiversity monitoring have been defined by:

● Directives in the field of nature protection - Directive 2009/147/EC of 30.10.2009 on the conservation of naturally occurring birds in the wild state (hereinafter referred to as the Bird Directive) and Directive 92/43/EC of 21.05.1992 on the conservation of natural habitats and of wild fauna and flora - the Habitat Directive);

● The EU Biodiversity Strategy 2020 and a similar Strategy 2030.

In addition, the role and place of biodiversity monitoring in biodiversity conservation policy is reflected in:

● The EU Action Plan for nature, people and the economy until 2019, adopted to improve the practical implementation of the Habitat and Birds Directives and the implementation of the EU Biodiversity Strategy 2020;

● EU Forestry Strategy for 2020 and 2030;

● Green Infrastructure Strategy.

According to the EU Habitat and Birds Directives, one of the most important aspects of biodiversity monitoring is the monitoring of the conservation status of fauna, flora and natural types of the habitats defined by these Directives, as well as the monitoring of the NATURA 2000 network of protected areas.

In Ukraine, similar monitoring should be performed on the territories of the Emerald Network.

The EU Action Plan on nature, people and the economy to 2019 one of the 15 needed actions has identified increasing knowledge, including through wider and more effective monitoring, and ensuring public online access to the data needed to implement the Directives (such as satellite images from the Copernicus programme).

Institutionally, biodiversity is organised and monitored by: the European Environment Agency as well as numerous thematic expert groups established to support the European Commission in this policy area, such as Nature Directive Expert Group, and the EU Biodiversity Platform. Expert groups include representatives of government agencies (ministries, etc.), scientific institutions, non-governmental organisations, businesses, and independent experts.

In 2010, the European Environment Agency published a technical report "Assessing biodiversity in Europe". According to this report, the vast majority of biodiversity monitoring results are obtained through specific scientific programmes of biodiversity monitoring and research (inventory), such as: Circumpolar Biodiversity Monitoring Programme, Pan-European Common Bird Monitoring Scheme (PECBMS), project the Delivering Alien Invasive Species Inventories for Europe (DAISIE).

Thus, in organizational and methodological terms, there is no single biodiversity monitoring system and programme in the EU. However, the European Environment Agency effectively aggregates various data, information and information sources related to the state of biodiversity and its monitoring, ensures their synthesis, maintains numerous public databases, and interacts with key implementers.

In terms of the technical and methodological principles of biodiversity monitoring in the EU, the general framework requirements for biodiversity monitoring and assessment have been defined in Article 17 and other related articles of the EU Habitat Directive.

The target parameters for biodiversity monitoring were indirectly defined in the Biodiversity Strategy, based on its objectives, in particular:

- improvement and streamlining of biodiversity monitoring and reporting. Notably, a new system of recording and reporting on birds and reporting in line with the requirements of the Habitat Directive has been foreseen;

- improvement of the data system on the NATURA 2000 network of protected areas of European importance;

- development of an information system on the state of biodiversity.

Obviously, in order to achieve these objectives, an effective system of monitoring and evaluation of the conservation status of the above-mentioned species of fauna and flora (including birds) and natural habitats is required.

In the EU, two thirds (72 per cent) of the territory are covered by agricultural and forestry land. Therefore, one of the priorities of the EU Biodiversity Strategy, in addition to assessing the status of biodiversity in

NATURA 2000 protected areas, was to assess the status of biodiversity in areas with agriculture and forestry.

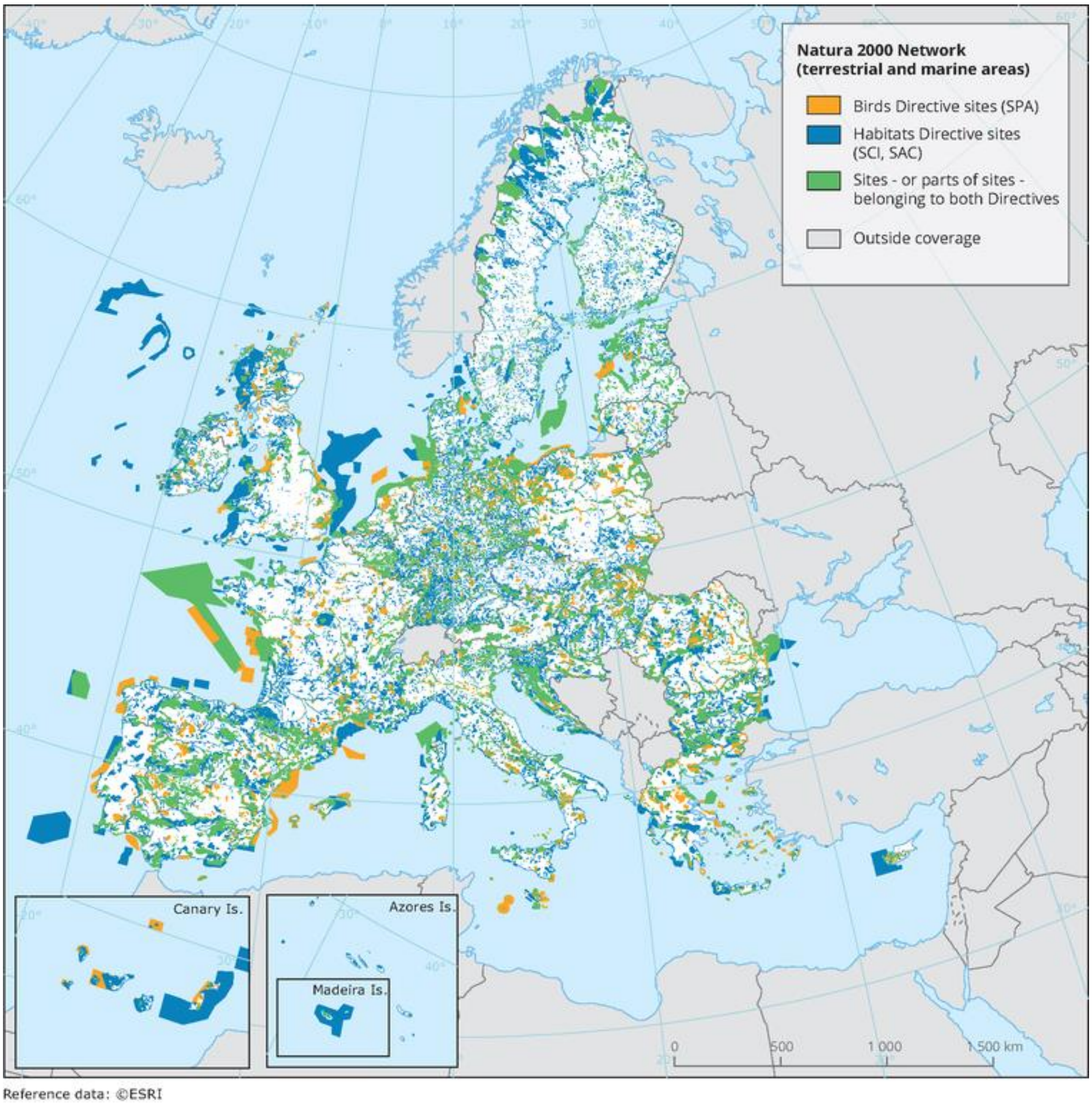


Figure 9.6 Natura 2000 Network (terrestrial and marine areas)
Source: https://www.eea.europa.eu/data-and-maps/figures/natura-2000-network-terrestrail-and

Bird and insect populations were used as indicators of the state of biodiversity and ecosystems in agricultural areas: their indicators proved to be particularly sensitive to the negative impact of human activities.

The next priority in Strategy 2020 was more sustainable fisheries as well as the protection of marine ecosystems. Therefore, there is a need to monitor the state of aquatic bioresources for fisheries, and to determine quotas for fishing and other aquatic bioresources on the basis of these data and taking into account the need to achieve balance and good environmental status of marine ecosystems.

Another area in Strategy 2020 that depends on effective biodiversity monitoring is overcoming threats posed by invasive species of fauna and flora.

The EU Biodiversity Strategy 2030, in addition to the above objectives, also sets the following:

- properly monitor all protected areas in the EU;

- identify, map, organise monitoring and strictly protect all remaining primary and ancient forests (primeval forests and natural forests).

In order to collect and retrieve data and information on EU biodiversity, the BISE (Biodiversity Information System for Europe) information system operates. In addition, there are public information systems for biodiversity data.

Public monitoring of birds, insects, and invasive plant and animal species is already well developed in the EU. The European Environment Agency is piloting the integration of public biodiversity monitoring data and other monitoring systems.

In the EU, the SEBI (Streamlined European Biodiversity Indicators) initiative was launched in 2005 as a product of a partnership between the European Environment Agency, its Biodiversity Thematic Centre (ETC/BD) and the European Commission's Directorate-General for Environment (DG ENV).

The system of these indicators is designed to monitor and assess progress in implementing biodiversity policies.

Table 9.1 SEBI 2010 indicators within CBD focal areas and EU headline indicators [15]

CBD focal area	Headline indicator	SEBI 2010 specific indicator
Status and trends of the components of biological diversity	Trends in the abundance and distribution of selected species	1. Abundance and distribution of selected species a. Birds b. Butterflies
	Change in status of threatened and/or protected species	2. Red List Index for European species
		3. Species of European interest
	Trends in extent of selected biomes, ecosystems and habitats	4. Ecosystem coverage
		5. Habitats of European interest
	Trends in genetic diversity of domesticated animals, cultivated plants, and fish species of major socioeconomic importance	6. Livestock genetic diversity
	Coverage of protected areas	7. Nationally designated protected areas
		8. Sites designated under the EU Habitats and Birds Directives
Threats to biodiversity	Nitrogen deposition	9. Critical load exceedance for nitrogen
	Trends in invasive alien species (numbers and costs of invasive alien species)	10. Invasive alien species in Europe
	Impact of climate change on biodiversity	11. Impact of climatic change on bird populations
Ecosystem integrity and ecosystem goods and services	Marine Trophic Index	12. Marine Trophic Index of European seas
	Connectivity/fragmentation of ecosystems	13. Fragmentation of natural and semi-natural areas
		14. Fragmentation of river systems
	Water quality in aquatic ecosystems	15. Nutrients in transitional, coastal and marine waters
		16. Freshwater quality
Sustainable use	Area of forest, agricultural, fishery and aquaculture ecosystems under sustainable management	17. Forest: growing stock, increment and fellings
		18. Forest: deadwood
		19. Agriculture: nitrogen balance
		20. Agriculture: area under management practices potentially supporting biodiversity
		21. Fisheries: European commercial fish stocks
		22. Aquaculture: effluent water quality from finfish farms
	Ecological Footprint of European countries	23. Ecological Footprint of European countries
Status of access and benefits sharing	Percentage of European patent applications for inventions based on genetic resources	24. Patent applications based on genetic resources
Status of resource transfers	Funding to biodiversity	25. Financing biodiversity management
Public opinion (additional EU focal area)	Public awareness and participation	26. Public awareness

These are 14 headline indicators (this list is periodically reviewed) relating to the status of biodiversity, the most important impacts on biodiversity and associated consequences.

Their assessment is based on a set of primary data from biodiversity monitoring, other types of monitoring, statistical and other relevant reporting information.

Consequently, the goals and objectives, organisational and methodological foundations of biodiversity monitoring in the EU are determined by a wide range of normative legal acts and strategic documents, as well as special expert knowledge and expertise. The core of this type of monitoring is monitoring in protected areas, in particular NATURA 2000 sites, but biodiversity monitoring is not limited to them.

The EU strategic documents on biodiversity conservation are characterised by close linkages with other sectoral policies and areas of economic activity.

The identification, review and updating of framework conditions for biodiversity monitoring also depends on the implementation of the CBD. Article 7 obliges parties to the Convention to monitor components of biological diversity (through sampling and other methods), paying particular attention to those requiring immediate action and those offering the greatest potential for sustainable use.

The Strategic Plan for Biodiversity 2011-2020 (Decision X/2 at COP 10) was adopted to implement the CBD. The ways and mechanisms for effective implementation of the Plan include, inter alia:

● biodiversity monitoring, namely actions to monitor the status of biodiversity and its trends, to store and share relevant data, and to develop and apply indicators and agreed measures for changes in biodiversity and ecosystems;

● systematic assessment of the status of biodiversity and ecosystem services, future scenarios of change and the effectiveness of solutions in response to these changes.

The Framework Convention on the Protection and Sustainable Development of the Carpathians (ratified by Ukraine in 2004) concerns co-operation between the countries of the Carpathian region in many sectors, including biodiversity protection. Parties should develop and/or facilitate compatible monitoring systems, coordinated regional species and habitat inventories, coordinated scientific research and their networking.

The Convention on the Conservation of Migratory Species of Wild Animals (Bonn Convention) does not contain direct requirements for biodiversity monitoring, but, in pursuit of the conservation of terrestrial and marine migratory species, as well as birds on their migration routes, provides for the protection or restoration of their habitats, reduction of the impact of obstacles to migration routes and control of other factors that may pose a threat to migratory species (depending on the category of conservation).

To ensure these measures, the country needs to have up-to-date information on the state of the environment.

Decisions of the governing bodies of international treaties (Conference or Meeting of the Parties, subsidiary bodies, etc.) detail the requirements for monitoring of certain groups of animals, and guidelines on how to monitor certain wild fauna have also been approved.

Thus, the CBD Parties developed and approved by decision of the 10th meeting of the Conference of the Parties to the CBD (Nagoya, Japan, 2010) the Strategic Plan on Biological Diversity for 2011-2020 and the Aichi Biodiversity Targets.

There are also separate initiatives within the CBD for individual components of biodiversity that require appropriate monitoring methods.

These initiatives are the Global Strategy on Invasive Alien Species, the Global Strategy for Plant Conservation, the Pollinator Initiative, and the Global Taxonomy Initiative.

Figure 9.7 Aichi Biodiversity Targets

Source: https://www.ilearncana.com/details/Aichi-Biodiversity-Targets/1201

Ukraine is a party to a number of other international agreements on the conservation of wild flora and fauna, which contain provisions for monitoring and research on species, especially endangered species. Within the framework of these international instruments, harmonised methods for monitoring individual animal groups have been developed, in particular:

- The Agreement on the Conservation of African-Eurasian Migratory Waterbirds (AEWA) - to study the biology and ecology of migratory waterbirds;

- Agreement on the Conservation of Cetaceans of the Black Sea, Mediterranean Sea and Contiguous Atlantic Area (ACCOBAMS) - cetacean monitoring, in particular in accordance with the Black Sea Cetacean Conservation Plan;

- Agreement on the Conservation of Populations of European Bats, or EUROBATS - for monitoring of bats;

- The Convention on the Protection of the Black Sea against Pollution (Bucharest Convention) - for monitoring the target groups of marine living resources described in the Black Sea Integrated Monitoring and Assessment Programme 2017-2022 (BSIMAP 2017-2022).

According to national experts, wildlife monitoring should address the following objectives:

● tracking population dynamics of endangered animal species in order to take timely measures aimed at preventing negative population trends of the species and maintaining or restoring it in an ecologically safe state;

● ongoing assessment of the status of populations of industrial animal species (game animals, aquatic bioresources, etc.) or species of commercial interest in order to prevent their depletion and overexploitation;

● control of biological invasions (invasive species) in order to prevent the entry into native ecosystems of species that pose a threat to their ecological sustainability, create competition with native species, causing economic damage or danger to human health;

● controlling the status of populations of animals that fulfil important functions in maintaining the viability of ecosystems (e.g., pollinator species);

● control of ecosystems through the use of indicator species.

The significant number of animal species found on the territory of Ukraine (about 45 thousand) does not allow simultaneous monitoring of all animal diversity due to the need to attract significant financial and human resources, so it is relevant to select priority species on which monitoring should be focused.

The indicative list of priority groups of animal species for monitoring may include:

- ✓ animal species listed in the Red Data Book of Ukraine or protected under Ukraine's international obligations;
- ✓ aquatic bioresources that are the objects of fisheries;
- ✓ species of commercial interest;
- ✓ game species of animals;
- ✓ invasive alien species;
- ✓ pollinator species;
- ✓ species that are indicators of the state of ecosystems.

9.7 Monitoring of landscapes

The Law of Ukraine "On the Ecological Network of Ukraine" provides for another type of monitoring in the sphere of bio- and landscape diversity, namely state monitoring of the ecological network, its natural complexes and objects.

At the same time, according to the Law, the territories and objects of the ecological network are subject to state registration, which is an integral part of the state land cadastre, state cadastres of other natural resources, territories and objects of the natural reserve fund, and state statistical reporting.

However, neither the procedure for monitoring the eco-network nor the procedure for accounting of its territories and objects (for example, as part of the state land cadastre in accordance with the Law of Ukraine "On State Land Cadastre", as part of the state cadastre of territories and objects of the natural reserve fund of Ukraine) has not been established at the moment.

Ecological network (Econet) is a single territorial system, that is formed to improve conditions for building and restoration of the natural environment, enrichment of natural resources in Ukraine, protection of landscape and biodiversity, places of habitation and growth of plant and animal species, genetic pool, animal migration routes through the combination of areas and objects of natural reserve fund and other areas of special value for environmental protection.

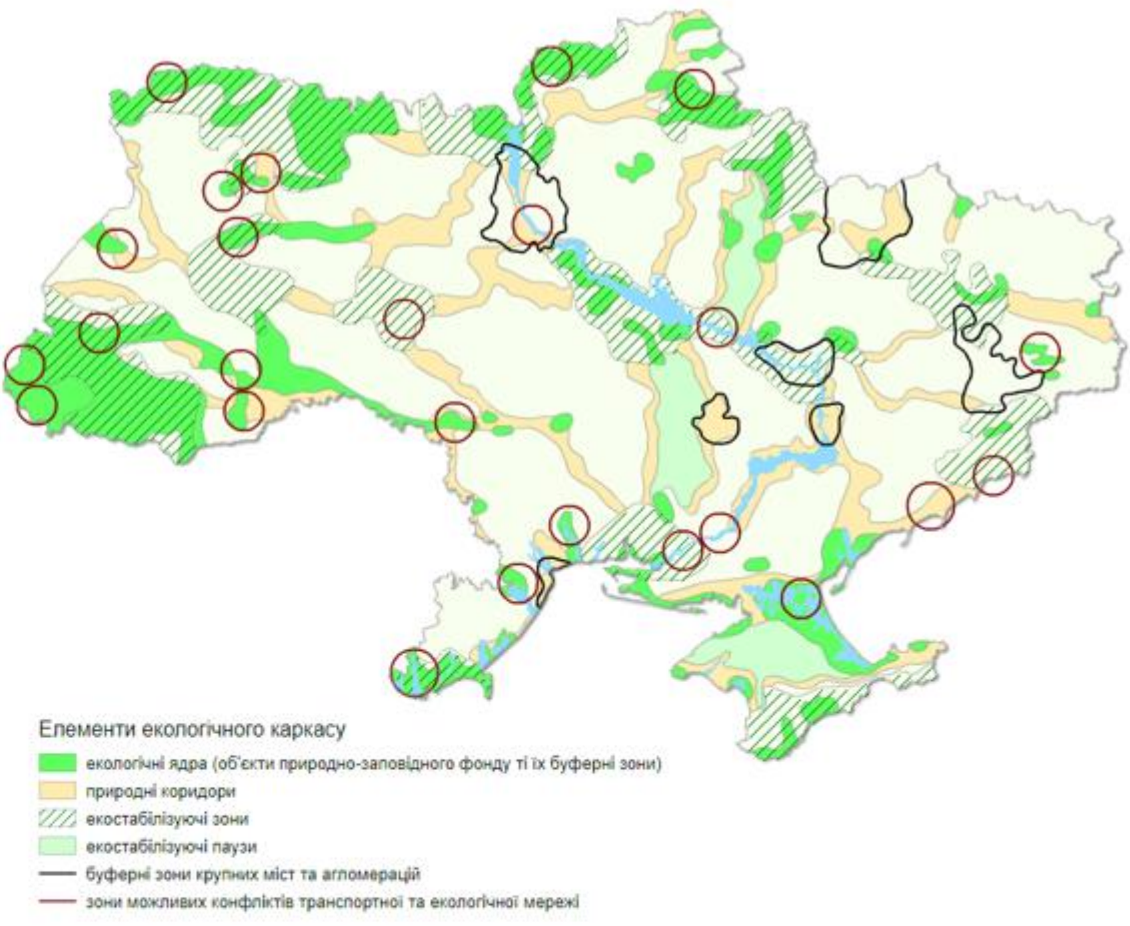


Figure 9.8 National Ecological Network

Source: https://geomap.land.kiev.ua/ecology-11.html

The initiative to create a Pan-European Ecological Network (European Ecological Network or EENET) as a system of interconnected ecologically valuable natural areas was proposed by a team of Dutch researchers in 1993 at the International Conference "Protecting Europe's

Natural Heritage by Creating a European Ecological Network" (Maastricht, the Netherlands).

In accordance with the majority of current views, the main goal of establishing an ecological network can be considered the overall improvement of the environment and condition of humans, the sustainability of the biosphere by removing anthropogenic fragmentation of the biogeocenotic complex that was established in the historical evolution of society, making it uninterrupted and functionally integrity and strengthening its ability to self-repair.

The relevant legal framework for monitoring landscape diversity has not yet been developed.

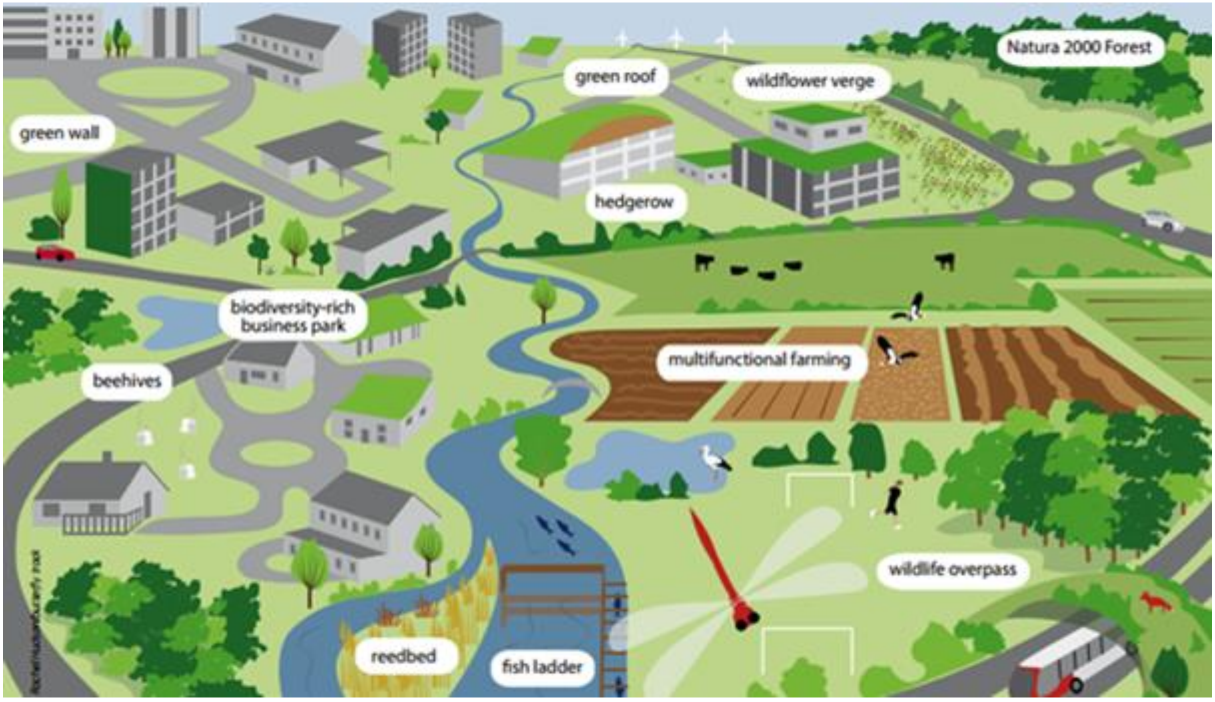


Figure 9.9 Examples of green infrastructure across an urban-rural landscape

Source: /topics/green-infrastructure

The policy of green infrastructure development in the EU (Green Infrastructure Strategy, 2013) is very similar to the state policy regarding the ecological network in Ukraine, therefore the EU Green Infrastructure

Strategy can be used to define and harmonise the goals and objectives of the state monitoring of the Ukrainian ecological network.

Green Infrastructure (GI) means a network of (semi-)natural territories that are protected and expanded to provide ecosystem services and benefit biodiversity and society in general.

Ukraine is a Party to the European Landscape Convention. Under the Convention, each Party undertakes to:

- identify its own landscapes throughout its territory;
- analyse their characteristics and the forces and pressures transforming them;
- record changes.

The procedure for such identification and assessment shall be regulated through an exchange of experience and methodology organised between the Parties at European level.

Furthermore, each Party undertakes to establish and implement a landscape policy aimed at the protection, management and planning of the landscape through specific measures.

These provisions could form the basis for the organisation and implementation of state monitoring of landscape diversity.

9.8 Background environmental monitoring in Ukraine

A special aspect (subsystem) of environmental monitoring is environmental baseline monitoring. Background environmental monitoring is aimed at observation, assessment and forecasting of the natural state of the environment outside the significant influence of human activity, and its data serve as baseline (reference) levels for comparison of monitoring data from other territories.

The functions of background environmental monitoring are assigned by the Law of Ukraine "On Natural Reserve Fund" to one of the territories of the natural reserve fund - biosphere reserves.

Biosphere reserves are nature protection and research institutions of national importance, they are formed for the purpose of preserving the most typical natural complexes of the biosphere in a natural state, performing background environmental monitoring, studying the environment and its changes under the influence of anthropogenic factors.

Within biosphere reserves, the natural complexes of the biosphere occupy vast areas, have a well-preserved structure, and the biosphere reserves themselves have an international status. This ensures the longevity and continuity, consistency and reliability of environmental baseline monitoring.

Figure 9.10 UNESCO Biosphere Reserves in Ukraine

Source: https://wownature.in.ua/yak-vidriznyty-biosfernyy-rezervat-vid-biosfernoho-zapovidnyka/

In 1995, the Seville Strategy for UNESCO Biosphere Reserves which changed the concept of biosphere reserves was adopted: whereas previously the area was intended purely for the conservation of landscape and biological diversity, now it became a place where the concept of sustainable development was realised.

Biosphere reserves in Ukraine operate on the basis of both national and dynamically adjusted international regulations, depending on the priorities and activities of the Man and the Biosphere Programme (MAB).

In 2016, the Action Plan for the MAB Programme and its WNBR for 2016-2025 (Lima Action Plan) was adopted. On 4 July 2018, the Action Plan for the implementation in Ukraine of the Lima Action Plan for the UNESCO Man and the Biosphere Programme and its World Network of Biosphere Reserves for the period until 2025 was approved.

These territories form the basis of the Emerald Network - an analogue of the European network NATURA-2000. The activities of biosphere reserves are aimed at the conservation and rational, non-destructive use of natural resources by humans and serve as a kind of bridge of unity between man and nature.

Currently, almost all of the areas included by developers in the Network are either existing NRF areas of national importance or regional landscape parks, reservoirs or Ramsar sites. Such choice of territories was due to the possibility of not conducting research or creating a database, but simply using the information already available to the Ministry of Environment.

However, not all NRF sites fulfil the criteria of Recommendation 16 of the Bern Convention. The fact that there is no database that can show how each of the proposed sites affects the adequacy of coverage of species populations by the network makes it questionable whether any of the areas should be included in the network. Some of the territories included in the Network do not meet the established criteria, some of the territories requiring inclusion are left out of the Network; the database on the basis of which the Network should have been developed and on the basis of which its further monitoring should have been carried out is missing. However, the absence of the database is not only a shortcoming of the work of the Network developers, but also evidence of the lack of information in Ukraine about the dissemination of the types of Resolution 6 of the Berne Convention per se.

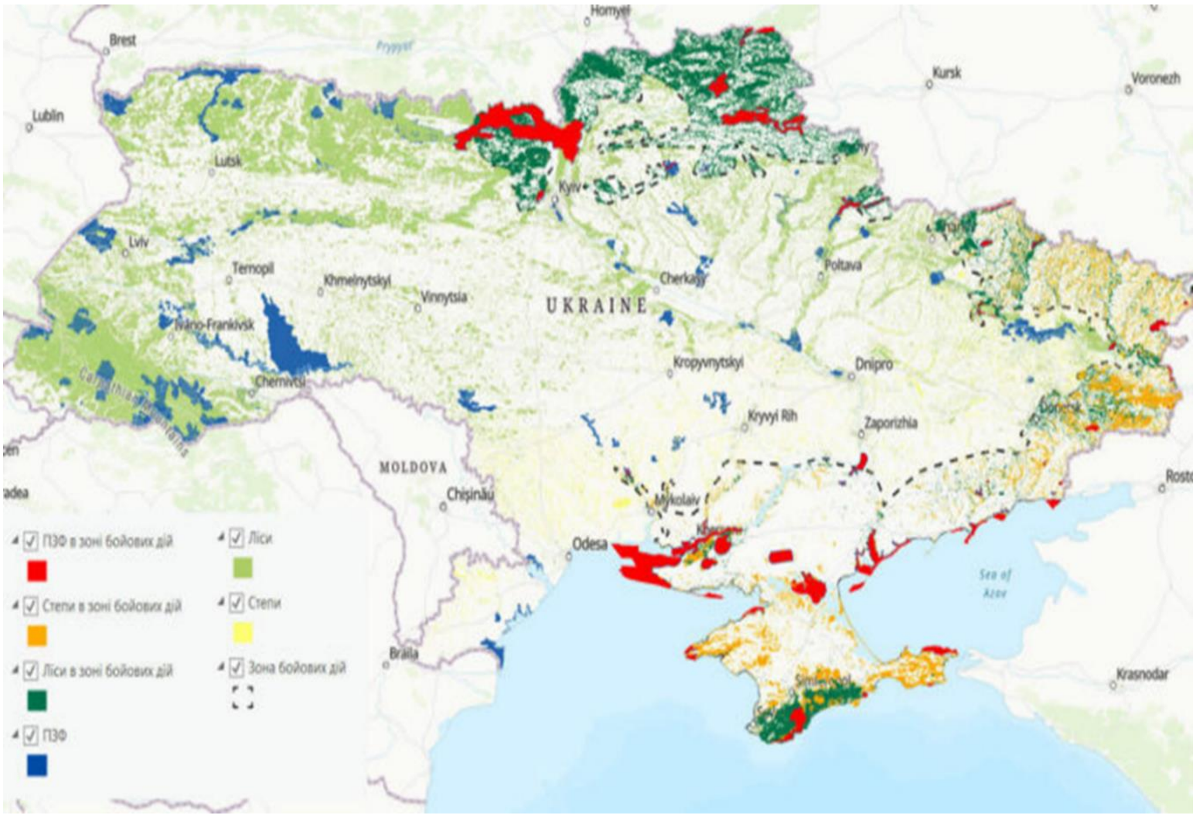


Figure 9.11 Visualisation of affected natural areas due to military invasion according to the NGO "Ukrainian Nature Conservation Group" (as of May 2022)

At the same time, russian military aggression has significantly shaken the balance of protected areas. The aggressors use the territories of the reserves as car parks for machinery, and biodiversity as raw materials and food, which is unacceptable given the value of fauna and flora. Thousands of hectares of forests within the reserves have been mined and thousands of hectares of steppe have been scorched by shelling. Landscapes are being changed due to the construction of fortification structures.

It will take many years to restore landscapes and biodiversity, but given the tasks performed by biosphere reserves, their restoration should be a priority in the country's post-war reconstruction.

Questions for self-control

1. Describe the concept of biological diversity. What does biodiversity include?

2. What are the ecological functions of forests?

3. What are the legislative acts on forest monitoring in Ukraine?

4. Forests, plants and animals are also monitored for the following indicators:

a. Regionally rare species;

b. Red Data Book species;

c. Rare species;

e. Green Data Book species.

5. Is there a single forest monitoring methodology in Europe today?

6. What is the monitoring of biological diversity?

7. Please specify a few legislative acts in the field of biodiversity monitoring in Ukraine.

8. The “Chronicles of Nature” programme has been maintained by: (choose the correct answer):

a. central executive authorities;

b. authorized staff of protected areas;

c. volunteers with supporting from international funding agencies.

9. Priority communities for biomonitoring are those listed in:

a. the Red Data Book of Ukraine;

b. the Cadastre of plant wildlife;

c. the Green Data Book of Ukraine.

10. Which target objects can be prioritised for biodiversity monitoring?

11. Which organisation organises biodiversity monitoring in the EU?

12. What are the SEBI indicators?

13. Is there any public monitoring of biodiversity in Europe?

14. How many categories of indicators were identified on the Strategic Plan for Biodiversity 2011-2020?

15. What is the Ecological Network? Why is its development so important for Ukraine?

16. What are the specifics of baseline environmental monitoring?

17. Which international programme is used to operate biosphere reserves in Ukraine?

18. What territories form the basis of the Emerald Network?

10. SPECIAL TYPES OF ENVIRONMENTAL MONITORING

10.1 Climate change and climate monitoring: international approaches

Climate is defined as the average weather over a thirty-year period. Therefore, climate change can only be perceived and understood if measurements of all factors that can determine or influence the climate are taken over long periods of time.

This includes factors such as temperature, wind, greenhouse gas concentrations, natural emissions and man-made emissions. Climate can be observed locally and globally. Statements on climate change usually concern worldwide averages, which show a change measured over a longer period of time. However, changes in the local climate are often more relevant to people.

These changes can be very different and even opposite to the global changes. The climate is highly variable by nature. No two years are alike. Therefore, trend-related changes are only provable if they exceed the noise of normal and local variations. Taking measurements, organizing data and constructing explanatory and predictive models for how the different climate factors affect each other is what we call ***climate monitoring***.

Climate monitoring concerns the monitoring of the atmosphere and of other components of the earth system as well as the monitoring of global climate indicators (e.g., global mean earth surface temperature and precipitation).

The earth climate shows great variability over different time scales spanning from decades to thousands of years and more. Past climate is studied by analysing ice cores, sea/lake sediments, shorelines movements, tree pollen, etc.

The knowledge of past climate can help in predicting the future.

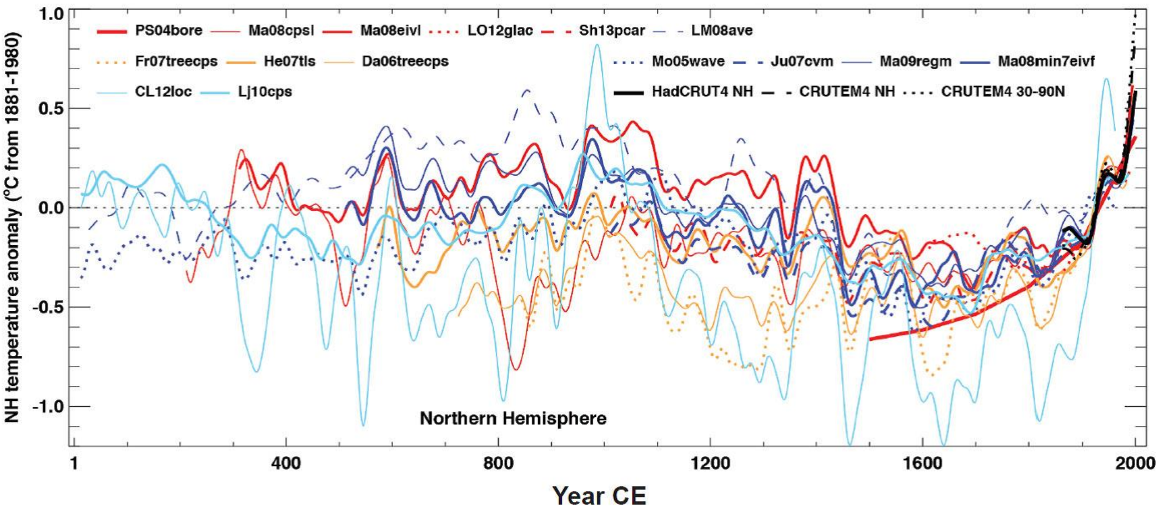


Figure 10.1 Reconstructed Northern Hemisphere annual temperature during the last 2,000 years

Source: https://www.ncdc.noaa.gov/global-warming/last-2000-years

Abrupt changes may serve in the identification of thresholds values that can trigger a non-linear behavior of the earth system (and hence may cause high variations). The overlapping of climate variability on different time scales is the very challenge in predicting climatic changes.

Many lines of scientific evidence show the Earth's climate is changing. It is worth noting that increasing global temperature is only one element of observed global climate change. Precipitation patterns are also changing; storms and other extremes are changing as well.

The World Meteorological Organization has developed a set of headline indicators for global climate monitoring. These seven indicators are a subset of the existing set of essential climate variables (ECVs) established by the Global Climate Observing System and are intended to provide the most essential parameters representing the state of the climate system.

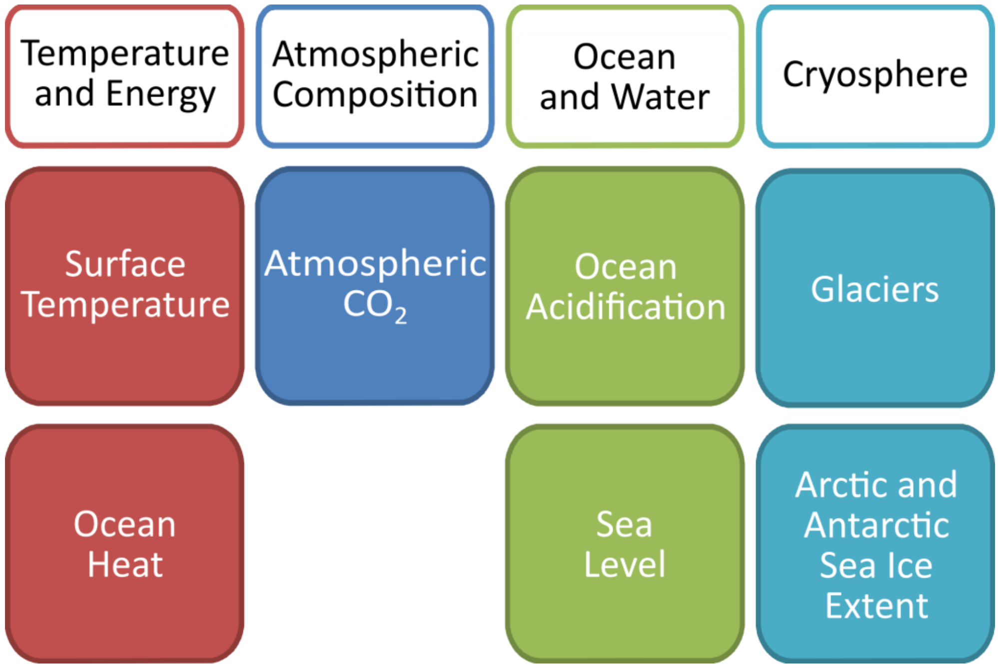


Figure 10.2 Global Climate Indicators

Source: https://gcos.wmo.int/en/global-climate-indicators

They form the basis of the annual WMO Statement of the State of the Global Climate. In addition, the Copernicus Climate Change Service (C3S) of the European Commission uses the Indicators implemented the Global Climate Indicators for their annual "European State of the Climate".

Global Climate Indicators include global mean surface temperature, global ocean heat content, state of ocean acidification, glacier mass balance, Arctic and Antarctic Sea ice extent, global CO_2 mole fraction, and global mean sea level.

Thousands of land and ocean temperature measurements are recorded each day around the globe. This includes measurements from climate reference stations, weather stations, ships, buoys and autonomous gliders in the oceans. These surface measurements are also supplemented with satellite measurements.

These measurements are processed, examined for random and systematic errors, and then finally combined to produce a time series of global average temperature change.

A number of agencies around the world have produced datasets of global-scale changes in surface temperature using different techniques to process the data and remove measurement errors that could lead to false interpretations of temperature trends.

The global surface temperature is based on air temperature data over land and sea-surface temperatures observed from ships, buoys and satellites.

According to latest IPCC (the Intergovernmental Panel on Climate Change) Special Report "human activities are estimated to have caused approximately 1.0°C of global warming above pre-industrial levels, with a likely range of 0.8°Co to 1.2°C. Global warming is likely to reach 1.5°C between 2030 and 2052 if it continues to increase at the current rate".

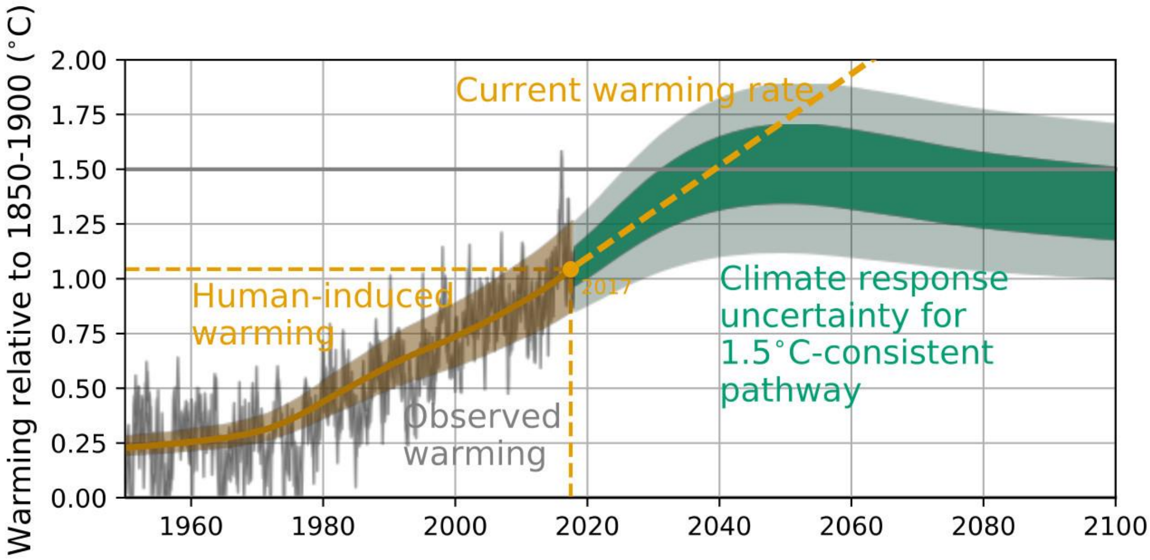


Figure 10.3 IPCC Special Report on Global Warming of 1.5°C

Source: https://www.wcrp-climate.org/news/wcrp-news/1396-summary-for-policymakers-approved-ipcc-special-report-on-global-warming-of-1-5-c

The *warming trend* that is apparent in all of the independent methods of calculating global temperature change is also confirmed by other independent observations, such as the melting of mountain glaciers on every continent, reductions in the extent of snow cover, earlier blooming of plants in spring, a shorter ice season on lakes and rivers, ocean heat content, reduced arctic sea ice, and rising sea levels.

A large body of evidence supports the conclusion that human activity is the primary driver of recent warming.

Multiple studies published in peer-reviewed scientific journals show that 98 percent or more of actively publishing climate scientists agree: Climate-warming trends over the past century are extremely likely due to human activities. In addition, most of the leading scientific organizations worldwide have issued public statements endorsing this position.

Global climate models clearly show the effect of human-induced changes on global temperatures (Figure 10.4).

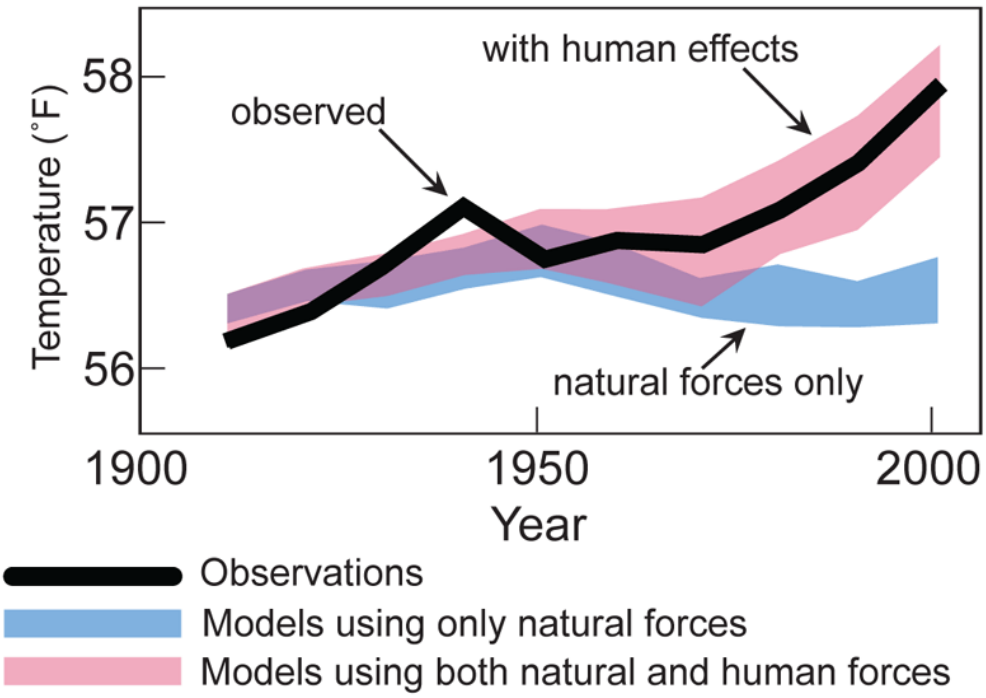


Figure 10.4 Separating Human and Natural Influences on Climate

Source: the IPCC's Fourth Assessment Report

The blue band shows how global temperatures would have changed due to natural forces only (without human influence). The pink band shows model projections of the effects of human and natural forces combined. The black line shows actual observed global average temperatures. The close match between the black line and the pink band indicates that observed warming over the last half-century cannot be explained by natural factors alone, and is instead caused primarily by human factors.

10.2 Characteristics and uses of climate observations

Climate observations are important because they help satisfy important social, economic and environmental needs. They are an integral part of reducing the risk of loss of life and damage to property.

Climate observations are sourced from the numerous meteorological and related observational networks and systems that underpin applications such as weather forecasting, air pollution modelling and environmental impact assessments. However, climate observations differ in a number of important aspects.

Firstly, climate observations need to account for the full range of elements that describe the climate system – not just those that describe the atmosphere. Extensive observations of the ocean and terrestrial-based systems are required.

Secondly, an observation at any point in time needs a reference climate against which it can be evaluated, i.e. a reference climatological period must be selected. In this regard, the observations from a station that only exists for a short period (i.e. from days to a few years) or which relocates very frequently will generally be of less value than those observations from a station whose records have been maintained to established standards over many years.

Thus, in order to derive a satisfactory climatological average (or normal) for a particular climate element, a sufficient period record of homogeneous, continuous and good quality observations for that element is required.

Thirdly, a climate observation should be associated – either directly or indirectly - with a set of metadata that will provide users with information, often implicitly, on how the observation should be interpreted and used. So, while climate observations serve multiple purposes beyond specific climate needs, we must ensure that they retain, and acquire, particular characteristics that serve a range of climate needs.

The Essential Climate Variables for assessment of climate variability from 1979 to present dataset contains a selection of climatologies, monthly anomalies and monthly mean fields of Essential Climate Variables (ECVs) suitable for monitoring and assessment of climate variability and change. Selection criteria are based on accuracy and temporal consistency on monthly to decadal time scales.

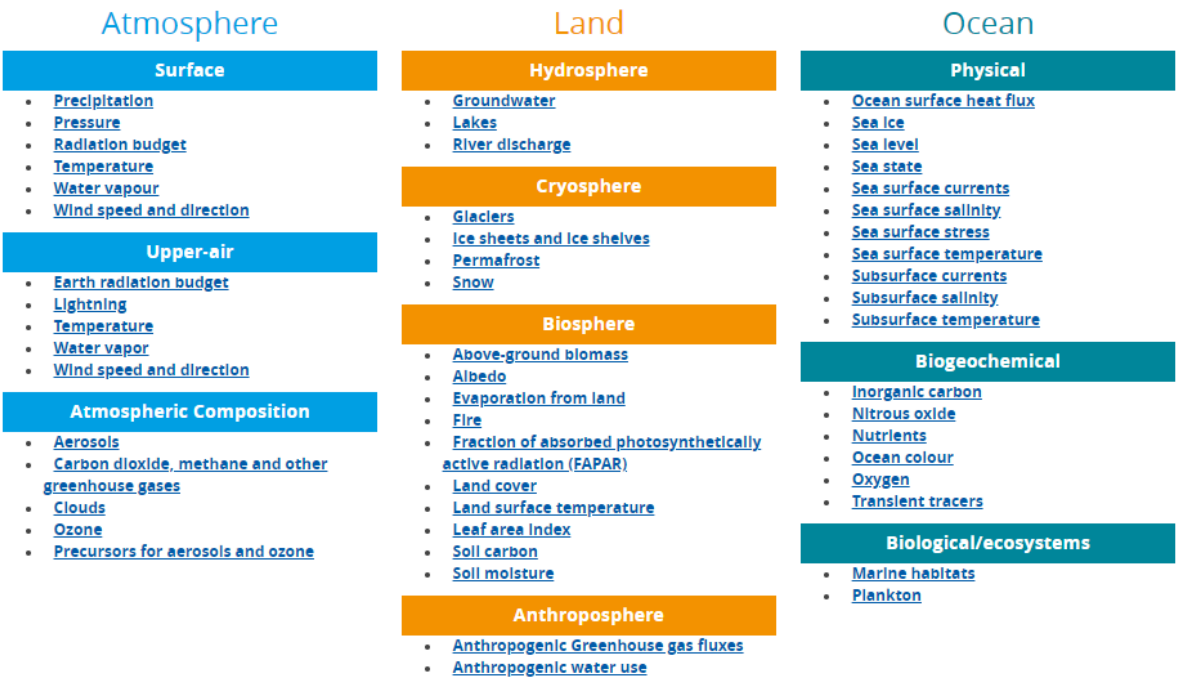


Figure 10.5 Essential Climate Variables (ECV) by Global Climate observing system

Source: World Meteorological Organization

An ECV is a physical, chemical or biological variable or a group of linked variables that critically contributes to the characterization of Earth' s climate. GCOS (Global Climate Observing System) currently specifies 54 ECVs.

ECV datasets provide the empirical evidence needed to understand and predict the evolution of climate, to guide mitigation and adaptation measures, to assess risks and enable attribution of climate events to underlying causes, and to underpin climate services.

They are required to support the work of the UNFCCC and the IPCC.

10.3 Signs and possible consequences of climate change in Ukraine

Ukraine is located in the central part of the European continent under difficult physiographic conditions, which determines the originality of the impact of major climate-forming factors on the formation of climate - the inflow of solar radiation, the atmospheric circulation as well as human activities. The peculiarities of their implication depend on the latitude, altitude elevation, orography etc. and are indicators of the climatic conditions of the area.

In general, the climate of Ukraine is temperate continental, on the Southern coast of Crimea – a subtropical Mediterranean climate. Ukraine receives sufficient heat and moisture, which create favorable natural-climatic conditions on its territory.

The knowledge about the climate of Ukraine is based on the laws of the space-time distribution of quantitative field indicators of the basic meteorological variables that characterize the state of the atmosphere as a component of the climate system and depend on both the natural and anthropogenic factors.

According to the Intergovernmental Panel on Climate Change (IPCC), climate system changes are unequivocal, as is now evident from observation of increases in global average air and ocean temperatures, widespread melting of snow and ice, and rising global average sea level. And climate of Ukraine is involved in these system changes.

The signs of climate change are apparent in Ukraine: extremes of temperature, an increase in the number of hot days, an overall reduction in atmospheric precipitation (although with a drastic rise in some areas), together with an increase in gales and rainstorms, catastrophic floods and droughts, forest fires and desertification.

The consequences of these trends are having a negative impact on agriculture, forests, water and other sectors, as well as on people's health and safety.

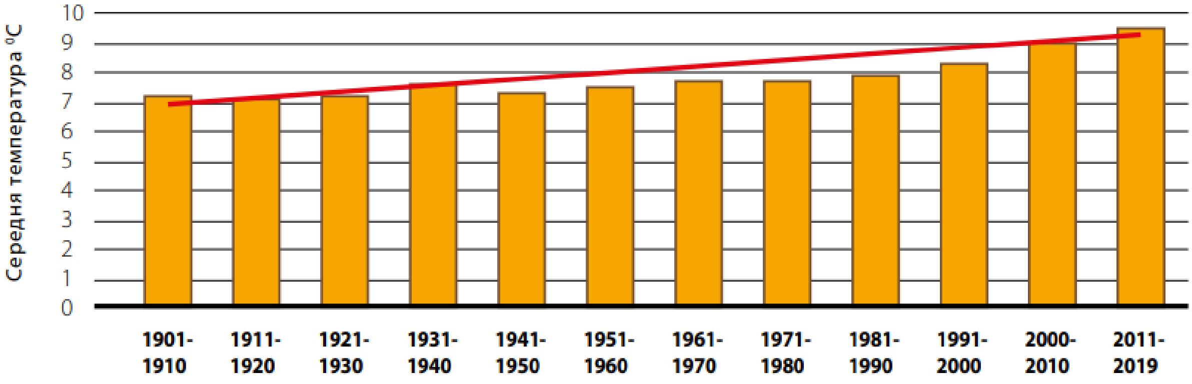


Figure 10.6 Average annual air temperature (by decade) in Ukraine

Source: https://ecolog-ua.com/

The main characteristic of climate change (the main parameter) is the change in the average annual air temperature of the lower atmospheric layer (at a height of 1 meter above the surface). It is determined by measurements from 163 meteorological stations of Ukraine, which have a continuous observation period of 65 to 140 years.

According to studies of this parameter, the modern climate of Ukraine is characterized by uneven warming over the territory, brightly expressed in the winter and summer months.

Over the past 30 years, the average annual air temperature in Ukraine has increased by more than 1°C.

The temperature increase during the cold period (November-March) is on average 1.3°C, while during the warm period (April-October) it is 1.1°C. The positive anomaly (deviation of air temperature from the norm) throughout the country during the period 1989-2019 was the largest in the history of instrumental weather observations.

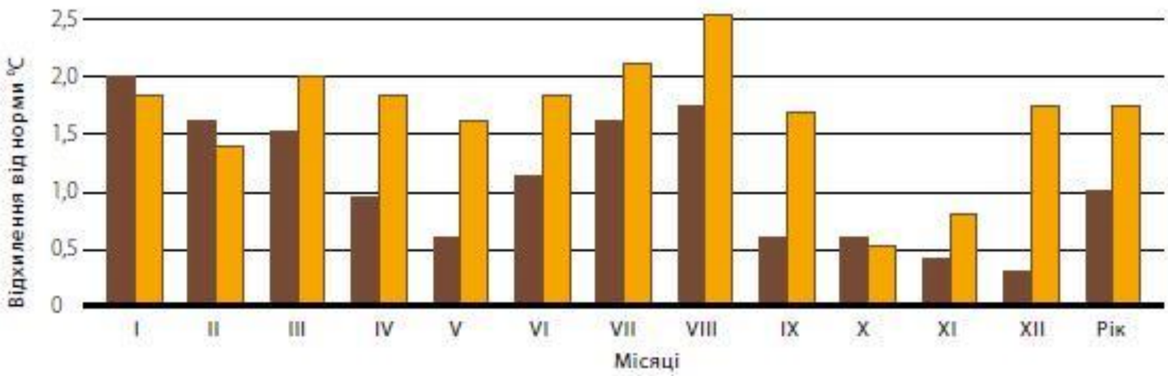


Figure 10.7 Deviations from the norm (1961-1990) of average monthly air temperatures for the periods 1991-2019 and 2010-2019

Source: https://ecolog-ua.com/

The number of days with so-called "tropical nights", when the temperature after sunset does not fall below 25°C, has also increased.

If greenhouse gas emissions are not reduced, in Ukraine, due to its large size, the changes of the air temperature will be different in different parts of the country, as well as throughout the year.

Scientists predict that the temperature increase will be between 1 and 5°C in various parts of the country by 2100. It is mainly the winter and spring months that will become warmer. Some researchers even believe that a tropical climate will reach Ukraine, and that the subtropical zone already present in country will further expand.

Although there is no unequivocal prediction of expected changes in the regime and amounts of precipitation, it is certain that these changes will be different in different parts of the country and at different times of year (Figure 10.8).

Ukrainian researchers believe that the country's climate has already become less continental and is growing more similar to a maritime climate in some areas.

These transformations have triggered a shift of climate zones that are slowly moving northward and are changing the natural system as they destroy natural ecosystems. The forest-steppe parts of Ukraine are no longer considered to be evenly humidified areas.

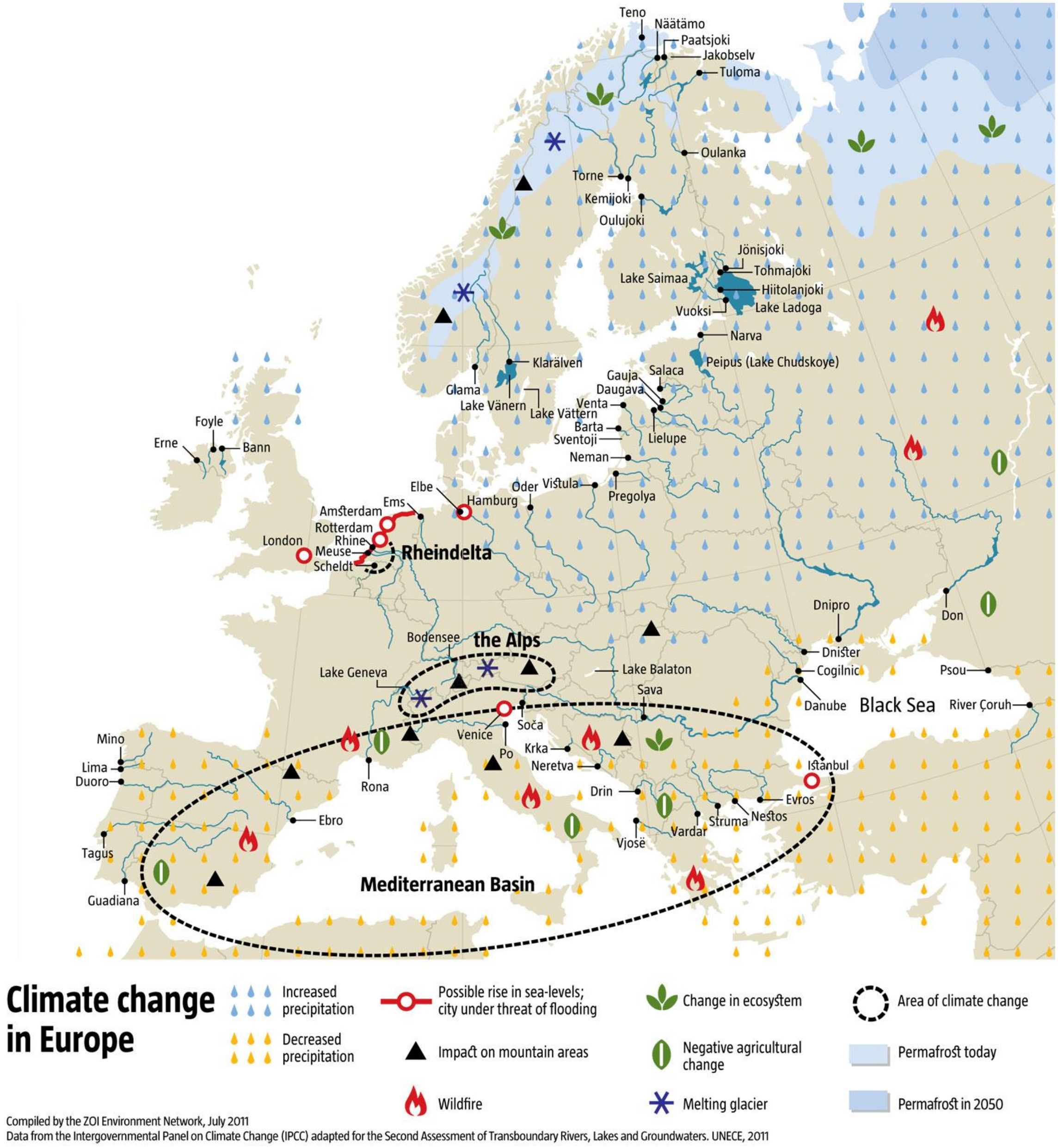


Figure 10.8 Climate change in Europe

Source: Compiled by the ZOI Environmental network, July 2011

Over the past decade, rainfall in July and August has been 15-27% less than normal, resulting in severe summer droughts. Droughts became more frequent and tended to cover bigger areas. In the past, they happened once every two to three years and covered from 10 to 30% of the country, but between 1989 and 2010 their frequency doubled, and the droughts started to spread through a wider area that previously had sufficient precipitation.

All transformations of climate have been affecting various areas of life in Ukraine for a while now. Their effect is particularly visible in agriculture.

Despite optimistic expert projections of better grain crops in the case of mild warming, the expected rapid rise of the average annual temperature will have a disastrous impact on Ukrainian agriculture, if it fails to adapt itself to new climate conditions.

Agricultural output will decline, while its share in GDP will drop by several percent in the long term. In addition to insect–pests, the amount of which is boosted by the warming, fertile soil can be damaged by erosion and desertification, as a result of the microclimate becoming more arid.

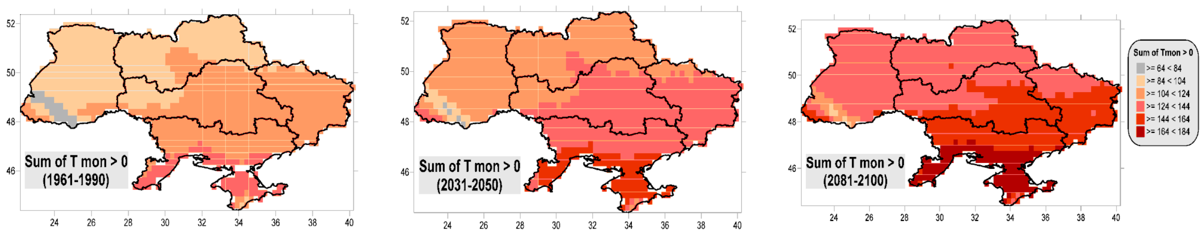


Figure 10.9 Dynamics of sums of positive monthly temperatures (indicator of heat availability by Vorobjov) for 1961–1990, 2031–2050 and 2081–2100

Currently, Ukrainian agriculture is not responding to climate change properly, as it is choosing the easiest way. To minimize the losses caused by natural disasters, many farms are switching to growing technical plants that are less vulnerable to bad weather.

Global warming will have a heavy impact on the water supply, primarily drinking water, in the most arid areas. Crimea and some Southern oblasts of Ukraine are already suffering from a shortage of good quality water, and the problem of the increase in the annual temperature will aggravate this. The quality of surface water, especially in shallow rivers, could also worsen, which will lead to the spread of infections.

In social terms, climate change will disproportionately affect people with a low income, having the heaviest impact on socially vulnerable groups with limited access to energy, water and a good quality food supply, as well as other services, including healthcare.

The war in Ukraine is exacerbating climate change in the world. Due to russian airstrikes on our oil depots and infrastructure, significant amounts of pollutants and greenhouse gases are being released into the air. At the same time, russia is destroying Ukrainian forests, wetlands, grasslands and pastures, which are major carbon sinks. All this affects climate change.

For example, according to preliminary estimates of experts of the Ministry of Environment, due to the increased consumption of petroleum products by military equipment, almost 4 million tonnes of CO_2 entered the atmosphere during the first 150 days of the full-scale intervention, which is 10 times more than the emissions of military equipment in Ukraine for the full year 2021.

The draft Recovery Plan for Ukraine, developed by the National Council for the Recovery of Ukraine from the Consequences of War, among the priority tasks in the area of "Climate Policy: Prevention and Adaptation to Climate Change" is noted: "Analyse the impact of the war on the state of implementation of climate policy and develop a plan to implement commitments under the UNFCCC, the Paris Agreement and the Montreal Protocol, including forming a methodological framework for taking into account climate change adaptation as a cross-cutting issue in state recovery planning."

In wartime, adaptation to climate change, according to experts, is both the conversion of armies to green fuels, changes in infrastructure and the ability to protect its territory from harmful effects on the environment.

10.4 Peculiarities of monitoring of waste generation, storage and disposal sites in Ukraine

Monitoring of waste generation, storage and disposal sites, as well as monitoring of the impact of genetically modified organisms on the environment are subsystems of the state environmental monitoring system.

Figure 10.10 Dynamics of waste generation and utilisation in classes 1-4, thousand tonnes [52]

In order to determine and forecast the impact of waste on the environment, timely identification of negative consequences, their prevention and overcoming, waste generators, their owners, as well as the central executive authority implementing the state policy in the field of environmental protection, regional, Kyiv and Sevastopol city state administrations, and on the territory of the Autonomous Republic of Crimea - the executive authority of the Autonomous Republic of Crimea on issues of environmental protection, monitor places of waste generation, storage and disposal (Article 29 of the Law of Ukraine "On Waste").

The necessity to perform monitoring of waste generation sites is also stipulated when conducting planned (unscheduled) measures of state supervision (control) on compliance by business entities with the requirements of legislation in the field of environmental protection, rational use, reproduction and protection of natural resources, as follows from the Unified form of the Act (p. 12 of Annex 4 to the Unified form of the Act drawn up as a result of a planned (unscheduled) event of state supervision (control) on compliance by a business entity with the requirements of legislation in the field of environmental protection, rational use, reproduction and protection of natural resources, approved by the order of the Ministry of Energy and Environmental Protection of Ukraine from 26 November 2019 № 450).

However, at the legislative level, the requirements for the procedure of monitoring the places of waste generation and temporary storage at the enterprise have not been approved.

One of the main problems of waste monitoring implementation in Ukraine is the outdated current legislation in the field of waste management.

At the same time, the Verkhovna Rada of Ukraine adopted the Law of Ukraine "On Waste Management", which came into force on 09.07.2023.

The Law establishes requirements for an economic entity that has received a permit to carry out waste treatment operations to monitor the waste treatment facility in accordance with the procedure approved by the Cabinet of Ministers of Ukraine (Article 42 of the Law).

Figure 10.11 Hierarchy of waste management priorities

Source: https://menr.gov.ua/news/33133.html

In addition, the owner (balance holder) of the landfill or the landfill management company should develop and implement a landfill monitoring programme during the lifecycle of the landfill.

The procedure for the development of the landfill monitoring programme and its requirements are approved by the central executive authority, which ensures the formation of state policy in the sphere of environmental protection (Article 40 of the Law).

An important legislative norm is the requirement to develop a National Waste Management Plan. The Law defines the main sections of the National Waste Management Plan:

1) Current situation of the waste management sector, which shall specify:

a) The main waste producers;

b) main waste management indicators (volumes of waste generation, collection, transport and treatment);

c) description of waste collection systems, including separate collection, the state of coverage of the country's territory by waste collection systems;

d) a brief description of the waste treatment facilities, including those that handle hazardous waste;

2) strategic planning of waste management, which indicates:

a) projected indicators of waste generation and expected development of the waste management system;

b) main goals/objectives for the development of the waste management system and targets set under the objectives;

c) measures to achieve the goals/objectives and targets, including establishing the responsibilities of the various agencies and organisations that will be involved in implementing the activities;

d) assessment of the need for closure of existing and establishment of new waste treatment facilities;

e) measures to prevent littering and clean up littered areas;

f) location of waste treatment facilities and their planned capacity;

g) historical waste sites and clean-up activities, costs and possible sources of funding;

h) indicators for assessing the implementation of the plan;

3) instruments for implementing the plan, including economic instruments, assessment of their suitability and projections of expected results;

4) monitoring and evaluating the effectiveness of the implementation of the plan.

At the same time, the Law of Ukraine "On Waste Management" also provides for the development of a National Waste Prevention Programme and monitoring of its implementation. By-laws defining monitoring procedures are under development.

10.5 Monitoring of waste management in the European Union

In addition to issues related to waste management planning and monitoring, Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008 on waste and repealing certain directives (Waste Framework Directive) provides for a number of measures to monitor and verify compliance with the obligations of the producer of a product concerning extended producer responsibility schemes and monitoring and evaluation:

● measures to prevent waste generation, including prevention of food waste generation;

● fulfilment of its reuse measures by measuring reuse based on a common methodology.

Council Directive 1999/31/EC of 26.04.1999 on waste disposal, as amended by Regulation (EC) 1882/200328 notes that Member States shall ensure that an application for an authorisation for a waste disposal activity necessarily contains, among other matters, a proposed operation, monitoring and control plan.

Actually, the landfill permit provides "requirements for landfill preparation, disposal operations, and monitoring and control procedures, including contingency plans, as well as preliminary requirements for closure and post-operational care operations."

Article 12 of this Directive deals with control and monitoring procedures during the operational phase and Annex III specifies the requirements for a control and monitoring programme.

The Directive 2006/21/EC of the European Parliament and of the Council of 15.03.2006 on the management of waste from the extractive industries and amending Directive 2004/35/EC29 states that monitoring procedures should be established during operation and after closure of waste disposal facilities.

The post-closure period for monitoring and control of Category A waste disposal facilities should be set in proportion to the risk constituting each individual waste disposal facility, in a manner similar to that required by Directive 1999/31/EC.

Member States should require extractive industry operators to apply monitoring and management controls to prevent pollution of water and soil and to identify any negative impact that their waste disposal facilities may have on the environment or on human health.

It is also interesting to review the basic principles of waste management in the EU, which are set out in the Waste Framework Directive. These include, in particular, that waste management should be: without threat to human health and damage to the environment; without any risk to water, air, soil, vegetation or wildlife; without inconvenience due to noise or smells; without adverse impact on the countryside and areas of particular interest.

The Waste Framework Directive has also defined priorities for waste management in Europe, as shown in the Figure 10.12.

Figure 10.12 EU Waste hierarchy

Source: https://environment.ec.europa.eu/topics/waste-and-recycling/waste-framework-directive_en

The European Green Deal Programme and the Circular Economy Action Plan both call for strengthened and accelerated action by the EU and Member States to address the environmental sustainability of the textile and food segments, as they are the most resource-intensive branches that cause large negative ecological externalities.

It has therefore been proposed to supplement and strengthen the Waste Framework Directive in 2023 with provisions aimed specifically at these waste generation sectors.

This focus on textile and food waste is aimed at achieving the main objectives:

- reduce impact on the environment and climate, enhance the quality of the environment and improve population health associated with the management of textile waste in accordance with the waste hierarchy,

- reduce the impact of food systems on the environment and climate linked to food waste generation. Prevention of food waste will also help to promote food security.

10.6 Monitoring the impact of genetically modified organisms on the environment

Article 15 of the Law of Ukraine "On the State System of Biosafety in the Creation, Testing, Transport and Use of Genetically Modified Organisms" (2007) defines the procedure for tracing and detection of products produced or containing GMOs. However, this law does not contain norms providing for monitoring of GMOs' impact on the environment.

But for 15 years of existence of such a document, no GMO products have been registered in Ukraine. In other words, de jure we do not have GMOs: they are not produced, grown or used. And de facto, in recent years, a shadow market of GMO products has formed in the country, which are in circulation beyond any control.

In order to implement 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, as well as the action plan for its implementation, a draft law (Law Draft No. 5839 of 05.08.2021 "On State Regulation of Genetically Engineered Organisms and State Control over the Circulation of Genetically Modified Organisms and Genetically Modified Products to Ensure Food Security") has been elaborated, which provides for post-registration monitoring of GMOs - monitoring of adverse effects on human health or the natural environment arising from the use of GMOs in accordance with the provisions of Directive 2001/18/EC of the European Parliament and of the Council of 12 March 2001 on the environment of genetically modified organisms.

According to the draft law, the following entities should be responsible for monitoring the impact of GMOs on the environment:

- business entities that put GMOs into circulation regardless of their intended use (feed, feed additives, food, cosmetic, medicinal products for cultivation, animals) - monitor at the interval established by law;

- the state, represented by the central executive authorities concerned (Ministry of Environment, State Environmental Inspectorate, Ministry of Economy, Ministry of Agrarian Policy, State Service of Ukraine for Food Safety and Consumer Protection, Ministry of Health), as well as the National Academy of Sciences and the National Academy of Agrarian Sciences for control purposes;

- non-governmental organisations and individuals.

Coordination of monitoring of the environmental impact of GMOs should be the responsibility of the Ministry of Environment.

Monitoring the environmental impact of GMOs in the EU. The main document of EU legislation is Directive 2001/18/EC of the European

Parliament and of the Council of 12 March 2001 on the deliberate release of genetically modified organisms into the environment.

The document stipulates that in order to obtain a permit for the release of GMOs for both testing and market placement purposes, a plan for monitoring the impact of GMOs on the environment is mandatory.

Regulation (EC) No 1830/2003 of 22 September 2003 on the traceability and labelling of genetically modified organisms and the traceability of food and feed produced from genetically modified organisms and amending Directive 2001/18/EC39 defines the environmental impact of food and feed produced, compounded or containing GMOs.

The Cartagena Protocol on Biosafety to the CBD also notes that monitoring the environmental impact of GMOs is mandatory and a prerequisite for the introduction of GMOs into circulation.

10.7 Monitoring of the geological environment

The part of the lithosphere directly acting as the mineral basis of the biosphere is one of the most important components of the natural environment and is distinguished under the name "geological environment" (GE).

According to the definition given in the Law of Ukraine “On State Geological Service of Ukraine” dated 04.11.1999 No. 1216-XIV, the ***geological environment*** is a part of the Earth's crust (rocks, soils, bottom sediments, groundwater, etc.), which interacts with elements of the landscape, atmosphere and surface water and may be affected by anthropogenic activities.

The complex of engineering structures and parts of the GE in the zone of their influence, that have fixed boundaries, is called a natural-technical system (NTS). NTS covers some space, including the technical system itself, as well as some part of the GE within the zone of influence of the GE technical system.

The GE includes soils and uppermost rock layers, which are considered as multicomponent systems, and the boundaries of the GE change not only in space, but also in time.

The external components of the GE are the atmosphere, the surface part of the hydrosphere (surface water), all types of engineering structures, communications and facilities.

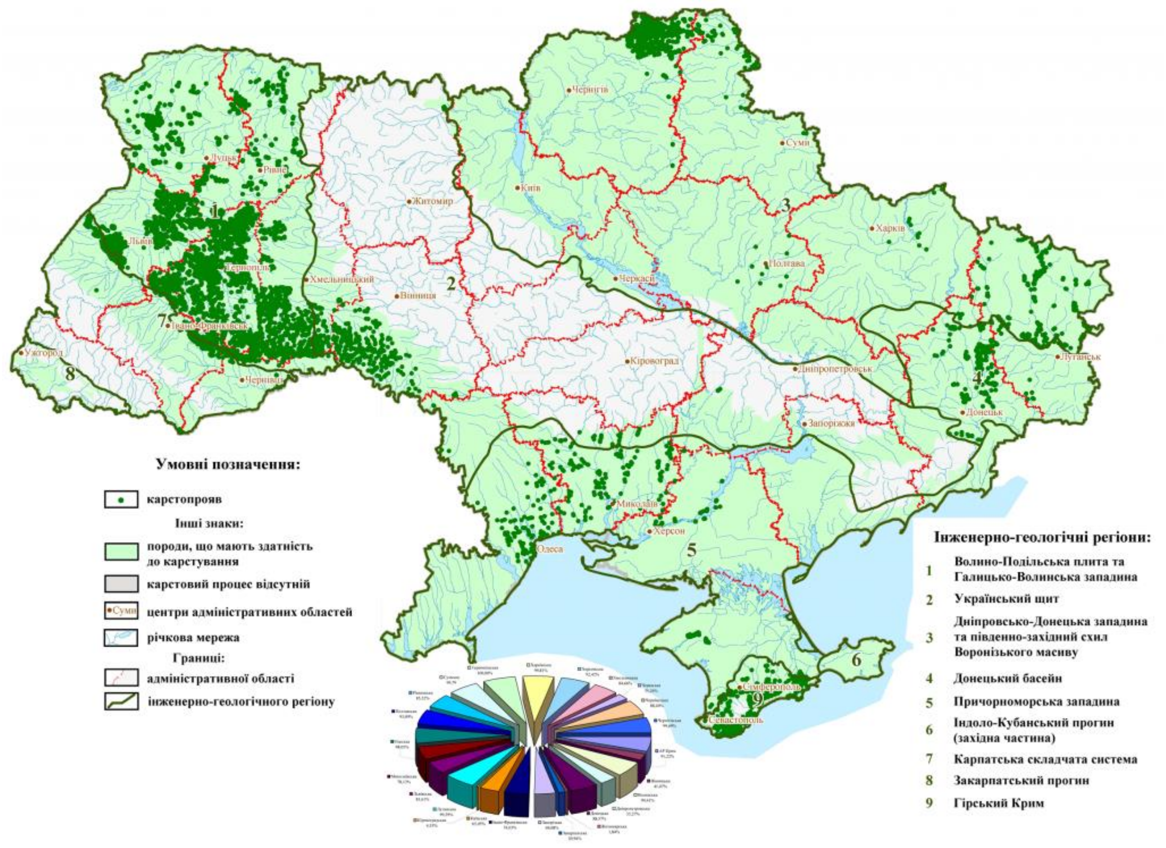


Figure 10.13 Occurrence of geological hazards

Source: http://geoinf.kiev.ua/ekzohenni-heolohichni-protsesy/

The internal components of the GE are soils; rocks composing the masses of this particular structure; relief and geomorphological features of the territory; groundwater; gaseous fillings of rocks.

The upper layer of the lithosphere (up to about 10 km) is actively used by human for the extraction of minerals and is called "subsoil".

Technological progress is based on the growing use of natural resources, including mineral resources. About 150 billion tons of rocks, including more than 20 billion tons of minerals, are withdrawn from the subsoil each year.

With modern technology of extraction and use of minerals, only 1-5% of the total volume of raw materials withdrawn from the subsurface is realized in the form of industrial products, while the rest is waste. About 18 million tons of waste tailings are produced in the world every year.

According to cadastral records in Ukraine at the beginning of 2020 there were 7,056 deposits of combustible, metallic and non-metallic minerals. Some of the largest in volume are reserves of coal, iron, manganese and titanium-zirconium ores, as well as graphite, kaolin, potassium salts, sulphur, refractory clays, and facing stone.

The State Balance of Mineral Reserves of Ukraine as of 01.01.2020 included 1705 deposits of drinking, technical and mineral groundwater.

The zone of influence of mining is characterised by disturbances of different types:

- geomechanical (deformations of rocks and earth surface, failures, developments);

- hydrodynamic (hydrological - surface, hydrogeological - underground);

- aerodynamic (surface) disturbances and pollution: lithospheric (surface), hydrospheric, atmospheric and biocenotic.

Mining negatively affects the state of such elements of the natural environment:

1) land, soil (landscape) - deformations of the earth surface, disturbance of soil cover, reduction of productive land area, deterioration

of soil quality, changes in the condition of surface and ground waters, deposition of dust and chemical compounds due to atmospheric emissions, erosion processes;

2) subsoil - changes in the stress-strain state of the rock massif, reduction of quality and loss of mineral resources and industrial value of deposits, subsoil pollution, development of karst processes;

3) water basin, groundwater - reduction of surface and groundwater reserves, violation of hydrogeological regime; pollution of water basin by waste and drainage water;

4) air basin - atmospheric pollution;

5) flora and fauna - deterioration of flora and fauna existence conditions, migration and reduction of wild animals, reduction of plant population, loss of crop yields, reduction of productivity of livestock, fisheries and forestry.

Enterprises of the State Geological Service carry out observation and monitoring of groundwater conditions at 1148 observation points. At these points the level of groundwater occurrence and its natural geochemical composition are assessed. Up to 22 parameters are determined, including concentrations of heavy metals and pesticides.

GE within urbanised areas is characterised by the appearance of artificial soils, significant closure of the surface by rigid pavement and buildings. Special geophysical and geochemical fields arise, affecting the condition of the GE and the conditions of living organisms and humans.

The functions of GE are considered from the perspective of evolution and life support of biota and, mainly, human society. There are three main approaches to assessing the ecological state of territories:

- by direct quantitative assessments of GE components (geological rocks, groundwater, soils, etc.) compared to MACs, background values, etc.;

- by ranking the territory by anthropogenic load (unchanged, weakly, moderately, strongly, very strongly and catastrophically changed);

- on assessing the role of the GE "geological matrix" in the current state of ecosystems.

There are 4 levels (classes) of natural and anthropogenic disturbances: norms, risks, crises, catastrophes or disasters.

The zone of ecological norm ("N") includes territories with no noticeable decrease in productivity and sustainability of the GE, its relative stability. Values of direct criteria are below MAC or background values. Land degradation is less than 5% of the territory.

The ecological risk zone (R) includes areas with a noticeable decrease in the productivity and sustainability of GE, which leads to their spontaneous degradation. The territory requires measures to improve environmental conditions. Values of direct criteria exceed MAC. 5-20% of lands are degraded.

The ecological crisis zone ("C") includes territories with a strong decrease in productivity and loss of sustainability of GE. Limited economic use of the territory with application of measures to improve environmental conditions is possible. Values of direct criteria significantly exceed MAC. 20-50% of lands are degraded.

The ecological disaster zone (‘D') includes areas with a complete loss of productivity and sustainability of the GE, which excludes the possibility of its economic use. The values of direct criteria are ten times higher than the MAC. More than 50% of the land is degraded.

The zones of ecological norm correspond to satisfactory ("S"), the zone of ecological risk - conditionally satisfactory ("CS"), the zone of ecological crisis - unsatisfactory ("U"), the zone of ecological crisis - catastrophic ("K") ecological and geological conditions. It should be noted that the condition of living organisms depends not only on ecological and geological conditions, but also on socio-economic factors.

To assess the environmental and geological conditions, direct and indicative criteria are used, which are divided into resource, geodynamic, geochemical and geophysical groups according to the nature of the assessment.

Direct assessment criteria within these groups are regulated by regulatory documents and relate to MAC, MPD, MPE or background and clark value.

The indicative criteria include: 1) in the resource group - residual reserves based on the achieved level of consumption (number of years); 2) in the geodynamic group - planar, volumetric and dynamic, as well as medical, botanical and zoological; 3) in the geochemical group - indicators for assessing the degree of lithosphere pollution; 4) in the geophysical group - criteria for assessing radiation pollution, etc.

Consequently, one of the main tasks in substantiating the criteria for assessing the ecological state of GE is to conduct comprehensive studies on migration, accumulation, transformation in ecosystems during the transition from one environment to another of various pollutants at auxiliary polygons. One of the most important current problems in assessing the state of the GE is the substantiation of the criteria for maximum permissible environmental and geological loads and maximum permissible environmental and geological impacts.

Monitoring of geological environment - a system of observation, collection, processing, transmission, storage and analysis of information on the state of the geological environment, forecasting of its changes, development of scientifically based recommendations for making appropriate decisions.

Monitoring of the state of the geological environment is carried out on: exogenous and endogenous geodynamic processes (including determination of their spatial and species characteristics, activity of manifestations); geochemical indicators (including determination of the content and distribution of natural and anthropogenic chemical elements and compounds); geophysical fields (including background and anomalous); groundwater (including assessment of resources, their hydrogeological and hydrochemical characteristics and parameters).

The purpose of the GE monitoring system is to identify trends in GE development and, on this basis, to support management decisions on optimising the natural-technological system. The main purpose of GE monitoring is to monitor the state of the GE and forecast changes in the GE, as well as to develop environmental protection measures based on the results of monitoring studies.

The structural scheme of GE monitoring can be presented in the form of 5 main blocks - observation, analysis of the current state of GE, forecasting and assessment of the predicted state, support of management decisions, interconnected by information channels in order to form an automated information system and engineering protection system.

Depending on the type of GE monitoring, 4 main groups of observations are used: inventory, retrospective, regime and methodological.

Inventory observations include a set of labour-intensive and costly observations of GE objects that are usually not included in routine observations. These observations for a separate period can be carried out with the order of once a year (or for 2-3 years and more) for the most conservative elements of GE, as well as in determining the background values of GE parameters in areas not disturbed by anthropogenic loads.

Retrospective observations are aimed at identifying trends in the development of the GE or its components and establishing patterns of their changes. Retrospective observations form the basis for solving forecasting tasks in GE monitoring. In terms of timing and periodicity they should be different depending on the intensity of changes in the GE elements.

Regime stationary observations are observations of the dynamics of processes (phenomena) at stationary sites, points, points to reveal their regularities and conditionality. They reflect temporal (annual, seasonal, monthly, daily, etc.) fluctuations of GE parameters. The network of regime observations (e.g., geotechnical and hydrogeological), which have some features of autonomy, should organically fit into the overall GE monitoring structure.

Methodological observations are aimed at improving GE monitoring methods or creating new methods. They are often conducted before retrospective and routine observations. Their role is especially significant at the initial stage of organising a GE monitoring network.

An observation programme is developed for each observation network. By analogy with observations of other natural environments, when developing an observation programme it is necessary to answer the following questions: what, where, what (how), with what frequency and periodicity should observations be carried out?

Observation networks within the GE are formed in three-dimensional space and, depending on the scale of research or the rank of the GE, should be detailed, local, regional and national. A distinction is made between an observation point (soil sampling point, well, spring, etc.) and an observation point (hydrogeological, engineering-geological, geophysical, etc.), an observation site that provides a group of observations, for example, hydrogeological.

Detailed observation polygons are intended for solving the tasks of collecting preliminary information at sites, the typical conditions of which correspond to the reference polygon. The reference polygon corresponds to the local level of research at a typical (reference) site of the area with the same type of GE. Varieties of reference polygons are background polygons designed to collect information on GE in areas not disturbed by anthropogenic processes.

The aggregate of reference polygons forms a regional research polygon. In addition, special polygons may be formed for observation of GE conditions at environmentally hazardous sites (for example, in the areas of existing NPPs), as well as experimental-methodological polygons and polygons for scientific research.

Among remote observation methods, the GE monitoring system uses aerospace methods (television, infrared, radar and photography, and others). In addition, geophysical methods are widely used (seismic and acoustic sounding, electrical sounding, thermometry, and so on).

Eco-geological studies consist of preparatory, field, analytical and desk work. The peculiarity of them is the complex study of GE by means of geological, geochemical, hydrogeological, engineering-geological, landscape and other studies, as well as analysis of aerospace survey materials. This makes it possible to collectively assess the state of GE, the direction of the technogenesis process and the ecological and geological situation in the study area.

The main tasks of eco-geological studies:

- study and mapping of areas with different degrees of anthropogenic impact;
- assessment of the state of the GE and the impact of natural processes occurring in it on the ecological situation;
- assessment of the totality of natural and anthropogenic factors of GE, determining the functioning of geological and technogenic systems and their environmental parameters;
- promptly informing state and environmental authorities, public organisations about environmentally hazardous conditions and unfavourable development of geological processes;

- development of recommendations on limitation and prevention of unfavourable and dangerous geological and technogenic processes.

The main objects of study of eco-geological research:

- rocks, soil and vegetation formations of the aeration zone, bottom sediments;

- endogenous and exogenous geological processes affecting the formation of GE;

- objects of the gas transmission system (territorial-industrial, fuel and energy complexes, industrial and urban agglomerations).

The ultimate goal of eco-geological studies:

- assessment of the state and forecasting of changes in GE and environmental parameters;

- justification of a set of measures for rational use and protection of the geological environment, limiting its negative changes and increasing the sustainability of geological and technogenic systems.

Aerospace (remote sensing) studies are a promising direction in improving the methods of ecological and geological mapping, allowing to create operational models of the current state of the geological environment.

The analysis of methodological approaches to the creation of maps of environmental content shows that the main principle of creating such models is the representation of natural and anthropogenic factors of environmental dynamics.

10.8 General provisions of radioecological monitoring in Ukraine

Increased levels of radiation overload on the environment have necessitated radioecological monitoring.

Radioecological monitoring is not a fundamentally new system requiring the organisation of a network of new observation stations, lines and telecommunications, data processing centres and other services. It forms an integral part of an overall system of environmental monitoring and control that has long been developing in a number of countries.

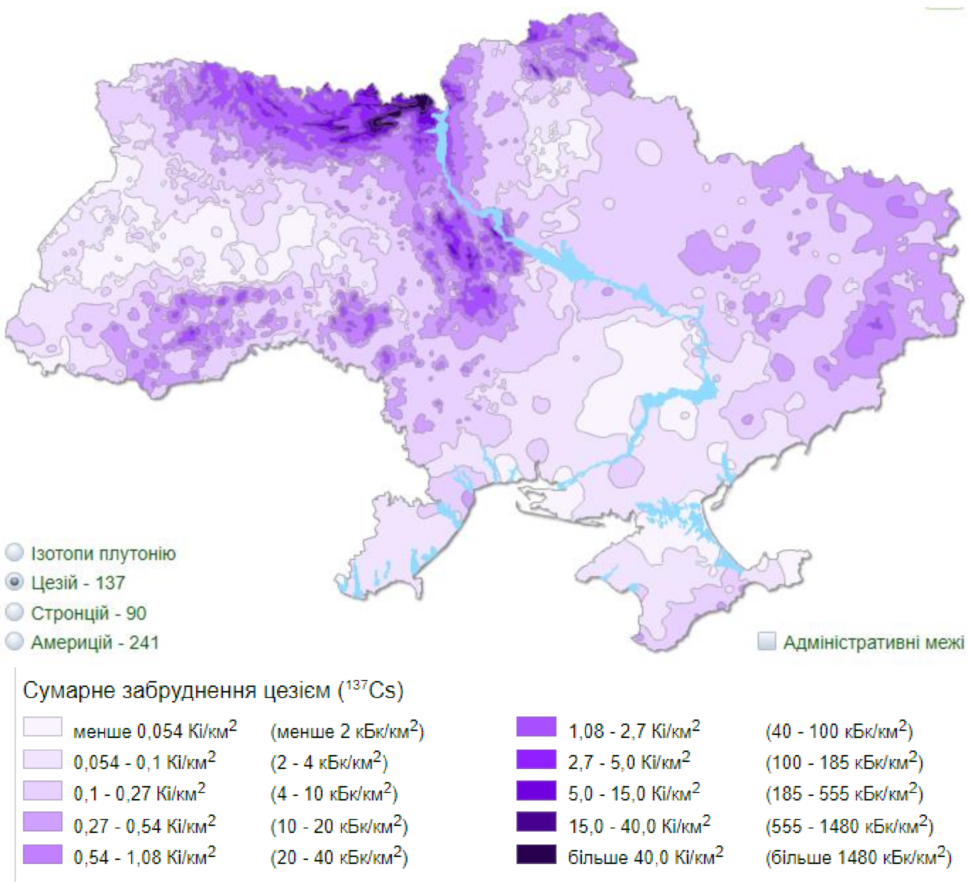


Figure 10.14 Contamination of the territory of Ukraine with cesium-137

Source: https://geomap.land.kiev.ua/ecology-5.html

Radioecological monitoring became especially relevant and important in our country after the Chernobyl accident. During this accident, which is the largest in the history of nuclear power development and received the status of a global catastrophe, more than 1.85×10^{18} Bq of a mixture of radioactive isotopes in the form of aerosol was released to a height of up to 7 km, according to the official 1986 estimate.

The issue of prompt assessment of the radiation state of environmental objects and decision-making to minimise the negative consequences of the impact of radioactive contamination on these objects, including humans and other living organisms, is still acute today in the remote period after the Chernobyl accident.

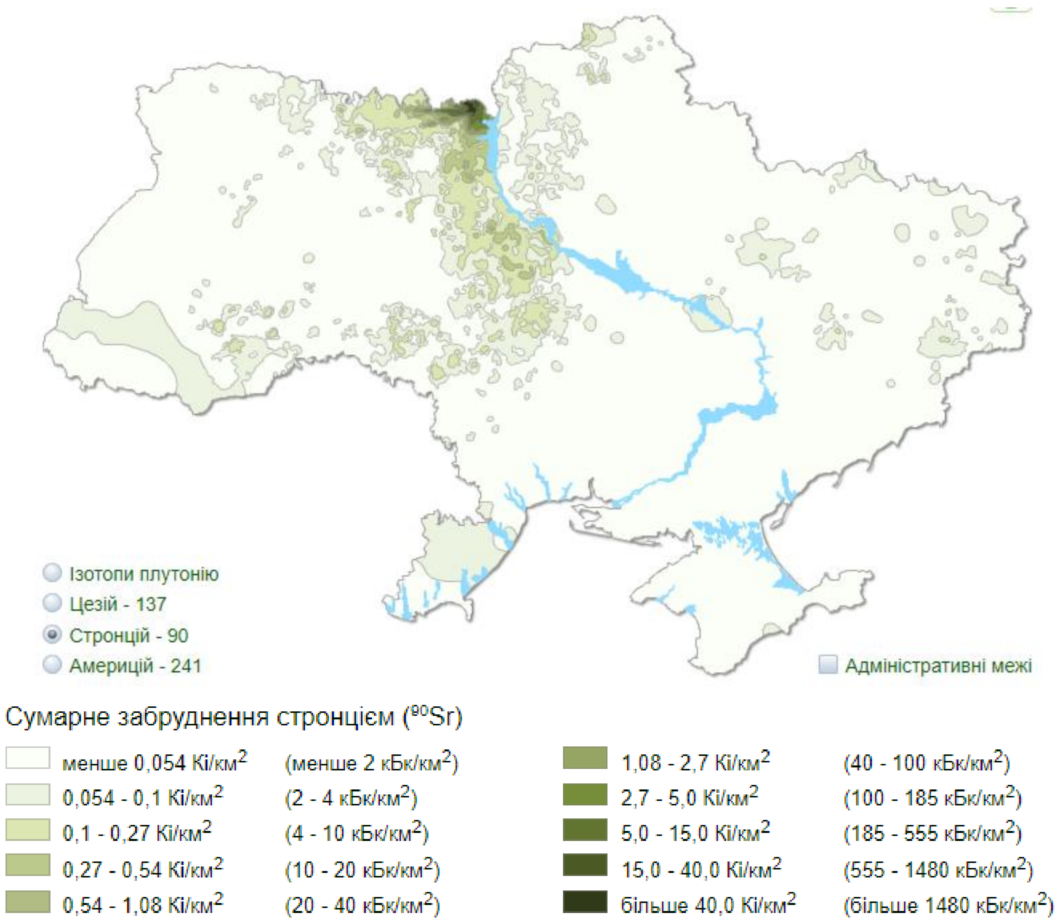


Figure 10.15 Contamination of the territory of Ukraine with strontium-90

Source: https://geomap.land.kiev.ua/ecology-5.html

The main and potential sources of radioactive contamination in peacetime are nuclear power plants, nuclear fuel production facilities, nuclear weapons storage facilities, nuclear waste processing facilities, waste disposal sites, and others.

Three names of monitoring based on the radionuclide share can be found in the scientific literature: radiological monitoring, radiation monitoring and radioecological monitoring. Radiological and radiation monitoring are practically one and the same thing, and are usually concerned with the inanimate objects of the environment.

In radioecological monitoring, emphasis is placed on the state of living organisms - plants, animals, humans and their habitat - atmosphere, soil, water. Undoubtedly, the objectives of these types of monitoring largely overlap and may coincide.

According to the Norms of Radiation Safety of Ukraine (NRSU-97), ***radioecological monitoring*** is a collection of primary information (measurement of dose rate absorbed in the air, determination of radionuclide content in environmental objects, food, drinking water, etc.) with the purpose of further use for radiation-hygienic control and dosimetric control.

Radioecological monitoring also involves determining the effects of ionising radiation on biota.

A clear distinction is usually made between monitoring under normal conditions and in emergency situations. Emergency radioecological monitoring is that carried out to provide the information necessary to make a decision on intervention and to determine the form, scale and duration of the intervention.

Both foreign and national publications regulating activities in the field of radioecological monitoring make a distinction between the concepts of source monitoring and environmental monitoring.

Radiation source monitoring is the monitoring of an individual source of ionising radiation (radiation facility of a certain purpose - medical, technological and others, radiation-nuclear facility, source of radiation hazard) or a type of activity with such sources.

Radioecological monitoring of the environment is a methodology and practice of measurements, observations, collection, processing, transmission, storage and analysis of information on the radiation state of the environment (external dose rates from radiation sources or radionuclide concentrations in the environment), forecasting of its changes and development of science-based recommendations for decision-making to prevent negative changes in the environment and compliance with radiation safety requirements.

Radioecological monitoring is an integrated information and technical system of observations, research, assessment and forecasting of the radiation state of the biosphere, territories near NPPs and other nuclear fuel cycle enterprises and facilities affected by nuclear and radiation incidents.

The main tasks of radioecological monitoring are:

- observation and control over the condition of the territory contaminated with radionuclides, its separate especially dangerous parts and development of ways to reduce the danger from contamination;
- assessment of the state of environmental objects by parameters characterising the radioecological situation both in the contamination zone and outside it;
- identification of trends in changes in the state of radioactive contamination of the environment in connection with the operation of radiation hazardous facilities, as well as in the implementation of radio-protection measures carried out in contaminated areas;
- ascertaining possible trends of changes in the health status of the population living in the territories contaminated with radionuclides;
- information support for the forecast of the radioecological situation in the areas contaminated with radionuclides and in the country as a whole.

Radioecological monitoring, like any monitoring, is implemented in three main directions, distinguishing, respectively, basic (standard), crisis (operational) and scientific (background) monitoring.

Basic radioecological monitoring is carried out through a network of observation points covering the entire territory of the country, including radiation control services for nuclear production.

Crisis radioecological monitoring is formed on the basis of activity of territorial services of observation and control of radioecological parameters of the environment in the territories where unfavourable situations have arisen.

Scientific radioecological monitoring is implemented by coordinating structures on the basis of research institutions developing methods and programmes of radioecological research.

In Ukraine, after the Chernobyl accident, radioecological monitoring of the main components of the environment is performed at different territorial levels according to the indicators that are characteristic only for our country.

Thus, radioecological monitoring of the following objects is carried out in the territories contaminated with radioactive substances (except for the 30-km exclusion zone around the Chornobyl NPP):

- landscape-geological environment in order to obtain basic information for assessment and forecasting of the general radioecological situation in the radionuclide contaminated territories and its impact on the ecological situation in Ukraine;
- surface and underground water systems;
- environmental protection measures and facilities;
- local long-term sources of actual and potential contamination (shelter facility, cooling pond, radioactive waste disposal sites, temporary radioactive waste localisation sites);
- biocenoses;
- medical and sanitary-hygienic.

At present, a full-fledged system of radioecological monitoring has not yet been created in Ukraine. Its separate components are represented by the following directions:

- monitoring of radioactive fallout from the atmosphere,
- monitoring of water resources,
- radiation monitoring of agricultural products,
- control of forest products,
- control of food products,
- control of construction materials.

Basically, these are the main components of radioecological monitoring, which cover the main spheres of the natural environment and from which the threat of exposure of the population can be created.

However, these separate components exist in isolation, solve, as a rule, narrow departmental tasks and are not linked by a common methodology. This reduces the efficiency of monitoring works, narrows the circle of users and, in the end, does not provide full-fledged fulfilment of radioecological monitoring tasks.

The radiation monitoring system involves the following consecutive stages: measurement of the ionising radiation level on the ground (field radiometry, dosimetry), sampling and preparation for examination, determination of radioactivity by express methods, radiochemical distribution of radionuclides, radiometry of separated radionuclides, calculation of activity.

Reliability and accuracy of information obtained in the process of radiological control is ensured by the use of radiation control methods. They are divided into radiometric, radiochemical and spectrometric methods. As a rule, the first two groups of methods are used.

Radiometric methods include field radiometry and dosimetry, rapid determination of radioactivity, ash radiometry, and radiochemical preparations.

Radiochemical methods are used following a certain sequence: selection and preparation of samples of the objects under investigation; introduction of carriers and mineralisation of samples; separation of radionuclides from samples; purification of separated radionuclides from extraneous nuclides and associated elements; identification and verification of radiochemical purity; radiometry of separated radionuclides; activity calculations and conclusions.

In Ukraine, radioecological monitoring is carried out by units of the State Emergency Situations Service, the Ministry of Health, the Ministry of Agrarian Policy and Food, the Ministry of Environment, the State Forest Resources Agency, the State Agency of Water Resources, as well as by various research institutes, external dosimetry laboratories of nuclear fuel cycle enterprises, etc.

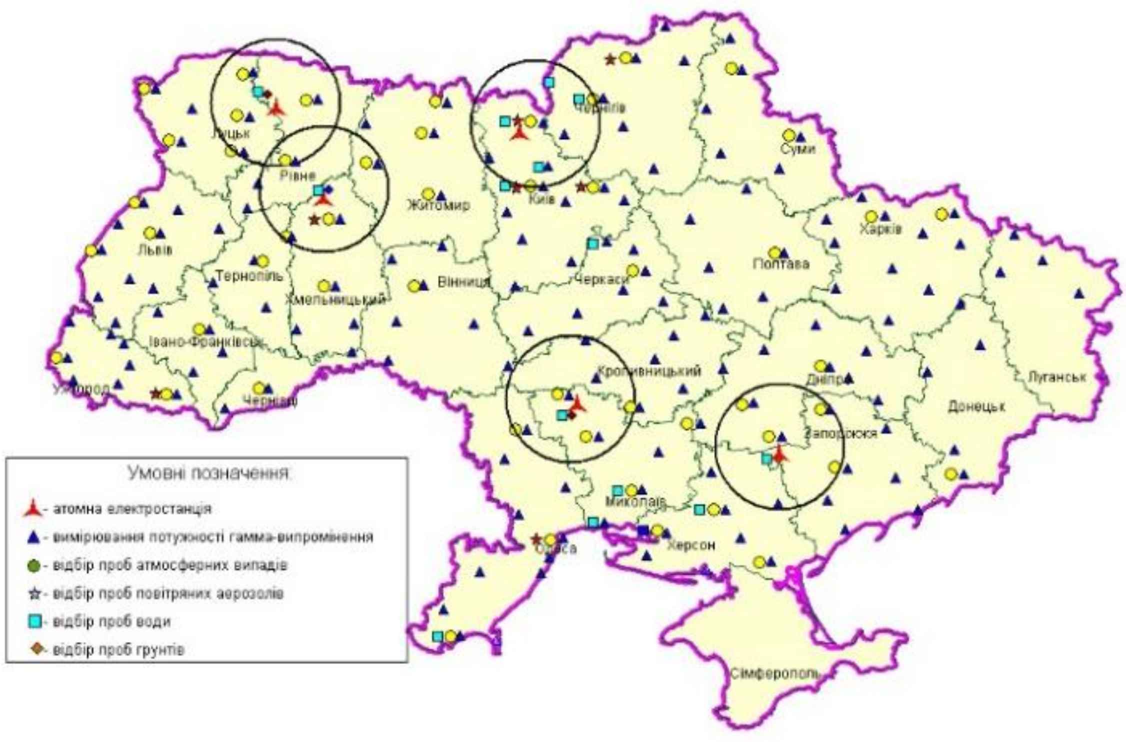


Figure 10.16 Map-scheme of location of hydrometeorological service observation points for radioactive contamination of the natural environment on the territory of Ukraine

Source: http://cgo-sreznevskyi.kyiv.ua/uk/?dv=radiation-ukraine

At present, radioecological monitoring is carried out in the territories contaminated with radionuclides:

- landscape-geological environment in order to obtain basic information on assessment and forecast of the general ecological situation in the territories contaminated with radionuclides and its impact on the ecological situation of the adjacent territories;

- soils;

- surface and underground water systems;

- biocenoses, agrocenoses and measures to improve natural landscapes;

- agricultural products, food and drinking water.

Radioecological monitoring involves mapping and forecasting of relevant radioecological indicators.

Radioecological monitoring is carried out in the following main areas:

- measurement of ionising radiation intensity;

- assessment of radionuclide content in the body and exposure of organisms;

- assessment of radioactive contamination of the surface layer of air and underlying surfaces (soil, etc.), surface and ground waters.

Planning of radioecological monitoring is considered in the form of a special programme, which should clearly provide for: type, frequency and methods of measurements, methods of sampling and their subsequent laboratory examination, methods of statistical processing, methods of interpretation and data recording.

The focus, scope and duration of the programme determine both the types of measurements and the list of actors assigned to carry out individual tasks.

Optimisation of radiation monitoring includes: analysis and clarification of monitoring goals and objectives, observation points, measured parameters and their quantitative characteristics, monitoring methods, measurement methods and equipment - development, modification, adaptation, etc., analysis of databases, review of the scope of implementation and dissemination of monitoring results.

The quality requirements of monitoring are addressed through a quality assurance system that permeates the entire programme from the setting of the monitoring goal and objectives to the presentation and sharing of monitoring results.

Questions for self-control

1. What is climate? Give the short definition.
2. Past climate are studied by analyzing:
   a. ice cores;
   b. sea currents;
   c. sea/lake sediments;
   d. shorelines movements;
   e. tree pollen.
3. Is the human activity the primary driver of recent global warming?
4. How do we know the Earth's climate is changing? Provide some examples.
5. Why the climate observations are so important?
6. Do climate observations need to account for the full range of elements that describe the climate system?
7. Fill in omitted word: “the climate of Ukraine is … continental”.
8. Is climate of Ukraine involved or uninvolved in global climate system changes?
9. What are the signs of climate change that are apparent in Ukraine?
10. What trend can we see in average air temperature in Ukraine?
11. Possible impact of climate change in Ukraine:

1. agriculture	*A will have a heavy impact on the drinking water in the most arid areas*
2. water supply	*B can affect people with a low income*
3. social environment	*C the amount of insect–pests can be boosted by the warming*
	D can have a heavy impact on healthcare
	E fertile soil can be damaged by erosion and desertification

12. З якою метою здійснюють моніторинг місць утворення, зберігання і видалення відходів?

13. Які нові норми закріплені у законі України “Про управління відходами”?

14. Який спосіб поводження з відходами в ЄС є пріоритетним? Який має найнижче значення в ієрархії?

a. disposal;

b. sea currents;

c. recovery;

d. prevention;

e. recycling.

15. How could you characterise the current state of monitoring the impact of GMOs on the environment?

16. What elements does the geological environment include? Does it include groundwater ?

17. How many levels (classes) of natural-anthropogenic disturbances are distinguished?

18. What are the direct criteria for assessing eco-geological conditions?

a. background and clark value;

b. MAC, MPE, MPD;

c. subsoil pollution.

19. Give a definition of radioecological monitoring.

20. What are the main and potential sources of radioactive contamination of the environment?

21. What is the difference between radiological, radiation and radioecological monitoring?

22. Radioecological monitoring is carried out in the following main areas:

a. measurement of ionising radiation intensity;

b. assessment of radionuclide content in the body and exposure of organisms;

c. assessment of radioactive contamination of thecomponents of the environment;

d. all of the above variants are correct.

GLOSSARY

Access to information – the ability, right and permission to access and use, as well as the general availability of knowledge transfer resources.

Aerial photography – photographing the earth's surface from an aeroplane or satellite using special aerial cameras. A remote method of studying the earth's surface by taking photographs in various areas of the optical spectrum from an aeroplane or other aircraft.

Air pollutants – substances that adversely affect the environment either directly or following chemical changes in the atmosphere, or in combination with other substances and pollutant effects.

Air quality. Degree of air pollution; authorised type and maximum concentration of pollutants derived from human activities.

Arable land – land plots systematically cultivated and used for crops, including crops of perennial grasses, as well as clean pairs, areas of greenhouses and greenhouses.

Baseline monitoring are special high-precision observations of all components of the natural environment, as well as the nature, composition, cycling and migration of pollutants, the response of organisms to pollution at the level of individual populations, ecosystems and the biosphere as a whole. Background monitoring is carried out in natural and biosphere reserves, in other protected areas, and at base stations.

Basin approach - complex (integrated) water resources management within the river basin area.

Benz(a)pyrene: A carcinogenic substance that is a type of aromatic hydrocarbon; under normal conditions appears as light-yellow crystals with a melting point of 179 °C; found in coal tar, tobacco smoke, polluted air of large cities, especially on major highways and near petrol stations, soil, crude oil; very strong mutagen and carcinogen; a health hazard in any quantity.

Benzene – a colourless flammable liquid with a peculiar odour, extracted from the products of dry distillation of hard coal or from petroleum.

Biochemical oxygen demand (also known as BOD or biological oxygen demand) – The amount of oxygen used for biochemical oxidation by a unit volume of water at a given temperature for a given time. BOD is an indicator of the degree of organic pollution of water. The more polluted river water with organic substances, the higher its BOD. According to normative indicators BOD content in river water should be more than 3 mg/dm^3.

Biodiversity: 1 variability of life at all levels of biological organisation; 2. a measure of relative diversity among the set of organisms that make up a particular ecosystem; 3. “variability among living organisms from all habitats, including, inter alia, terrestrial, marine and other aquatic organisms, and among the ecological complexes of which they are part; this includes variability within species, between species and between ecosystems” (CBD).

Biological contamination − different organisms that appeared due to the vital activity of humankind - bacteriological weapons, new viruses (causative agents of AIDS, Legionnaires' disease, epidemics, other diseases, as well as catastrophic reproduction of plants or animals moved from one environment to another or accidentally).

Biomonitoring: operational monitoring of the environment based on observations of the state and behaviour of biological objects (plants, animals, etc.).

Built-up area. An area built up with residential houses, shops, offices and other structures, very often with limited open space.

Carbon dioxide (CO_2) – a strong chemical compound common in natural gases containing it in amounts ranging from a few per cent to almost pure carbon dioxide. Colourless, tasteless and odourless. Is the end product of carbon oxidation, does not burn, does not support combustion and breathing. Atmospheric carbon dioxide is a source of carbon for plants. It is a natural component of the atmosphere and is not harmful in itself, but plays a major role in the greenhouse effect. It is formed as a result of combustion of natural fuels, in the process of which carbon interacts with oxygen. It is also a product of respiration of living organisms. An essential nutrient for plants. Phytoplankton in the oceans can absorb and produce this gas in large quantities.

Chemical Oxygen Demand (COD) is the amount of oxygen consumed in the process of oxidation of organic and inorganic substances. Normally, this indicator should not exceed 15 mg/dm^3.

Chemical pollution is pollution that is caused by substances of chemical nature, for example, chlorinated polychlorinated biphenyls, hydrocarbon pesticides, metals such as lead, mercury, cadmium, arsenic, etc.

Chromatographic analysis. Analysis of chemical substances that are placed in a glass vessel containing an adsorbent. The different components of the substance move through the adsorbent at different rates depending on the degree of attraction to it, thus forming colour bands at different levels of the adsorption column.

Climate change. Long-term variations in readings of temperature, precipitation levels, wind direction, and other aspects of climate of the Earth. External influences such as changes in solar radiation levels, Earth's orbital parameters (inclination, eccentricity, clarity), lithospheric movement, and volcanic activity are factors in climate change. Internal variations in the climate system, such as changes in the volume of greenhouse gases, can also be the cause of significant and noticeable climate change.

Coliform organism: Escherichia coli bacteria, a group of bacteria of the Enterobacteriaceae family conventionally distinguished by morphological and cultural characteristics, used by sanitary microbiology as a marker of faecal contamination, belong to the group of so-called sanitary-indicative microorganisms.

Contamination The introduction into or application to the soil, water, air or other environment of microorganisms, chemicals, toxic agents, wastes, waste water or other pollutants in such concentration as to render the environment unfit for their intended use.

Data collection. An organised, constantly updated set of documented information about something (for example, about the state of the natural environment, its pollution).

Database – a set of interrelated data stored in a computer system to provide information retrieval from local and remote terminals.

Desertification 1) The development of desert conditions as a result of human activities or climatic changes. 2) The process of land destruction accompanied by loss of vegetation cover, deterioration of soil structure, loss of nutrients and reduced fertility.

Dissolved oxygen: gaseous oxygen (O_2) dissolved in water. Oxygen enters water by various pathways, including the following: 1) diffusion from the atmosphere; 2) turbulent water movement (waves, waterfalls, rapids, etc.); and 3) as a by-product of photosynthesis. Dissolved oxygen concentration levels can be altered by temperature and water movement.

Drinking water – water that is fit for drinking, does not pose a threat to health and whose quality is generally regulated by legislative act.

Emission control − procedures aimed at reducing or preventing damage caused by emissions to the atmosphere.

Emission source A chemical process, building, blast furnace, factory or other source responsible for the release of pollutants or toxic substances into the environment.

Emission: Release into the air, discharge into water bodies and land plots.

Endangered species: One of the three degrees of "rarity" of species used by the International Union for the Conservation of Wildlife. All animals and plants in these categories need protection. Endangered species are those whose survival will be threatened unless action is taken to remove the source of the threat or reduce its impact.

Environment friendly Activities of an individual, or organisation, or products that improve rather than destroy the integrity of an ecosystem.

Environmental Data: information that relates to the state or conditions of the environment.

Environmental impact assessment Analyses and assessment of the temporary or permanent environmental impacts of any large-scale construction or project. Should also include an assessment of social impacts as well as proposed alternative activities.

Environmental indicator – an indicator, statistical or cost-based, to approximate or confirm the effect of an environmental management programme or the state of the environment.

Environmental Information Transmitted or received knowledge relating to any aspect of an ecosystem, the natural resources within it and, more generally, the external factors surrounding and affecting human life.

Environmental management Measures and control instruments aimed at preserving the environment, rational and sustainable distribution and use of natural resources, optimising the relationship between society and the environment, and improving the well-being of people of present and future generations.

Environmental monitoring – periodical and/or continued measurement, evaluation and establishment of environmental parameters and/or pollution levels in order to prevent negative and destructive environmental impacts. Also includes forecasting of possible changes in the ecosystem and/or biosphere as a whole.

Environmental protection technology. Technologies developed on the principle of pollution prevention and therefore compliant with environmental regulations. Technological solutions for environmental control taken into account in the early stages of design, as opposed to solutions oriented towards later stages, contribute to improving the technical and economic level of the process.

Equipment: A collection of materials, supplies or appliances installed or supplied to realise an event or activity.

Erosion. A general process or series of processes by which materials of the earth's crust are pulverised, eroded or disappear from the surface, moving simultaneously from one place to another, due to natural factors such as the effects of weather, dissolution processes, corrosion, but generally excluding the mass wasting of these materials.

EU directive. A legislative act issued by the EU that is binding on EU member states on the results to be achieved, but leaves it to the countries to choose their own methods of achieving these results.

Eutrophication: an increase in the nutrient content of the water body, which causes rapid algae growth, a decrease in water transparency and dissolved oxygen content in the deep layers due to decomposition of organic matter of dead plants and animals, as well as mass death of bottom organisms.

Field study – a scientific study conducted outdoors to gather information that cannot be obtained in a laboratory setting.

Fine dust. Airborne particulate matter resulting from human activity or released from a natural source, such as wind-blown soil, which eventually settles to the earth's surface due to the earth's gravity and which can be harmful to the respiratory system of humans or animals if inhaled in excessive amounts.

Forecast: Estimation or prediction of future state.

Fossil fuel: Energy-containing materials that have formed from trees, plants or organisms during thousands of years underground. Physical and chemical processes have taken place in the Earth's crust to turn them into coal, peat, oil or natural gas.

Framework legislation A set of rules established by the government, often consisting of several interrelated sections, whose purpose is to establish or lay the foundations of a new project, agency or organisational structure.

Fresh water: Water containing relatively low levels of minerals, usually less than 500 mg/l of dissolved solids.

Gas chromatography A separation technique involving the passage of a gaseous moving phase through a column containing a fixed phase; used primarily for the quantitative analysis of volatile compounds.

Genetic diversity Differences between individuals and distinct populations within a species.

Genetically modified organism – an organism whose basic set of genes has been altered by external intervention.

Geographic information system (GIS): An organised collection of computer hardware, software, geographic data and specialists dedicated to the efficient collection, storage, updating, modification, analysis and presentation of all forms of geographic reference information that can be derived from a variety of sources, both statistical and cartographic.

Geophysical environment. The physical land and surrounding conditions consisting of oceans and inland waters, lower and upper atmosphere, free space, land masses and land forms.

Greenhouse effect – the heating of the Earth's atmosphere caused by an increase in the concentration of atmospheric gases such as water vapour or carbon dioxide. These gases absorb radiation from the Earth, thus slowing down the transfer of energy from the Earth to space.

Greenhouse gas (GHG) A common term applied to those components of the atmosphere that contribute to the greenhouse effect, in particular carbon dioxide, methane, nitrogen oxides, CFC gases, and water vapour.

Groundwater body – an underground water body or part of it.

Groundwater Water that fills pores and crevices in underground soil and rock layers and accumulates above the water-tight layer. It can move under the influence of gravity either downwards towards the watertight layer or downhill.

Hazardous substance: Any material that poses a threat to human health and/or the environment. As a rule, hazardous substances are toxic, corrosive, flammable, explosive, chemically active.

Heavy metal: A metal with a specific gravity of approximately 5.0 g/cm^3 or higher: Cu, Zn, Ni, Pb, Cd, Co, Sb, Sn, Bi, Hg and others. They are often used in industry and are part of inorganic and organic compounds, herbicides, insecticides and medical preparations.

Invasive species, or alien species are those plant and animal species that are not native to an area. They often pose a threat to native species, habitats or ecosystems and their presence should be strictly monitored by humans.

Land cover. Land cover is the physical state of the earth's surface. It is a combination of vegetation, soils, rocks, water and man-made structures that make up a landscape. Land cover is a kind of interface between the earth's crust and the atmosphere that influences the exchange of energy and matter in climate systems and biogeochemical cycles.

Land degradation is the reduction or loss of biological or economic productivity and complexity of rainfed cropland, irrigated cropland or grassland, forests or woodlands as a result of natural processes, land use or other human actions and habitation patterns, such as contamination of land, soil erosion and destruction of vegetation cover.

Land use This term refers to human activity on the land and the methods by which the surface of the earth is, or can be, adapted to human needs.

Liquid waste This is waste consisting of sanitary and domestic sewage, waste water, other liquids resulting from industrial production, especially such as pulp and paper, food processing, and chemical production.

Load bearing capacity: The maximum load that the system can support without collapsing.

Long-term trend The prevailing trend or general direction of the dynamics of a particular indicator in the future, often established as a result of the evaluation and analysis of statistical data.

Management of natural resources The planned use of natural resources, in particular non-renewable resources, in accordance with principles that ensure its optimal long-term economic and social benefits.

Mapping The process of making a map of an area of the earth's surface; especially the fieldwork involved in making a map.

Marine pollution Any adverse change in the marine environment caused by the accidental or deliberate release of poisonous or toxic substances, such as industrial or municipal wastewater.

Maximum admissible concentration (MAC) The maximum permitted exposure to a physical or chemical reagent during an 8-hour working day that does not result in illness or damage to health.

Maximum permissible discharge (MPD) – mass of substance in return water, maximum permissible for diversion under the established regime of this water body point per unit of time.

Maximum permissible emission (MPE) – a scientific and technical standard established on the condition that the content of pollutants in the surface layer of the atmosphere from a source or a combination of sources, taking into account the development prospects of industrial enterprises, would not exceed the atmospheric air environmental safety standards: maximum permissible concentrations of pollutants in the atmospheric air for people and environmental objects.

Meteorological parameter Variables such as pressure, temperature, wind strength, humidity, and so on, from which you can conclude about the upcoming weather.

Modelling It is a research technique using a mathematical or physical representation of a system or theory that illustrates some or all of its known properties. A model is often used to test the effects of changes in the components of a system on the resulting performance of the whole system.

Monitoring network An interconnected system of monitoring stations to observe pollution levels.

Monitoring station A station where there is qualitative and quantitative measurement of the presence, exposure or level of any pollutant in air or water, noise levels, radiation, traffic, land surface movement or change in vegetation patterns.

Monitoring. Regular inspection to ascertain changes in quality or quantity.

Natural environment A complex of atmospheric, geological and biological characteristics of an area in the absence of signs or influence of technological progress, human culture.

Nitrogen oxides. Oxides formed and released during all normal combustion; produced by oxidation of atmospheric nitrogen at high temperature. Entering the atmosphere with car exhausts, stove smoke, power plant emissions, etc., they include nitrous oxide, pentoxide, nitrogen dioxide, nitric acid, etc. Nitrogen oxides go through many reactions in the atmosphere to form photochemical smog.

Oil slick. A smooth area on the surface of water formed by the presence of petroleum.

Organic matter – plant and animal residues that decompose and become part of the soil.

Organic pollution. Pollution caused by animal or plant materials derived from living or dead organisms that may contain pathogenic bacteria and adversely affect the environment.

Particle: 1) Any very small particle of matter, such as a molecule, atom or electron. 2) Any relatively small particle of matter whose diameter is between a few angstroms and a few millimetres.

Permissible exposure limit. An exposure level established for hazardous or noxious substances and adopted by the Health and Occupational Diseases Act as a standard. Based on average concentrations of a substance for a normal 8-hour working day and 40-hour working week.

Persistant organic pollutant Organic pollutants that do not break down chemically and remain in the environment. Pollutants that are more persistent can be very harmful to the environment.

Phenol. A white crystalline, water-soluble, acid derivative of benzene used as an antiseptic and disinfectant in the manufacture of resins, nylon, paints, explosives and medical preparations.

Pollutant: A substance usually left over from human activities that has undesirable influence on the environment.

Polluted air According to the World Health Organisation definition, polluted air is air whose composition can adversely affect human, plant and animal health, as well as soil and water. Most often the air is polluted with sulphur dioxide, nitrogen oxide, and dust masses.

Pollution control Chemical and physical methods of reducing emissions of most pollutants; for reducing carbon dioxide emissions, there are currently no economic or practical means of reducing emissions other than reducing the use of mineral fuels. Specific means of removing pollutants from gaseous wastes include, for example, desulphurisation of waste gas, fluidised combustion, the use of catalytic converters, improvements to equipment such as furnaces and car engines to reduce pollutant emissions.

Pollution prevention Eliminating the emission of hazardous waste and greenhouse gases at source within the production process. This can be achieved through a variety of relatively simple measures, including small changes in the production process, replacement of polluting substances with non-polluting substances, and simplification of packaging.

Pollution. Direct or indirect alteration of the biological, thermal, physical, radioactive properties of any environment that results in a direct or potential threat to human health, health, safety or welfare of other species.

Protected species Unstable, endangered or threatened species that are being preserved from extinction as a result of preventive measures.

Radiation monitoring The continuous or periodic observation, analysis or monitoring of the level of radiation energy present in a given area in order to ascertain whether that level meets a specified value or safety standard.

Radioactive contamination. Contamination of a substance, living organism or site caused by radioactive material.

Rare species. Species that have limited distribution in the world.

Remote sensing 1) Scientific detection, recognition, inventory, analysis of land and water surface areas by means of remote sensing or recording devices such as photographic equipment, thermal scanners, radars, and others. 2) A set of techniques for remotely measuring electromagnetic radiation emanating from objects.

Removal – a general definition refers to the elimination of substances from the environment or surroundings.

Residual pesticide A pesticide that remains in the environment for quite a long time, with effects lasting for days, weeks, or months.

Return water - water returned by technical facilities and means from the economic link of the water cycle to its natural links in the form of wastewater, mine, quarry or drainage water.

Sampling technique A method of randomly selecting items from an entire batch with the expectation that the selected item will represent the entire batch as a whole.

Sampling: Obtaining a small representative amount of material for the purpose of subsequent analysis.

Satellite image A graphical representation of data projected onto a two-dimensional coordinate grid of individual image elements (pixel) and acquired from an artificial vehicle orbiting a planet, star, or natural satellite.

Self-purification A natural process of organic decomposition, the product of which is nutrients consumed by autotrophic organisms.

Soil degradation Soil can be degraded either by the physical movement of soil particles from a particular site or by the destruction of water-soluble elements within the soil that provide nutrition for crops, other plants, grasses, trees, etc. The physical movement of soil particles is commonly attributed to the phenomenon of erosion. Physical movement of soil particles is usually associated with the phenomenon of erosion. Erosion can be promoted by wind, water, glaciers, animals, and tools used in soil cultivation.

Soil quality All current positive and negative features relevant to soil utilisation and function.

Source of pollution. The place, locations, or areas from which a pollutant is released into the air, water, or where noise is generated. The source may be point source, such as a single major producer of pollution, or linear, such as noise and car exhausts.

Statistical information Knowledge related to collecting, classifying, analysing and interpreting digital data.

Sulphur dioxide: A gas resulting from the combustion of fossil fuels in power plants and other industrial installations. Sulphur dioxide is formed because sulphur is often present as an impurity in coal and oil. When fuels are burned, sulphur reacts with oxygen in the air to form sulphur dioxide.

Surface water body - a surface water object or a part of it. The surface water bodies of each river basin area should fall into one of the following categories: rivers, lakes, transitional (transit) waters, coastal waters, artificial and substantially modified.

Surface waters – waters of various water bodies located on the earth's surface.

Sustainable development Development that ensures economic, social and environmental progress for the future, taking into account the needs of present and future generations. The concept was formulated by the International Commission on Environment and Development in 1987 as follows: “development that meets the needs of the present generation without compromising the ability of future generations to meet their future needs".

Threshold value. The maximum concentration of a particular substance to which an employee may be exposed during a specific time period.

Toxic substance A chemical or mixture of chemicals that may pose a risk to health or the environment or is likely to cause harm to them.

Transitional waters – surface waters within estuarine sections of rivers and estuaries where fresh and saline waters are mixing.

Volatile organic compound (VOC): An easily vaporised, organic compound. These are chemical compounds that are released as gases from solids or liquids. VOCs are volatile because they evaporate easily at room temperature and are organic compounds because they contain carbon. VOCs have a wide spectrum of action and varying degrees of toxicity.

Unmanned aerial vehicle (UAV) – an aircraft that can take off, fly and land without the physical presence of a pilot on board. The flight of a UAV can be remotely controlled by a human operator, as a remotely piloted aircraft (RPA), or with varying degrees of autonomy, such as autopilot assistance, up to fully autonomous flight without human intervention.

Waste minimisation Measures or practices, including plans or directives, to reduce the amount of waste produced. Examples include environmentally sound waste recycling processes, practices to reduce waste from production activities.

Waste treatment A process or combination of processes that changes the chemical, physical or biological composition or nature of a waste, reducing or eliminating its harmful properties for any purpose.

Waste water discharge – the flow of treated effluent generated after the wastewater treatment process.

Waste. Material, often unused, left over from a manufacturing, agricultural or other process involving humans. Material damaged or altered by an industrial process and therefore rendered unusable.

Wastewater – water formed in the process of household and industrial activities (except for mine, quarry and drainage water), as well as water discharged from the built-up area where it was formed as a result of precipitation.

Water monitoring - a system of observation, collection, processing, storage and analysis of information on the state of water bodies, forecasting of its changes and development of scientifically based recommendations for making appropriate decisions.

Water pollution. A change in the chemical, physical, biological or radiological integrity of water caused by or resulting from human activities.

Water quality – a characteristic of the composition and properties of water that determines its suitability for specific uses.

Water Quality Index – is a set of biological and physical-chemical characteristics of water: trophosaprobility, salinity, hardness, hydrogen pH, concentration of harmful substances, etc.

Water quality standards These are established (standardised) values of water quality indicators (physical, chemical, biological) meeting certain requirements, under which human health is reliably protected, as well as creating favourable conditions for water use, water protection and ecological well-being of a water body. Physical indicators of water quality include temperature, clarity or turbidity, colour, odour and taste. Chemical parameters include active reaction (pH), acidification, water salinity (total salt content) and a range of soluble chemicals (major ions, soluble gases, nutrients, trace elements, radioactive substances, specific pollutants). Biological (microbiological) indicators include E. coli content (coli index), and saprophytic bacteria.

Wetlands. Areas that are inundated by surface water or groundwater at intervals sufficient to support plant or aquatic life that require moist or seasonally wet soil conditions for growth and reproduction. The three basic types of wetlands are considered by most scientists to be bogs, swamps, and marshes.

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