NATIONAL UNIVERSITY OF LIFE
AND ENVIROMENTAL SCIENSES OF UKRAINE

Department of General Ecology, Radiobiology and Life Safety

ENVIRONMENTAL MONITORING

STUDY GUIDE

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У підручнику вперше англійською мовою 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 галузі екологічного моніторингу. Підручник відповідає рекомендованій Міністерством науки і освіти України програмі навчальної дисципліни, яка побудована за модульним принципом і є сучасним підручником з даної дисципліни англійською мовою для фахівців освітньо-кваліфікаційного рівня «Бакалавр».

LIST OF CONTENT

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 direction 101 Ecology. The main objective of the discipline is formation the theoretical knowledge and practical skills on the 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 Study Guide 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. Topics 1, 3, 4 were created by Volodymyr Bogoliubov, Prof., Doctor of Education Sciences; topics 2, 5−8 were created by Olena Rakoid, Assoc. Prof., Candidate of Agrarian Science.

1. BASIC CONCEPTS OF ENVIRONMENTAL MONITORING. CLASSIFICATION OF THE MONITORING SYSTEM

The environment is all-encompassing. It is “the totality of surrounding conditions“. Trying to describe the state of the environment is a monumental task. Even assessing the health of a small part of it – a certain lake that become polluted, or air quality over a particular city – is fraught with difficulties.

This is because any part of the environment is a subset of a larger area and its state is not stable but in constant flux.

Furthermore, we still lack a complete picture of how ecosystems work. Finally, the task is complicated by the blurred distinction between us and the environment.

It is not simply “out there “where we can get a good look at it from a distant and dispassionate vantage point. Humans are an integral part of the environment.

To report on its conditions we have to observe and interpret a complex, dynamic system of which we are an interacting component.

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 have been developed by experts of the special commission SCOPE (Scientific Committee on Problems of the Environment) in 1971. The main elements of the monitoring as system were first described by the R. Mann (1973).

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[1]; Wiersma, 2004[2]).

Monitoring can be conducted for a number of purposes, including to establish environmental "baselines, trends, and cumulative effects" (Mitchell, 2002, pg. 318[3]), 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).

[1] Artiola, J.F., Pepper, I.L., Brusseau, M. (Eds.). (2004). Environmental Monitoring and Characterization. Burlington, MA: Elsevier Academic Press.
[2] Environmental Monitoring. G. Bruce Wiersma. CRC Press, 2004, 792 Pages.
[3] Mitchell, B. (2002). Resource and Environmental Management (2nd ed.). Harlow: Pearson Education Limited.

According to P. Venugopala Rao[4], "Environmental monitoring means collecting a representative portion of water, waste or air from an area to ascertain its quality and characteristics."

Environmental monitoring also 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 organization. EPE can be interpreted as a certain type of environmental monitoring.

Lastly, environmental monitoring may be defined according to DWAF's[5] 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".

Environmental monitoring can be described as a programme of recurring, systematic studies that reveals 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.

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[4] Principles Of Enviournmental Scince And Engineering by P. Venugopala Rao, Prentice-Hall of India Pvt.Ltd; 1 edition, 2006. 288 pages

[5] DWAF - Department of Water Affairs and Forestry, http://www.dwaf.gov.za/

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.

Objectives of environmental monitoring are:

- To establish a base-line of exposure.

- To co-relate with a suspected source of contamination.

- To estimate the changes in levels of the pollutants in the environment.

- Confirming and reconfirming the success of the pollution control measures.

- Collection of meaningful and relevant information.

- Know the nature and degree of pollution from various sources.

- Recommendation of improves mitigation measures to be undertaken.

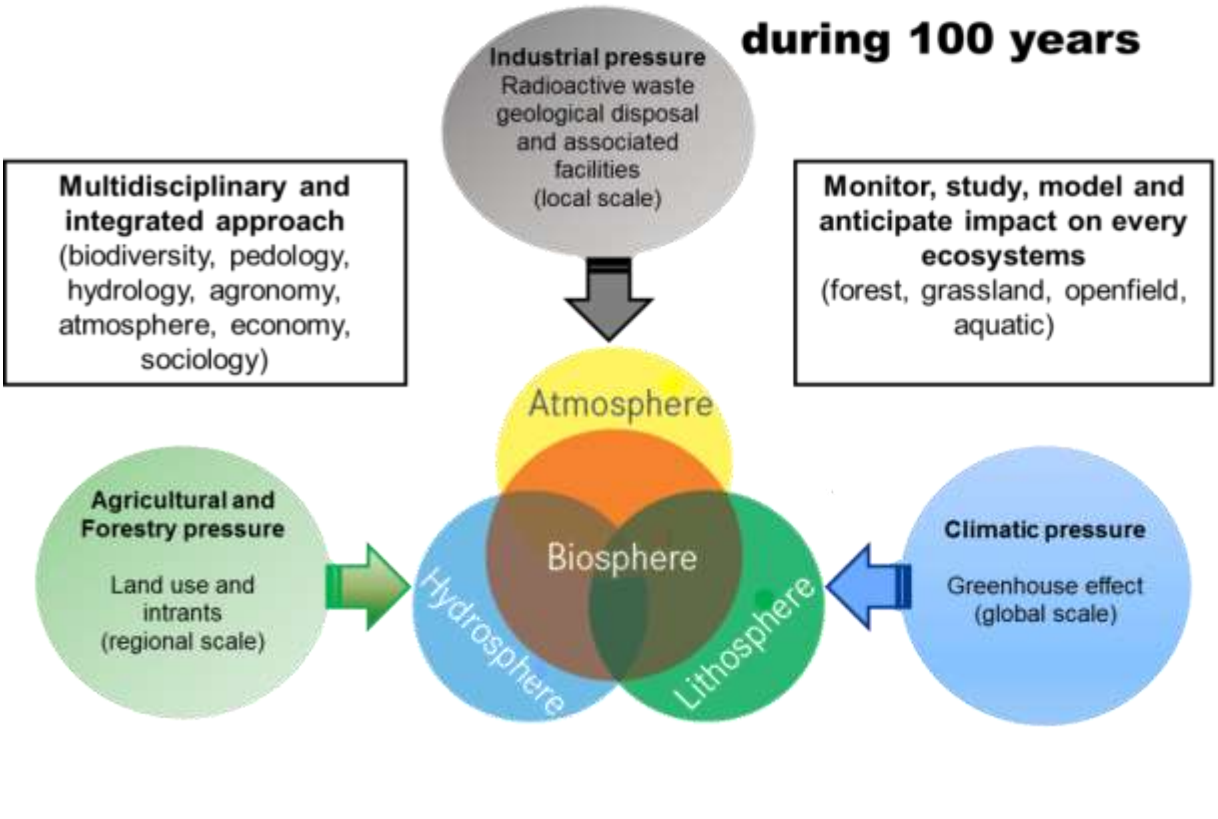


Figure 1.1 − Objectives of environmental monitoring[6]

[6] Source: https://www.researchgate.net/publication/314236667_Environmental_Monitoring_Definition_Objectives_Methods_and_Techniques

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. 1.2: "Observation", "Evaluation of the actual situation (current state)", "State-of-environment forecast", "Evaluation of projected state" and "Support decision-making".

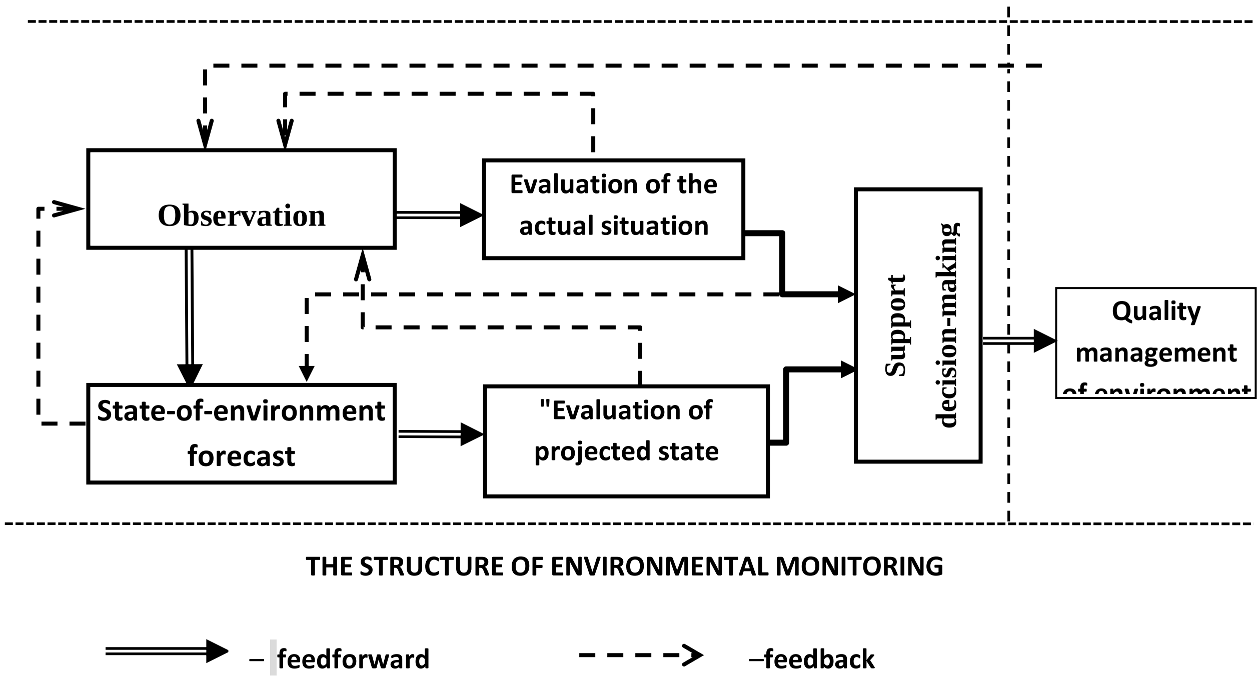


Figure 1.2 − The structure of environmental monitoring

National (state) monitoring is called monitoring system within one country. Types of environmental monitoring (According to the former Resolution of the Cabinet of Ministers of Ukraine dated September 23, 1993 "On Approval of the Regulation on the State Environment Monitoring"[7]):

- General (standard) monitoring;

- Operational (crisis) monitoring;

- Baseline (scientific) monitoring.

The system of environmental monitoring in Ukraine has three levels:

[7] https://zakon2.rada.gov.ua/laws/show/785-93-%D0%BF

1) local – covers the territory of selected objects (enterprises, cities, plots of landscapes);

2) regional – carries within the administrative and territorial units, economic and natural regions;

3) national − covers the territory of Ukraine in whole.

General approaches to determine the monitoring objects:

Generalized classification of all possible systems (or subsystems) of monitoring can be seen in the table 1.1.

Table 1.1 – Generalized classification scheme of monitoring systems

Principle of classification	**Current or long-term monitoring systems**
By universality of the system	Global (including baseline and paleomonitoring). National, "international" (transboundary pollutants transport monitoring), regional
According to the 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 the influence sources	Monitoring of sources of pollution, ingredient monitoring (selected pollutants, ionizing radiation, noise, etc.)
By the influences (impact factors)	Biotic and abiotic monitoring
By the severity and by the scale of the problem	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 complexity of approach	Biomedical or health-related monitoring, bioenvironmental monitoring, climate monitoring. Variants: biomonitoring, geoecological, monitoring of biosphere, monitoring of resources and others.

Classification of monitoring systems in the context of observations

In all systems block of observation by the state of the environment must provide surveillance as sources of anthropogenic impact and the state of elements of the biosphere, as well as changes in their structural and functional parameters (including the response of living organisms to various influences).

There are 5 sections of observations:

Table 1.2 – 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

Provided that, it is necessary to obtain data about the initial state of all components of the biosphere in advance, that is provided by background or basic monitoring system.

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

Factors and indicators as studied in the environmental monitoring:

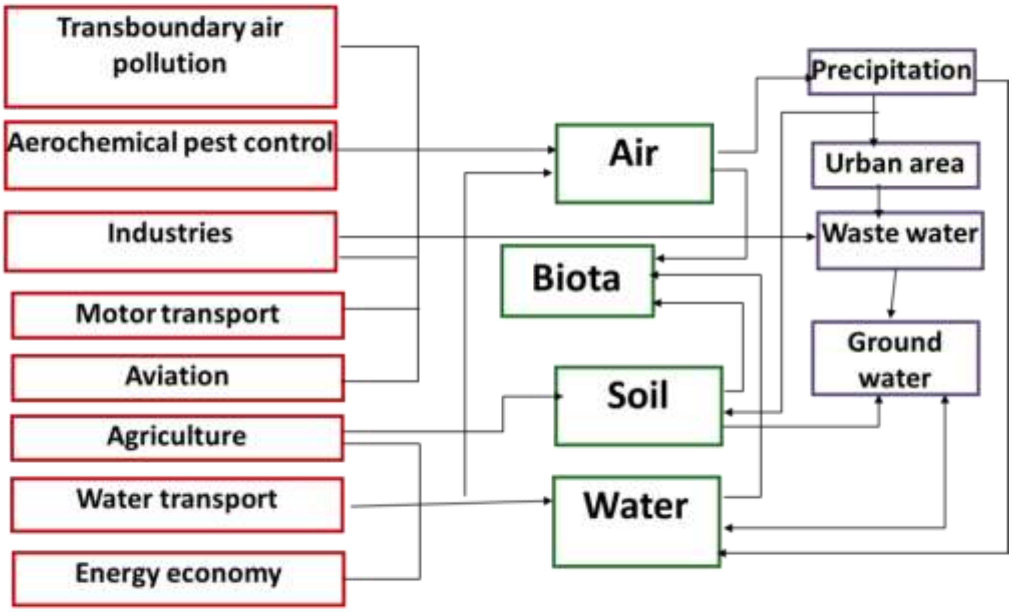


Figure 1.3 − Block diagram of the influence of the main sources of pollution on the biosphere

<u>Environmental indicators are developed in order to:</u>

- assist in the development of optimal environmental policy;
- compare countries and regions;
- ensure understanding of the problem;
- study of the relationship of industrial activity and cause-effect relationships.

For example, European Environment Agency (EEA) uses five types of integrated indicators[8]. These indicators are designed to answer key

[8] https://www.eea.europa.eu/data-and-maps/indicators/about

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.

The EEA currently maintains 122 indicators[9], covering 13 environmental topics (Air pollution, Biodiversity – Ecosystems, Climate change adaptation, Climate change mitigation, Energy, Environment and health, Industry, Land use, Resource efficiency and waste, Soil, Sustainability transitions, Transport, Water and marine environment).

The EEA indicators are also organized by set. The sets currently in use are the following: APE (Air pollutant emissions), CLIM (Climate state and impact indicators), ENER (Energy indicators), INDP (Industrial pollution indicators), LSI (Land and soil indicators), MAR (Marine indicators), Outlook indicators, SCP (Sustainable consumption and production), SEBI

[9] https://www.eea.europa.eu/data-and-maps/indicators/#c0=10&c12-operator=or&b_start=0

(Streamlining European biodiversity indicators), TERM (Transport and environment reporting mechanism), WAT (Water indicators), WREI (Water resource efficiency indicators), and WST (Waste indicators).

By drawing from the different sets, a Core Set of Indicators (CSI) is regularly identified, aimed at prioritizing improvements in the quality and coverage of data flows, streamlining contributions to other international indicator initiatives, and providing a manageable and stable basis for indicator-based assessments of progress against environmental policy priorities. Many of the core set indicators[10] are used in other international indicator processes implemented elsewhere, notably at the European Commission, OECD, WHO and UNECE. The set is often used as a model for indicator sets at country level.

At the Intergovernmental Meeting on Monitoring (Nairobi, 11-20 February 1974) was developed method, criteria and priorities of different pollutants. Found priorities were divided into eight classes (table 1.2), with the definition of the environment and the type of measurement program («I» — impact, «R» — regional, «B» — baseline and «G» — global).

If we speak about observations over areas the highest priority has cities and areas which are sources of drinking water.

The higher priority among the environments has air and water from fresh water bodies (especially lentic).

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

For water there will be biogenic products, phenols and oil products.

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

[10] https://www.eea.europa.eu/data-and-maps/indicators/#c5=&c7=all&c0=10&b_start=0&c10=CSI

Table 1.3 – Classification of priority pollutants by priority classes

Class	Polluting substance	Environment	Program Type
1	Sulfur dioxide, suspended solids, Radionuclides (^{90}Sr + ^{137}Cs)	Air Food	I, R, B I, R
2	Ozone DDT (dichlorodiphenyltrichloroethane) and other chloroorganics Cadmium and its compounds	- troposphere stratosphere Biota Food, water	G B I, R I
3	Nitrates, nitrites Nitrogen oxide	Freshwater, food Air	I I
4	Mercury and its compounds Lead Carbon dioxide	Food, water Air, food Air	I, R I B
5	Carbon oxide HC-hydrocarbon (petroleum)	Air Sea water	I R, B
6	Fluorides	Freshwater	I
7	Asbestos Arcenic	Air Drinking water	I I
8	Microtoxins Microbiological pollution Reactive pollution	Food Food Air	I, R I, R I

There are such integrated indexes that characterize the changes in ecological balance:

- Balanceness of biological productivity (the ratio between primary biological productivity and secondary biological productivity);

- Rate of biological product (the ratio between biological productivity and total biomass);

- Degree of turnover of biogenic substances.

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)[11].

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.

Environmental monitoring is a necessary component of environmental science and policy design[12]. Despite criticisms that environmental monitoring can be ineffective and costly when programs are poorly planned, well-planned monitoring programs cost little in comparison

[11] The United Nations Economic Commission for Europe (UNECE or ECE) was established in 1947 to encourage economic cooperation among its member States.

[12] Source: https://smu.ca/partners/cbemn/documents/Env_Mon_Overview_and_Significance.pdf

to the resources that can be protected and the policy design that can be informed.

Successes and failures of monitoring programs in the preceding decades have been thoroughly analyzed by the scientific community, and practical solutions for addressing the standard challenges of monitoring programs are readily available in the scientific literature. In order to achieve valuable results from environmental monitoring activities, it is necessary to adhere to sampling processes that are supported by the traditional scientific method, and any effective monitoring program must include focused and relevant questions, appropriate research designs, high quality data collection and management, and careful analysis and interpretation of the results.

Long-term monitoring programs are often faced by the challenge of securing long-term funding that will remaining stable in a dynamic political environment. In light of the increasing frequency and magnitude of environmental issues that are emerging in this era of globalization, government funding institutions are encouraged to commit to meaningful, stable, and long-term funding of monitoring programs in acknowledgement of the cost savings associated with the protection of natural resources and the improved efficiency of policy design.

In order to encourage a greater commitment to monitoring on behalf of funding agencies, management relevancy, as well as the quality and effectiveness of monitoring programs, program design should include a collaborative effort on behalf of scientists, statisticians, policy makers, and natural resource managers.

Despite the challenges that are faced by environmental monitoring, monitoring remains an important tool in the achievement of major advances in environmental science.

The relevance of environmental monitoring in environmental science and policy design is well-established. Environmental monitoring will continue to improve its methodology through advancements in modern science, and government and other funding institutions should increase meaningful, long-term funding towards the establishment of effective monitoring programs distributed from the local to global scales.

Comprehension questions

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. The environmental monitoring provides (exclude the wrong answer):

a) observation of the environment and the factors that affect the separate elements of the environment;

b) evaluation and analysis of the actual state of all components of the environment;

c) predictions of the state of environment and evaluation of the environmental condition;

d) providing scientific information to support for management decision making;

e) participation in bilateral agreements.

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

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

7. The principles of classification of current monitoring systems:

1 By universality of system	*A Monitoring of anthropogenic changes in atmosphere, hydrosphere and lithosphere*
2 By the main components of the biosphere	*B Aerospace monitoring (remote sensing methods)*

	Monitoring of physical, chemical and biological parameters
3 By the methods of observation	*C Global, national, "international", regional*

8. European Environment Agency (EEA) uses five types of integrated indicators (choose the right answers):

a) Descriptive indicators

b) Estimated indicators

c) Performance indicators

d) Efficiency indicators

e) Indicators of political efficiency

f) Aggregate welfare indicators

9. What do EEA performance indicators characterize?

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

11. What is the highest priority among the observations over areas?

12. Classification of priority pollutants by priority classes

1 class	*A Nitrates, nitrites, Nitrogen oxide*
2 class	*B Sulfur dioxide, suspended solids, Radionuclides (^{90}Sr + ^{137}Cs)*
3 class	*C Microtoxins, Microbiological pollution, Reactive pollution*
8 class	*D Ozone, DDT (dichlorodiphenyltrichloroethane) and other chloroorganics, Cadmium and its compounds*

13. What is the purpose of environmental monitoring?

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

2. THE STATE ENVIRONMENTAL MONITORING SYSTEM OF UKRAINE

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 Law of Ukraine “On Protection of the Environment” (articles 20 and 22) envisages 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 Ecology and Natural Resources of Ukraine 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 the Regulation, the State Environmental Monitoring System – is an open information system, priority operations of which are the protection of vital important ecological interests of human and society; preservation of natural ecosystems; prevention crisis changes in the ecological state of the environment and prevention of emergency environmental situation.

The basic principles of SEMS operations are specified in the Resolution of the Cabinet of Ministers of Ukraine of 30.03.1998 № 391 “On Approval of the Statement on the State Environment Monitoring System”, namely:

- coordination of regulatory legal and organizational and methodological implementation, interoperability of technical, information and software implementation of its parts;

- systematic character of observations on the environment and technogenic objects that influence it;

- timely obtaining, complexity of processing and use of ecological information that comes and stored in the monitoring system;

- objectivity of primary, analytical and forecasting ecological information and efficiency of its delate to the public authorities, local governments, public organizations, media, population of Ukraine, interested international organizations and the international community.

Functions and objectives of observations and information provision (within SEMS) are carried out by subjects the State Environment Monitoring System:

- the Ministry of Environmental Protection and Natural Resources of Ukraine;

- the Ministry of Economic Development, Trade and Agriculture of Ukraine;

- the State Agency of Ukraine on Exclusion Zone Management;

- the State Service of Geology and Mineral Resources of Ukraine;

- the Ministry of Communities and Territories Development of Ukraine;

- the State Space Agency of Ukraine;

- the State Emergency Service of Ukraine (Department of Hydrometeorology);

- the State Agency of Forest Resources of Ukraine;

- the State Agency of Water Resources of Ukraine;

- the State Service of Ukraine on Geodesy, Cartography and Cadastre

and their territorial bodies, enterprises, institutions and organizations belonging to the sphere of their management, oblast, Kyiv and Sevastopol city state administrations, as well as the executive authorities of the Autonomy Republic of Crimea on environmental protection issues.

Each body of SEMS monitors those ’objects of the environment that are defined by the Statement on the state system of monitoring and statements on the state monitoring of some natural components of the environment.

The current system of environmental monitoring comprises the sub-systems of state parties of monitoring and is based on the fulfillment of the distributed functions that are defined by the Statement on the state monitoring system. Each sub-system (at the level of separate body of the monitoring system) has its own structural, organizational, scientific, methodological basis. However, each sub-system functions on the basis of single statutory, methodological and metrological provision.

In Ukraine, the work of the monitoring bodies is regulated by the statutory and methodological documents. The only principle that is adopted in these documents is the environmental (different components of environment) approach in the monitoring i.e. monitoring of air, surface waters, ground water, geological environment, etc.

The basic regulations governing the environmental objects of monitoring are as follows:

- Regulation of the Cabinet of Ministers of Ukraine 20.08.1993 № 661 "On Approval of the Statement on Land Monitoring";

- Regulation of the Cabinet of Ministers of Ukraine 26.02.2004 № 51 "On Approval of the Statement on Soil Monitoring on Agricultural Land";

- Regulation of the Cabinet of Ministers of Ukraine 19.09.2018 № 758 “On Approval of the Procedure for State Water Monitoring”;

- Regulation of the Cabinet of Ministers of Ukraine 14.08.2019 № 827 “Some issues of state monitoring in the field of atmospheric air protection”;

- Order of the Cabinet of Ministers of Ukraine 31.05.2017 № 616-р “On the Approval of the Concept of reforming of the system of state supervision (control) in the field of environmental protection” etc.

The areas of responsibility of main subjects of SEMS[13]

Functions and objectives of the *Ministry of Environmental Protection and Natural Resources of Ukraine* in the sphere of environmental monitoring:

- Control of water objects in nature protected territories (background concentration of pollutants, including radionuclides);

- State of soils in nature protected territories (pollution content, including radionuclides);

- State Environmental mapping of the territory of Ukraine to assess its condition and its changes under the influence of economic activity;

- Control of surface and marine waters (background concentration of pollutants, including radionuclides);

- Endangered species of flora and fauna as well as and species under special protection.

Implementation of these functions is based on long-term systematic observations of the integrated environmental network of monitoring points.

The functions are carried out to assess, analyze and predict the state of natural environment to support managerial decisions.

Functions and objectives of the *State Emergency Service of Ukraine* (at the stations of the state system of hydrometeorological observations) in the sphere of environmental monitoring:

[13] Source: https://zakon.rada.gov.ua/laws/show/391-98-%D0%BF

- Control of atmospheric air and precipitation (pollution content including radionuclides, transboundary pollutants transport);

- Snow cover;

- Monitoring of terrestrial (hydrochemical and hydrobiological indicators including radionuclides) and marine water (hydrochemical indicators) ecosystems;

- State of soils of various designation (pesticide residue and heavy metals pollution);

- Control of the radiation situation, hazardous nature events and disasters.

Implementation of these functions is based on observations of the integrated environmental network of monitoring points according to special programmes in areas of increased environmental pressure, zones of catastrophes and hazardous nature events. The functions are fulfilled via establishments managed by the Ministry to ensure operational actions in response to crisis and environmental emergencies.

Functions and objectives of the *State Agency of Ukraine on Exclusion Zone Management* (at the exclusion zone and evacuated part of the zone of unconditional (obligatory) resettlement) in the sphere of environmental monitoring:

- Control of atmospheric air (pollution content including radionuclides);

- Control of surface and ground waters (pollution content including radionuclides);

- Monitoring of terrestrial and water ecosystems (bioindicator identification);

- Control of soils and landscapes (pollution content including radionuclides, spatial distribution);

- Control of sources of emissions (pollution content, volume of emissions);

- Control of sources of sewage water discharge;

- Objects of storage and/or disposal of radioactive waste (radionuclide content, radiation situation

Functions and objectives of the Ministry of Economic Development, Trade and Agriculture of Ukraine in the sphere of environmental monitoring:

- Control of agricultural soils (radiological, agrochemical and toxicological evaluations, residual quantity of pesticides, agrochemicals and heavy metals);

- Monitoring of agricultural plants and products produced out of them (toxicological and radiological evaluations, residual quantity of pesticides, agrochemicals and heavy metals);

- Monitoring of agricultural animals and products produced out of them (zootechnical, toxicological and radiological residual quantity of pesticides, agrochemicals and heavy metals);

- Control of surface waters of agricultural designation (toxicological and radiological evaluations, residual quantity of pesticides, agrochemicals and heavy metals);

Implementation of these functions is based on long-term systematic observations of the integrated network of monitoring points and areas as well as full or selective control of plants and animals in agricultural zones.

The functions are fulfilled in order to assess, analyze and predict level of impact on agricultural objects to support managerial decisions.

The activity is implemented via establishments that are managed by the Ministry in the regions.

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

- Control of soils and lands of forest fund (radiological evaluations, residual quantity of pesticides, agrochemicals and heavy metals);

- Control of the state of forest vegetation (condition, productivity, damage by biotic and abiotic factors, biodiversity, radiological evaluations);

- Control of the state of game fauna (specific, quantitative and spatial characteristics).

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

- Control of the state of rivers, water reservoirs, canals, water areas within boundaries of water utilization systems; control of the state of water bodies in areas impacted by nuclear power stations (hydrochemical and radiological indicators);

- Monitoring of surface waters in border regions;

- Control of irrigated and drained lands (groundwater depth and mineralization, salinity level and soil alkalinity);

- Submergence area (rural settlements, coastal zones of reservoirs (re-shaping of coast and flooding of territories)).

The activity is implemented via Basin Agencies of Water Resources and Water Organizations in the regions.

Functions and objectives of the S*tate Service of Ukraine on Geodesy, Cartography and Cadastre* in the sphere of environmental monitoring

- Control of soils and landscapes (pollution content, erosion and other exogenous processes, spatial pollution of land by industrial and agricultural production);

- Monitoring of irrigated and drained lands (secondary submergence and soil salinization);

- Monitoring of coastal lines of the rivers, seas, lakes and water reservoirs as well as hydro-technical utilities (time history, damage of land resources).

Functions and objectives of the *Ministry of Communities and Territories Development of Ukraine (Minregion)* in the sphere of environmental monitoring:

- Control of drinking water quality of the centralized water supply system (pollution content, consumption);

- Control of sewage waters of the city sewage system and treatment facilities (pollution content, volume of sewage flow);

- Monitoring of green plantations in settlements (plant damage degree by harmful insects and plant diseases);

- Monitoring of submergence areas in settlements.

Functions and objectives of the *State Service of Geology and Mineral Resources of Ukraine* in the sphere of environmental monitoring

- Monitoring of ground waters (resources, usage, levels and chemical composition);

- Monitoring of endogenic and exogenic geological processes;

- Control of geophysical fields (background and abnormal evaluations);

- Control of geochemical state of landscapes (the content and distribution of natural and technogenic chemical elements and compounds).

The activity is implemented via Agencies of Utilities in the regions.

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

- Monitoring of the state of the territories according to the data of remote sensing of the Earth (keeping track of thermal anomalies, flood and flood situation, ice situation);

- Monitoring of seismic conditions and other geophysical phenomena in Ukraine and around the globe;

- Monitoring of the radiation situation at the home station of the units of special control; space situation in the near-Earth space (determining the of the impact locations of spacecrafts, carrier rockets and their parts).

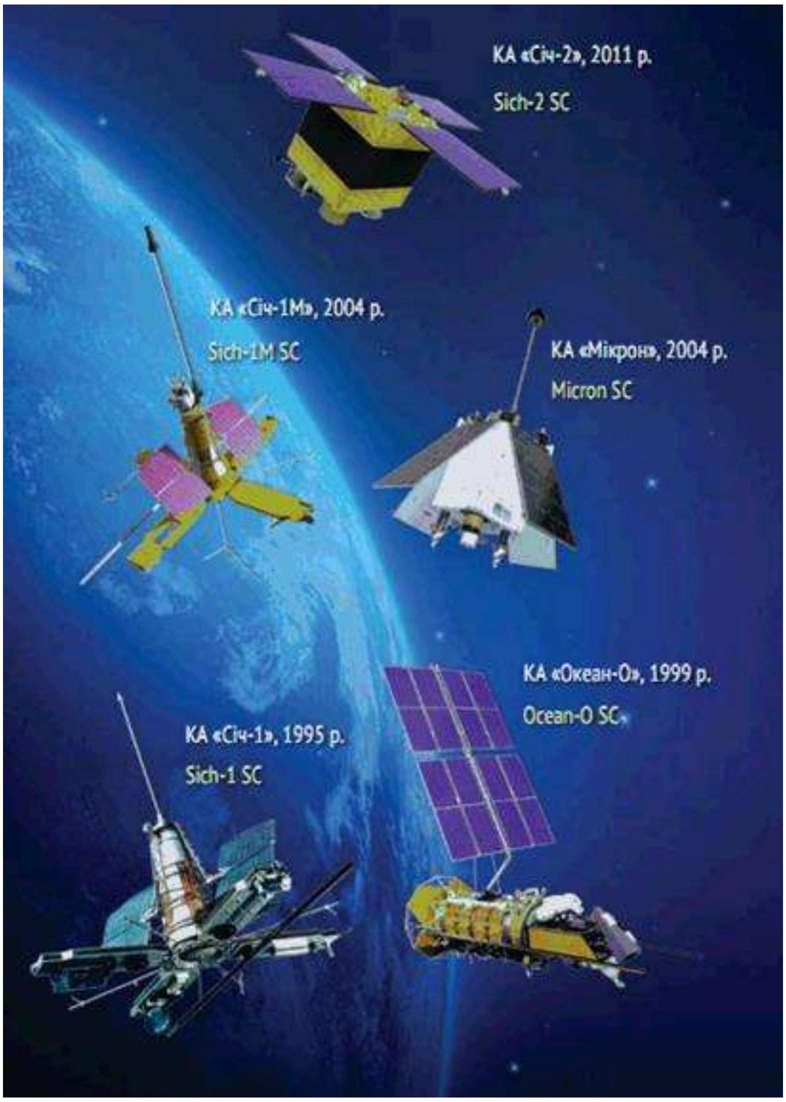


Figure 2.1 − Spacecrafts of Ukrainian design and manufacture

The *Ministry of Health of Ukraine* was excluded from the list of subjects of SEMS, but… According to paragraph 22 of the Regulation of the Cabinet of Ministers of Ukraine № 391 dated 30.03.1998 "On Approval of Statement on the State Environmental Monitoring System" (last edition), the assessment of the impact of environmental pollution on the health of the population rests in the Ministry of Health and its territorial bodies (in the case of their formation), which should inform in a timely manner public authorities and local self-government bodies about negative trends or crisis changes in the state of health of the population due to the deterioration of the environmental situation.

State Statistics Service of Ukraine: this Service is not a body of environmental monitoring. Its work is focused on the collection and provision of statistical information related to technogenic impact on the environment.

Its functions and objectives in the sphere of information provision are:

- preparation and dissemination of statistical collections of environmental information for regions and Ukraine in total;

- accumulation and maintenance of information databases of statistical and administrative reporting.

The statistical yearbook contains information on the state of the environment, the impact of economic activity on it, the availability and use of natural resources, and the environmental protection expenditures for 2010-2018.

There is information for the whole country, by region and for the city of Kyiv. Some indicators are presented by selected localities and by type of economic activity. Most of the information provided is based on state statistical observations of the State Statistics Service of Ukraine.

Interaction between the environmental monitoring bodies

In the existing environment monitoring system, the functions are distributed among its subjects and the system includes the subsystems subordinated to its subjects. Each subsystem at the level of individual subjects of the monitoring system has its structural and organizational, methodological and technical framework.

SEMS operates at three levels, which are determined based on the coverage:

- national level, covering the monitoring priorities and objectives throughout the country;

- regional level, covering the monitoring priorities and objectives across a region; and

- local level, covering the monitoring priorities and objectives within certain areas with high anthropogenic load.

The subjects of SEMS have created or are in process of developing their corporate database containing monitoring information. The existing system of information interaction between the corporate environmental monitoring subsystems provides for the exchange of information at the national and regional levels.

Organizational integration of subjects of environment monitoring at all levels is performed by the Ministry of Environmental Protection and Natural Resources of Ukraine and its regional bodies.

Development of national state of the environment reports

The development of National state of the environment reports is ensured by the Ministry of Environmental Protection and Natural Resources of Ukraine according to Article 25 of the Law of Ukraine “On the Protection of the Environment”.

The resolution of the Cabinet of Ministers of Ukraine of 07.02.1992 N 61 “On provision of the development of the national state of the environment report in Ukraine” envisages establishment of an inter-departmental commission to coordinate development of reports.

The national report is developed using information materials from more than 50 organizations – ministries, agencies, scientific and public organizations. The developed report is forwarded to the Supreme Council of Ukraine for approval. Following that, the national report is printed publication and is uploaded on the website of the Ministry of Ecology and Natural Resources.

Generalized environmental information is also provided in a series of other reports that are published in Ukraine. They include:

- National report on the state of technogenic and natural safety in Ukraine;

- National report on the state of drinking water and water supply,

- National report on the state and perspectives of implementation of the state policy on energy efficiency;

- National communication of Ukraine on climate change;

- The Statistics books and other information documents.

Statistical observations about the protection of the environment in Ukraine are carried out by the bodies of state statistics as well as sector ministries and agencies. In the first case, the state statistics data is being collected, in the second – administrative data is collected. The main statements and principles of the statistical observations are determined by the Law of Ukraine “On State Statistics”.

The laws of Ukraine that regulate statistical observations are:

- On State Statistics;
- On Environmental Protection;
- On Air Protection;
- On Waste;
- On Nature Reserve Fund;
- Forest and Water Codes of Ukraine and other.

The following international documents are used when conducting statistical observations in Ukraine:

- Recommendations of the UN Statistical Commission on the inventory of air emissions (CORINAIR-99);

- European classification of air emission sources (SNAP);

- European waste classification (EWC-Stat);

- EU Waste framework directive;

- Classification of areas of the nature protection activities and costs (Cepa-2000).

In Ukraine statistical information is collected in relation to the natural environments (air, surface waters, soils, etc.).

But absence of a single methodology for interpretation of data and exchange of environmental monitoring results makes it difficult to assess the quality of the environment.

Several groups of environmental indicators are traditionally used in the development of national state of the environment reports. They are:

- Air pollution and depletion of the ozone layer;
- Climate change;
- Water resources;
- Biodiversity,
- Land resources and soils;
- Waste;
- Agriculture;
- Efficiency indicators of the environmental policy implementation.

Since 2007, indicators on energy and transport have also been used in the reports. The main sets of indicators are presented in separate chapters of the national report.

Multilateral environmental agreements and obligations

The main method available under international law for countries to work together on global environmental issues is the multilateral environmental agreement (MEA). MEAs are agreements between states which may include obligations varying from more general principles about a particular environmental issue, through to definitive actions to be taken to achieve an environmental objective.

The Ministry of Environmental Protection and Natural Resources of Ukraine and bodies of SEMS (State Environmental Monitoring System) have concluded bilateral agreements on cooperation in the sphere of environmental monitoring that approve procedures on environmental information exchange. This has been done to regulate information exchange on indicators and deadlines of information provision.

Ukraine is a party to 20 international environmental conventions (see Table 2.1); two more agreements have been signed but not ratified. Ukraine has joined nine protocols to environmental conventions and signed but not ratified six of them.

Table 2.1 − Participation of Ukraine in Multilateral Environmental Agreements and Programs

No	Agreement/Programme	Date of ratification (Rt), accession (Ac), approval (Ap), adoption (At) entry into force (EIF)
	Global	
1	UN Framework Convention on Climate Change (New-York, 1992)	13.05.1997 (Rt)
	Kyoto Protocol (Kyoto, 1997)	12.04.2004 (Rt)
	The Paris Agreement	14.07.2016 (Rt)
2	Convention for the Protection of the Ozone Layer (Vienna, 1985)	18.06.1986 (At)
	Montreal Protocol on Ozone Depleting Substances (Montreal, 1987)	20.09.1988 (At)
3	Convention on Persistent Organic Pollutants (Stockholm, 2001)	25.09.2007 (Rt)
4	Convention on Biological Diversity (Rio-de-Janeiro, 1992)	07.02.1995 (Rt)
	Cartagena Protocol on Biosafety, 2000	06.12.2002 (Ac)
	Nagoya Protocol on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits Arising from their Utilization to the Convention on Biological Diversity	29.10.2010
5	Convention on the Control of Transboundary	08.10.1999 (Ac)

	Movement of Hazardous Wastes and their Disposal (Basel, 1989)	
6	UN Convention to Combat Desertification (Paris, 1994)	27.08.2002 (Ac)
7	Convention Concerning the Protection of the World Cultural and Natural Heritage (Paris, 1972)	12.10.1988 (Rt)
8	International Convention for the Prevention of Pollution from Ships, 1973, as modified by the Protocol of 1978 relating thereto	25.05.1980 (EIF)
9	Convention on the Conservation of Antarctic Marine Living Resources (Canberra, 1980)	22.04.1994 (Rt)
10	Protocol on Environmental Protection to the Antarctic Treaty (Madrid, 1991)	24.06.2001 (EIF)
11	Convention on International Trade in Endangered Species of Wild Fauna and Flora (Washington, 1973)	29.03.2000 (EIF)
12	Convention on Wetlands of International Importance Especially as Waterfowl Habitat (Ramsar, 1971)	01.12.1991 (EIF)
13	Convention on the Conservation of Migratory Species of Wild Animals (Bonn, 1979)	01.11.1999 (EIF)
	Agreement on the Conservation of Populations of European Bats	30.09.1999
	Agreement on the Conservation of African-Eurasian Migratory Waterbirds	01.01.2003 (EIF)
	Agreement on the Conservation of Cetaceans of the Black Sea, Mediterranean Sea and contiguous Atlantic Area	23.10.2003 (Rt)
14	International Convention for the Regulation of Whaling (Washington, 1946)	
15	Global Forest Resources Assessment (FAO)	Participates
	Regional	
16	Convention on Long-range Transboundary Air Pollution (Geneva, 1979)	05.06.1980 (Rt)
	Protocol on Long-term Financing of the Cooperative Programme for Monitoring and Evaluation of the	30.08.1985 (At)

	Long-range Transmission of Air Pollutants in Europe (EMEP) – 1984	
	Protocol on the Reduction of the Sulphur Emissions or their Transboundary Fluxes by at least 30 per cent, 1985	02.10.1986 (At)
	Protocol on Limitation of Emissions of Nitrogen Oxides or their Transboundary Fluxes, 1988	24.07.1989 (At)
	Protocol on Limitation of Emissions of Volatile Organic Compounds or their Transboundary Fluxes, 1991	
	Protocol on Further Reduction of Sulphur Emissions, 1994	
	Protocol on Heavy Metals, 1998	
	Protocol on Persistent Organic Pollutants, 1998	
	Protocol to Control Oxidation, Eutrophication and Ground Ozone, 1999	
	International Co-operative Programme on Assessment and Monitoring of Air Pollution Effects on Forests (ICP Forests)	Participates
17	Convention on the Protection and Use of Transboundary Watercourses and International Lakes (Helsinki, 1992)	08.10.1999 (Ac)
	Protocol on Water and Health (London, 1999)	26.09.2003 (Rt)
18	Convention on the Transboundary Effects of Industrial Accidents (Helsinki, 1992)	
19	Convention on Environmental Impact Assessment in a Transboundary Context (Espoo, 1991)	20.07.1999 (Rt)
	Protocol on Strategic Environmental Assessment (Kiev, 2003)	
20	Convention on Access to Information, Public Participation in Decision-Making and Access to Justice in Environmental Matters (Aarhus, 1998)	18.11.1999 (Rt)
	Protocol on Pollutant Release and Transfer Register (Kiev, 2003)	

21	Convention on the Conservation of European Wildlife and Natural Habitats (Bern, 1979)	01.05.1999 (EIF)
	Subregional	
22	Convention on the Protection of the Black Sea Against Pollution (Black Sea Convention) – Bucharest, 1992.	14.04.1994 (Rt)
	Protocol on the Protection of the Marine Environment of the Black Sea from Land-Based Sources and Activities (1992)	14.04.1994 (Rt)
23	Framework Convention on the Protection and Sustainable Development of the Carpathians	11.05.2004 (Rt)
	Protocol on Conservation and Sustainable Use of Biological and Landscape Diversity	28.04.2010 (EIF)
24	Convention on Cooperation for the Protection and Sustainable Use of the Danube River	13.03.2003 (EIF)

Comprehension questions

1. Please specify a few legislative acts of Ukraine in the field of environmental protection and monitoring.

2. What are the levels of environmental monitoring (according to Resolution of the Cabinet of Ministers of Ukraine, 1998)?

3. What does the abbreviation „SEMS” mean?

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

5. Among the bodies of State Environmental Monitoring System of Ukraine are (choose the right answers):

– *Ministry of Environmental Protection and Natural Resources of Ukraine*

– *The State Emergency Service of Ukraine (Department of Hydrometeorology)*

– *The State Statistics Survey of Ukraine*

– *The State Agency of Ukraine on Exclusion Zone Management*

– *The State Sanitary and Epidemiological Survey*

– *the Ministry of Economic Development, Trade and Agriculture of Ukraine*

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

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

8. What is the role of the State Statistics Survey of Ukraine in the system of environmental monitoring?

9. What does include a series of environmental reports that are published in Ukraine?

10. What are the international documents used when conducting statistical observations in Ukraine?

11. Is statistical information in Ukraine collected in relation to the natural environments?

12. Fill the gaps in the statement: "Absence of a … for interpretation of data and … of environmental monitoring results makes it difficult to assess the quality of the environment".

13. Global multilateral environmental agreements and obligations:

1 UN Framework Convention on Climate Change	*A Vienna, 1985*
2 Kyoto Protocol	*B Stockholm, 2001*
3 Convention for the Protection of the Ozone Layer	*C New-York, 1992*
4 Convention on Persistent Organic Pollutants	*D Kyoto, 1997*
5 Convention on Biological Diversity	*E Paris, 1994*
6 UN Convention to Combat Desertification	*F Rio-de-Janeiro, 1992*

14. Groups of environmental indicators that are traditionally used in the development of national state of the environment reports (choose the wright answers):

1) *Air pollution and depletion of the ozone layer;*
2) *Climate change;*
3) *Water resources;*
4) *Biodiversity;*
5) *Radionuclides;*
6) *Land resources and soils;*
7) *Waste;*
8) *Agrochemistry;*
9) *Agriculture.*

3. AIR POLLUTION AND AIR MONITORING

Air pollution (sources and effects)

High-quality air, along with water, is a crucial element for human life and all components of the biosphere. The high speed of mass movement within the atmospheric strata leads to air pollution migration across significant distances, within the ozone layer as well, and negative consequences, namely acid rain or acceleration of karstic processes.

Envelope of air around the Earth forms the atmosphere with thickness up to 20 km.

Table 3.1 − 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 is contamination of the indoor or outdoor environment by any chemical, physical or biological agent that modifies the natural characteristics of the atmosphere.

Table 3.2 − Comparative characteristics of emissions into the atmosphere 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 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.

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.

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.

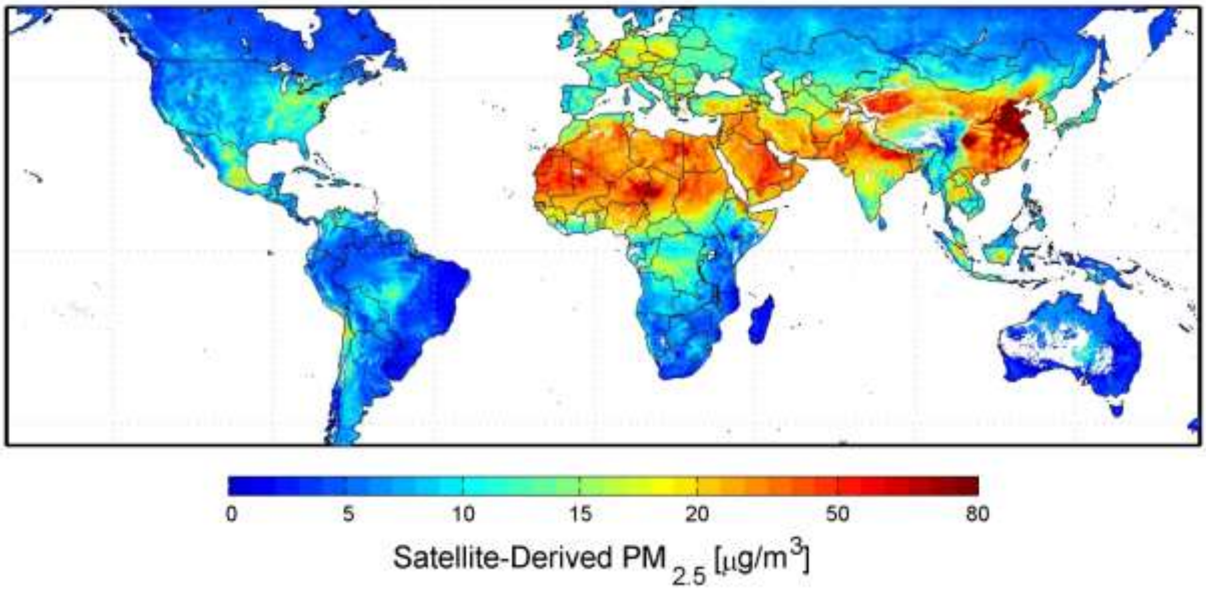


Figure 3.1 − Global satellite-derived map of $PM_{2.5}$ averaged over 2001-2006[14]

PM stands for particulate matter (also called particle pollution): the term for a mixture of solid particles and liquid droplets found in the air. Some particles, such as dust, dirt, soot, or smoke, are large or dark enough to be seen with the naked eye. Others are so small they can only be detected using an electron microscope.

Particle pollution includes:

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

- **PM_{10}** : inhalable particles, with diameters that are generally 10 micrometers and smaller; and
- **$PM_{2.5}$:** fine inhalable particles, with diameters that are generally 2.5 micrometers and smaller.

How small is 2.5 micrometers? Think about a single hair from your head (Figure 3.2). The average human hair is about 70 micrometers in diameter – making it 30 times larger than the largest fine particle.

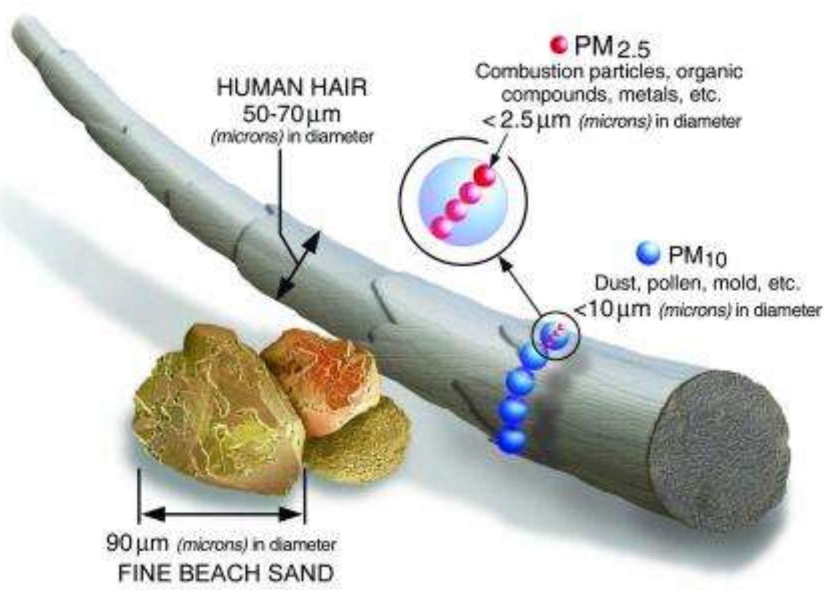


Figure 3.2 − Size comparisons for PM particles

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

For instance in recent years, up to 40 % of Europe's urban population may have been exposed to ambient concentrations of coarse PM[15] (PM_{10}) above the EU limit set to protect human health.

Up to 50 % of the population living in urban areas may have been exposed to levels of ozone that exceed the EU target value.

[15] PM_{10} – particles less than 10 micrometers in diameter (PM_{10}). Particles less than 2.5 micrometers in diameter ($PM_{2.5}$) are called "fine" particles. These particles are so small they can be detected only with an electron microscope. Sources of fine particles include all types of combustion, including motor vehicles, power plants, residential wood burning, forest fires, agricultural burning, and some industrial processes.

Fine particulate matter ($PM_{2.5}$) in air has been estimated to reduce life expectancy in the EU by more than eight months.

These particles come in many sizes and shapes and can be made up of hundreds of different chemicals.

Some are emitted directly from a source, such as construction sites, unpaved roads, fields, smokestacks or fires.

Most particles form in the atmosphere as a result of complex reactions of chemicals such as sulfur dioxide and nitrogen oxides, which are pollutants emitted from power plants, industries and automobiles.

Ground-level ozone is a colorless and highly irritating gas that forms just above the earth's surface. It is called a "secondary" pollutant because it is produced when two primary pollutants react in sunlight and stagnant air.

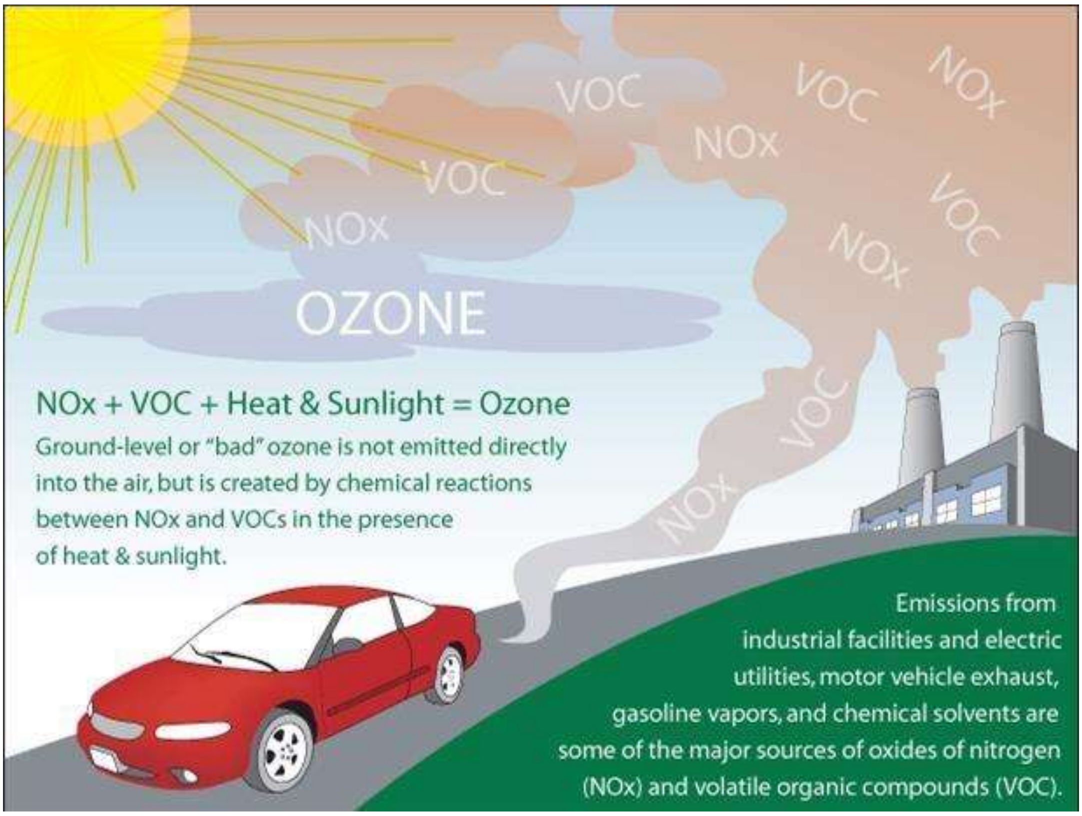


Figure 3.3 – Formation of ground-level ozone[16]

[16] Source: https://www.epa.gov/ground-level-ozone-pollution/ground-level-ozone-basics#formation

These two primary pollutants are nitrogen oxides (NOx) and volatile organic compounds (VOCs).

NOx and VOCs come from natural sources as well as human activities. About 95 per cent of NOx from human activity come from the burning of coal, gasoline and oil in motor vehicles, homes, industries and power plants. VOCs from human activity come mainly from gasoline combustion and marketing, upstream oil and gas production, residential wood combustion, and from the evaporation of liquid fuels and solvents. Significant quantities of VOCs also originate from natural (biogenic) sources such as coniferous forests.

Ozone is known to have significant effects on human health. Exposure to ozone has been linked to pre-mature mortality and a range of morbidity health end-points such as hospital admissions and asthma symptom days. In addition to its effects on human health, ozone can significantly impact vegetation and decrease the productivity of some crops.

Ozone can also damage synthetic materials, cause cracks in rubber, accelerate fading of dyes, and speed deterioration of some paints and coatings. As well, it damages cotton, acetate, nylon, polyester and other textiles.

Air pollution damages our health as well as our environment.

Acidification is caused by acid deposition of excess sulphur and nitrogen compounds.

Eutrophication, is an environmental problem that caused by the input of excessive nutrients into ecosystems, in particular by excessive atmospheric nitrogen.

Crop damage is caused by exposure to high ozone concentrations.

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;

- waste treatment;

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

The state of air pollution in Ukraine

Not so long ago, Ukraine was among those countries with high absolute and weighted air pollution levels.

The tendency toward reduced pollution emissions witnessed during 1992-2000, has ended. Today, pollution is again rising.

In 2000, fuel and energy complex enterprises released 35 percent of pollution emissions into the atmospheric air, particularly 55.6 percent of the atmosphere's mechanical pollution, 75 percent of sulfur dioxide emissions, 58 percent of nitrogen oxide pollution and 5.4 percent of carbon oxide pollution.

Dust content exceeded specifications in 23 Ukrainian cities, particularly increasing in Kamianske (Dniprodzerzhinsk) (50 percent), Kremenchug (33 percent), Jani Kapu (Krasnoperekopsk) (36 percent), Poltava and Yalta (25 percent). The atmospheric air of Ukraine's industrial regions contains such harmful substances as formaldehyde, benzapyrene, hydrogen fluoride, carbon oxide, and from time to time, they exceed their maximum allowed concentrations.

In 2017, 3.97 million tons of pollutants were released into the atmosphere. Among them, 2.6 million are from stationary sources and 1.4

million are from mobile sources. Besides pollutants, 148.2 million tons of carbon dioxide was released into the atmosphere.

In 2015, there were 11303 enterprises that released pollutants into the atmosphere from stationary sources. The emissions content is dominated by sulfur compounds (31.7%), carbon monoxide (26.7%), methane (18.0%), substances in the form of suspended solids (12.2%), nitrogen (9.2%), other pollutants (2.1%).

The main air polluters in Ukraine are enterprises that produce electricity, gas and water (41.1%), processing industry (32.9%), mining industry and quarry development (17.2%).

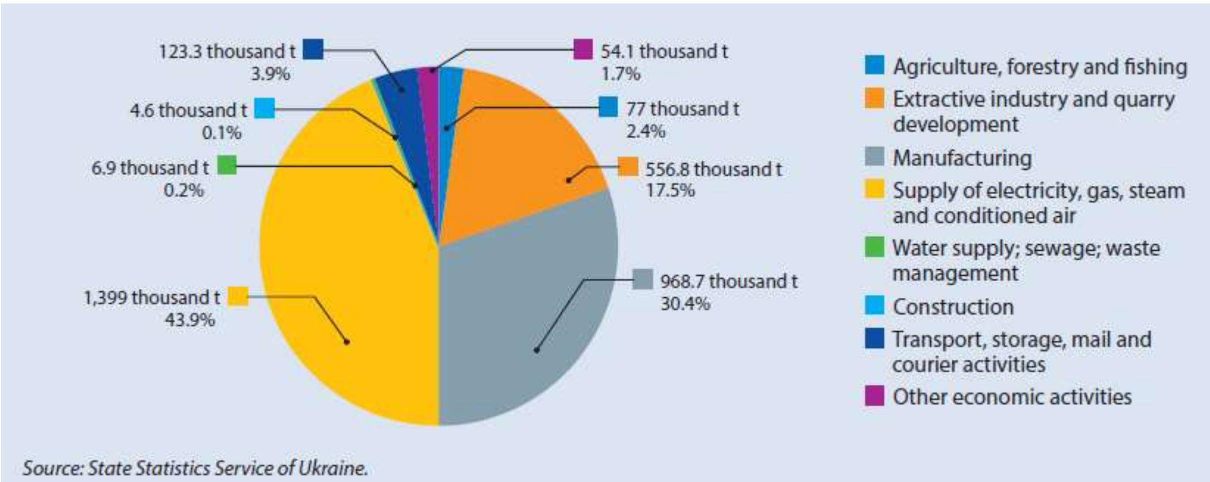


Figure 3.4 − Emissions of pollutants into the atmosphere in Ukraine by economic activity, 2014

Among human settlements of the Ukraine, the atmosphere of 6 cities (Burshtyn, Kamianske, Kurakhove, Energodar, Kryviy Rih, Mariupol) suffers from the highest anthropogenic load from stationary sources of emissions (over 100 thousand tons of emissions per year). Mainly these cities have power plants and enterprises of metallurgy and coke.

The majority of PE (Pollutant Emissions) from mobile sources is from automobile transport (88.7% of all emissions) and mobile production equipment (8.7%).

In Ukraine, statistical data on emissions from mobile sources are collected since 2007. They take into account road, rail, aviation and water transport, as well as production equipment.

The emissions structure of the main chemical substances that came into the air during the exploitation of vehicles and production equipment was dominated by carbon monoxide (72.9%), nitrogen dioxide (13.2%), light non-methane organic compounds (10.7%), soot (1.7%) and sulfur dioxide (1.5%).

If data are compared with WHO (World Health Organization) recommendations on air quality in Europe, air quality improves regarding typical polluting substances, except for nitrogen oxide. But when the question is about specific and toxic substances, even WHO standards are exceeded in almost all of Ukraine's large cities.

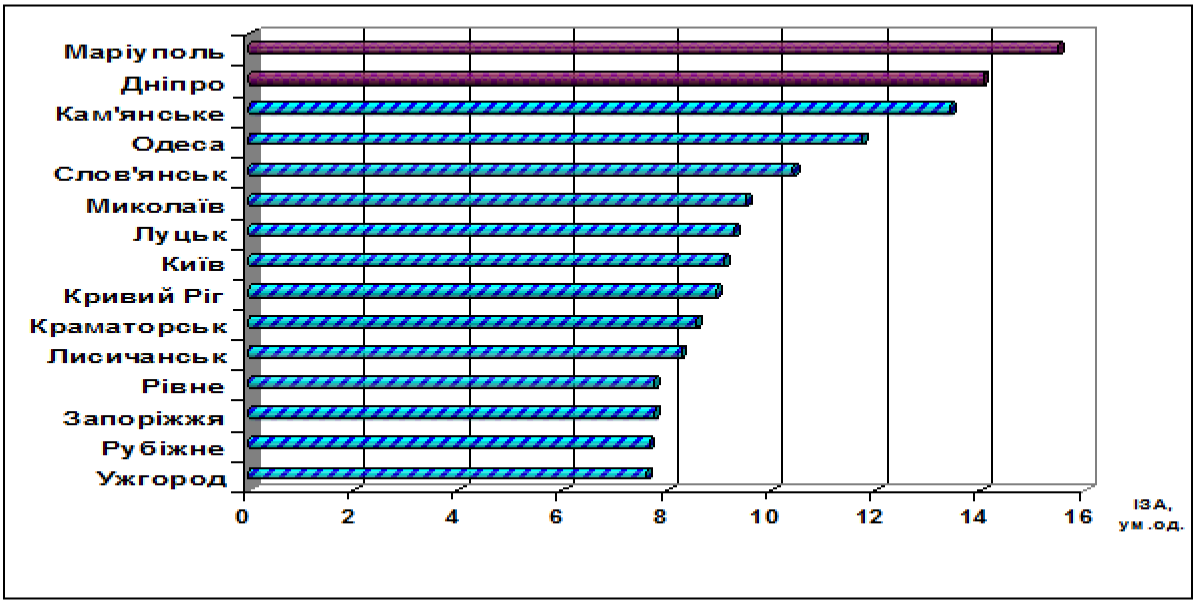


Figure 3.5 – The value of the Air Quality Index (AQI) in the most polluted cities of Ukraine in 2017[17]

[17] Source: https://kr.gov.ua/ua/news/pg/160818525878025_n/

The worst air pollution is in Kiev, Kherson, Dnipro, Kryvyi Rih, Kamianske, Mariupol, Odessa, and Kramatorsk.

Industrial regions produce greater ecological hazards, with emissions densities exceeding average country indicators. In general, emission volumes per person exceed indicators for developed countries by several times.

Close to 20% of elements that enter the atmosphere from stationary sources, meanwhile, are mutagenic.

The growing number of automobiles has resulted in an increase of atmospheric air pollution, in the nation's big cities primarily. The quantity of automobile transportation will probably grow, and accordingly, the volume of air pollution from automobile sources will grow as well.

Monitoring of atmospheric air in Ukraine

Monitoring of atmospheric air − is an informational and technical system of observation, evaluation and prediction of the air pollution level and providing on this basis recommendations for measures to protect air quality.

In accordance with the reversed Resolution of the Cabinet of Ministers of Ukraine of March 9 1999, No. 343 "On Approval of the Procedure for the Organization and Monitoring of Air Pollution“ in Ukraine monitoring of air quality were carried out by three bodies of State Environmental Monitoring System:

1. The State Emergency Service of Ukraine (Department of Hydrometeorology) carried out monitoring of air pollution in 39 cities of Ukraine by 129 stationary sites and 2 cross-border transfer stations (Svityaz, Rava-Ruska).

Figure 3.6 – Map of Ukrainian cities where air pollution monitoring was carried out in 2016 by the Department of Hydrometeorology

At the stationary posts, observations are carried out 4 times a day except Sundays and public holidays. Sampling is performed with the absorption filters within 20 minutes with subsequent determination of substance concentration.

Until recently in accordance with the Resolution of the Cabinet of Ministers of Ukraine of March 9 1999, No. 343 "On Approval of the Procedure for the Organization and Monitoring of Air Pollution", mandatory air quality monitoring at the national level ("List A") covered seven pollutants: dust, nitrogen dioxide, sulfur dioxide, carbon monoxide, formaldehyde, lead and benzo(a)pyrene.

Some stations also control other pollutants. In accordance with the above-mentioned Procedure, monitoring of other 29 pollutants ("List B" -

substances whose presence in the air is additionally determined by the decision of local executive authorities or local authorities) is carried out only at the regional level in accordance with the regional programs.

From List B, by the observation network of the Hydrometeorological Center of Ukraine determines ammonia, aniline, nickel, nitrogen oxide, hydrogen chloride, iron, soot, hydrogen sulfide, cadmium, phenol, hydrogen fluoride, manganese, chromium, copper, zinc; but doesn't monitor such substances as benzene, ozone, hydrogen cyanide, mercury and its compounds, ethylbenzene, carbon disulfide, toluene, nitric acid, sulfuric acid, xylene, chlorine, chloranilin, arsenic and its compounds (as arsenic).

In total, 22 polluting impurities are determined in samples.

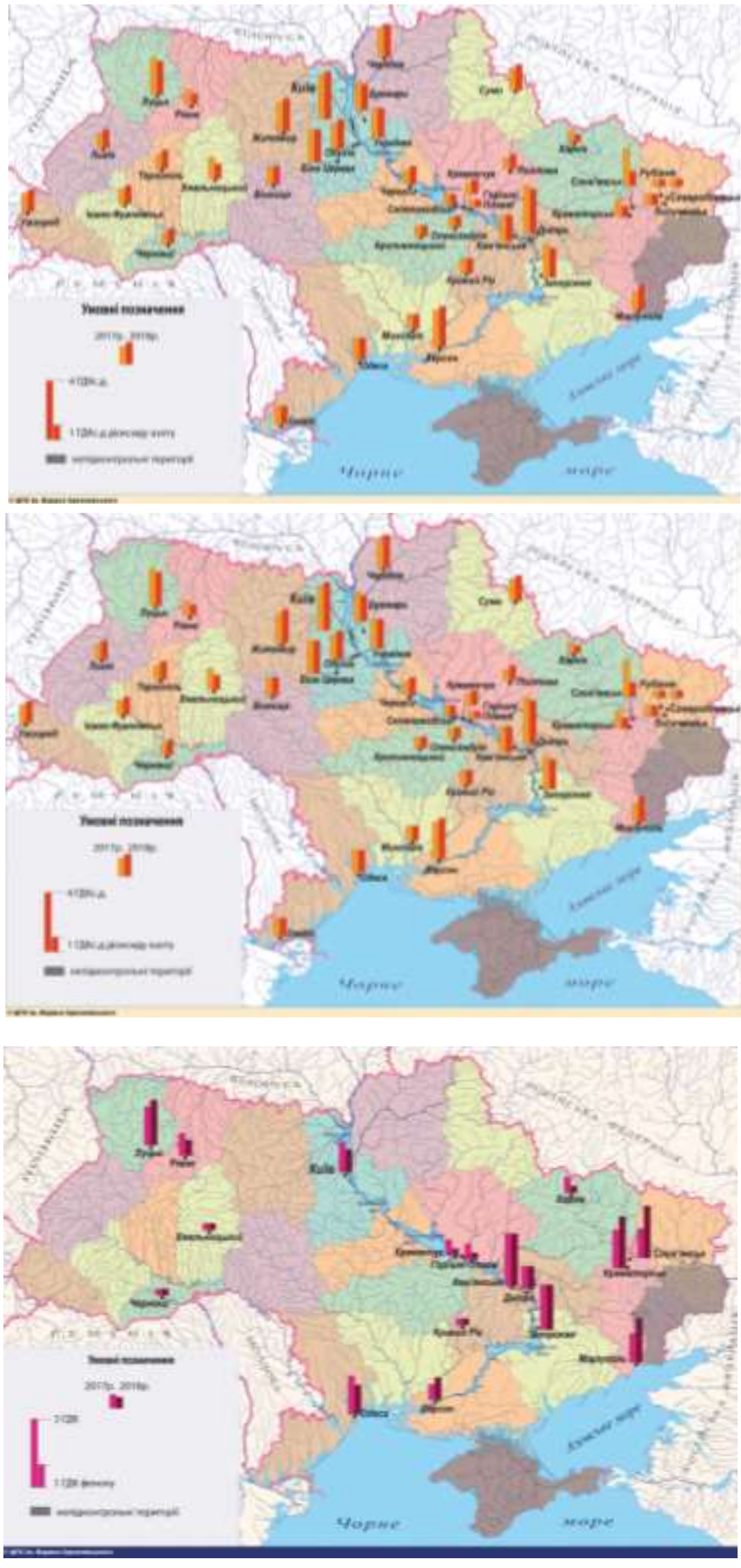
In addition, the analysis of pollutant presence is carried out in precipitation (41 weather stations) and snow cover (54 weather stations); hydro-meteorological parameters are also observed. The sulfate-hydrocarbonate type of precipitation remained as the dominant type on the greater part of the territory of Ukraine.

The observations are carried out in accordance with the requirements of the GD 52.04.186-89 "Guidelines for atmospheric pollution control".

It should also be noted that In Ukraine concentrations of ozone, $PM_{2,5}$ and PM_{10} were not controlled in human settlements until 2019[18] (except only 1 observation post of SI "O.M. Marzeiev Institute for Public Health of National Academy of Medical Sciences of Ukraine" and 6 stations of monitoring of the atmospheric air quality of the Automated Environmental Monitoring System of Donetsk Regional State Administration).

Concentrations of arsenic and mercury were controlled by the sanitary-epidemiological stations when the need arises.

[18] Source: https://zakon.rada.gov.ua/laws/show/343-99-%D0%BF



a)

b)

c)

Figure 3.7 – Maps of atmospheric air pollution by the most widespread impurities, according to observations of the Department of Hydrometeorology [19]: a) suspended solids; b) nitrogen dioxide; c) phenol

[19] Source: http://cgo-sreznevskyi.kiev.ua/index.php?fn=u_zabrud&f=ukraine

2. The State Sanitary and Epidemiological Survey carries out periodic monitoring of air quality in residential and recreational areas, particularly near major roads, sanitary protection zones and residential buildings, on the territory of schools, preschool and medical institutions in urban areas.

In addition, the analysis of air quality is carried out in residential areas upon inhabitants' complaints. The flare observations are also carried out near the sources of emissions.

Usually observations are carried out accordingly to the various social and health monitoring programs (5-15 air pollutants). The SES air quality monitoring programs are approved for each city and major settlement.

Monitoring of air quality is carried out on mobile or stationary control posts. Observations on the stationary posts are carried out by sampling with absorption filters during 24 hours with subsequent determination of daily average concentrations by laboratory methods.

3. State Ecological Inspection of Ukraine (SEI) provides selective sampling at the emission sources. It measures over 65 parameters at more than 3,000 major sources of emissions, which belong to more than 1,500 enterprises.

Governance of state ecological monitoring of the Ministry of Environmental Protection and Natural Resources, as well as Regional governances of ecology and natural resources collects data from monitoring entities. The Ministry of Environmental Protection and Natural Resources does not have its own network of air quality monitoring.

It should be noted that Ukraine is a participant of some international conventions directed towards protecting the quality of atmospheric air, among which – the Montreal Protocol, the United Nations Framework Convention on Climate Change and others. Ukraine's international cooperation leads to implementing a corresponding national policy and concrete actions in this direction.

However there is no any special strategic document for air quality protection in Ukraine which would be analogous to the Thematic Strategy on Air Pollution (Communication of 21 September 2005 from the Commission to the Council and the European Parliament).

There is a strategic program document that is related to emissions of dust, sulfur and nitrogen dioxides, ammonia, hydrocarbons and light organic compounds (Resolution of the CMU № 610-p on 15.10.2003), but the document is outdated and requires revision.

In Ukraine, there are no any special strategic documents in the domain of air quality control that concern heavy metals and persistent organic compounds.

Key standard acts and normative-technical documents regulating air quality monitoring are:

- The Law of Ukraine “On air protection”;
- The Resolution of the Cabinet of Ministers of Ukraine of 14.08.2019 No. 827 "On Approval of the Procedure for the Organization and Monitoring of Air Pollution" (see Annex A).

According to new Resolution, now **List A** includes:

1. Sulfur dioxide
2. Nitrogen dioxide and nitrogen oxides
3. Benzene
4. Carbon monoxide
5. Lead
6. Particulate matter (PM_{10})
7. Particulate matter ($PM_{2,5}$)
8. Arsenic
9. Cadmium
10. Mercury

11. Nickel

12. Benz (a) pyrene. To assess the concentration of benzo (a) pyrene at certain monitoring points identified in the state air monitoring program for each zone and agglomeration, an assessment is made of other polycyclic aromatic hydrocarbons, the list of which includes benzo (a) trace, benzo (b) fluoranthene, indeno (1,2,3-cd) pyrene, dibenz (a, h) anthracene.

13. Ozone

Indicators and components of **precipitation:**

1. Ammonium ions
2. Hydrocarbonate ions
3. Potassium ions
4. Calcium ions
5. Total acidity
6. Magnesium ions
7. Sodium ions
8. Nitrate ions
9. Sulfate ions
10. Chloride ions
11. pH

List B includes:

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 (1-butene; 1-pentene; 1,2,3-trimethylbenzene; 1,2,4-trimethylbenzene; 1,3-butadiene; 1,3,5-trimethylbenzene; 2-pentene; acetylene; benzene; ethane; ethylbenzene; ethylene; total amount of non-homologous hydrocarbons of methane; i-butane; i-hexane; isoprene; i-octane; i-pentane; m + p-xylene; n-butane; n-hexane; n-heptane; n-octane; n-pentane; o-xylene; propane; propene; toluene; trans-2-butene; formaldehyde; cis-2-butene

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).

Current situation with national system of air monitoring

The state air monitoring has got new legal framework on August 14, 2019. The Procedure is based on Directive No. 2008/50/EC and Directive No. 2004/107/EC, which define the requirements for the monitoring of atmospheric air and air quality.

The Government's decision completely revised the old monitoring system, changed the approach to the formation of a network of observations and assessment of atmospheric air quality, clearly defined functions of the monitoring entities, revised mandatory indicators and regimes, introduced a mechanism for mandatory regular information and development long-term action plans.

But does adoption of the new framework mean Ukraine can start practical air monitoring in line with the European standards? In fact, there are several factors which will postpone or prevent effective implementation of the new air monitoring framework.

The organization and methodology of atmospheric air quality monitoring in Ukraine does not meet EU standards:

- Requirements for the number of observation posts in settlements in Ukraine exceed similar EU standards;

- The list of substances monitored in Ukraine does not meet current needs;

- The use of indicative measurement or modeling is a poorly regulated by legal framework of Ukraine;

- Another disadvantage of the existing monitoring system is that measurements are taken at set time intervals;

- Hygienic air quality standards used in Ukraine are also imperfect;

- Ukraine lacks a legal framework for informing the public about the quality of atmospheric air.

Organization of the monitoring of atmospheric air

Categories, location and number of observation posts

The existing network of air pollution survey includes:

- stationary sites,

- route sites,

- mobile sites (under plume sites).

Site (observation post) is the selected location (point of detail), where the pavilion or car equipped with the appropriate instruments is located.

Figure 3.7 – Stationary post of the automated atmospheric air monitoring system of the Kiev Regional State Administration[20]

Stationary site is intended to provide for a regular air sampling to identify and register pollution content.

Route site is intended to provide for a regular air sampling in areas where impossible or impractical to set a stationary site.

Mobile site (under plume site) is designed for sampling in smoke (gas) plume to identify zone of influence of a particular source of industrial emissions.

Selecting of site location depends on: 1) the level of air pollution, which is representative of the respective region or 2) concentration of contaminants in a particular point that is influenced by emissions of individual industrial enterprise, highway or other source.

The most cities in the CIS[21] have 3−6 stationary sites, the largest of them – 6−20 (Kyiv − 16), most cities in Western Europe have 1−3 stationary sites.

[20] Source: http://koda.gov.ua/news/u-vasilkovi-vstanovleno-pershiy-stac/
[21] CIS – The Commonwealth of Independent States

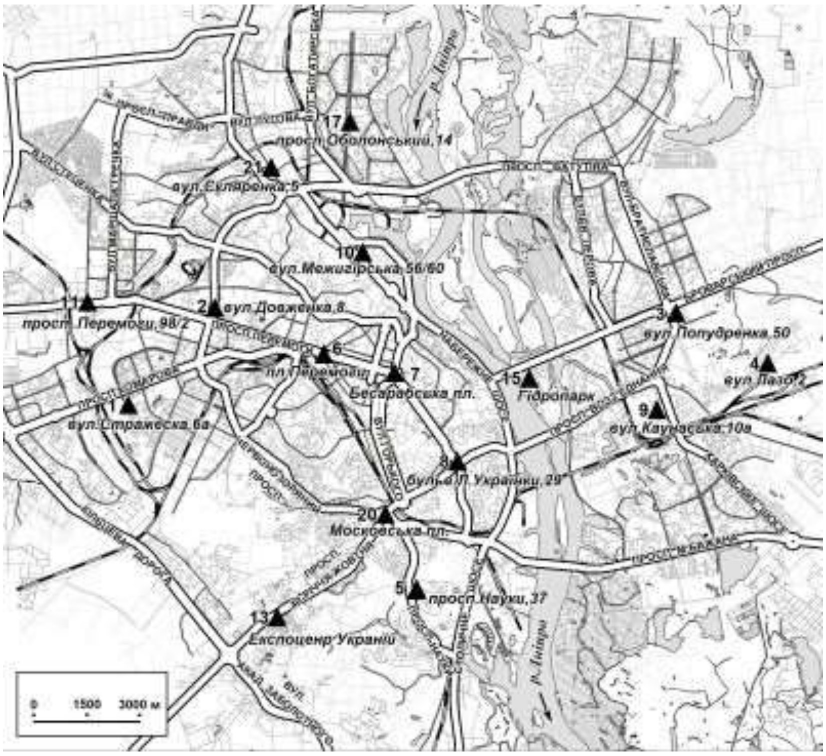


Figure 3.8 – Layout of stationary sites of observations in Kyiv

Regular observations at stationary sites held by one of the *four monitoring programs*:

- complete monitoring program
- incomplete monitoring program
- reduced monitoring program
- daily monitoring program

Simultaneously with air sampling such meteorological parameters are determined: wind speed and wind direction, air temperature, weather conditions and the underlying surface conditions.

Between concentration q of pollution agent (PA) and its MPC (maximum permissible concentration, mg/m^3) should be performed such relation:

$$q \leq MPC$$

It is found that in the places of resort (recreation areas) level of air pollution should not exceed 0.8 MPC.

There is the summation effect for some PA.

The presence in the atmosphere of several (n) PA that have the effect of summation, their dimensionless total concentration should not be greater than 1:

$$\frac{q_1}{MPC_1}+\frac{q_2}{MPC_2}+....+\frac{q_n}{MPC_n}\leq 1.$$

Depending on exposure duration are distinguished:

- MPC one time concentration (MPCo.t.),
- MPC daily average (MPCd.a.),
- MPC in the working zone (MPCw.z.).

Table 3.2 − Maximum permissible concentration (MPC) of pollutants in the air of settlements

Substance	MPCo.t.	MPCd.a.	MPCw.z.	Class of hazard
Nitrogen dioxide	0,085	0,04	5,0	2
Sulphur dioxide	0,5	0,05	10,0	3
Carbon monoxide	5,0	3,0	-	4
Dust	0,5	0,15	-	3
Ammonia	0,2	0,04	20,0	4
Mercury	-	0,0003	0,01	1

If MPC are not designed for some pollutants, it is used such indexes as: relatively safe maximum permissible action level or temporarily allowable concentration of contaminants in the atmosphere − for a term of 2 years.

LC_{50} − lethal concentration for 50 percent of the animals used for testing[22];

LC_{100} − lethal concentration for 100 percent of the animals used for testing[23].

There are four substance hazard categories:

1. Extremely hazardous substance – benzapyrene, lead, mercury and chromium compounds, hexachlorane, hydrogen cyanide, DDT − dichloro-diphenyl-trichloroethane, ozone etc.

2. Highly hazardous substance – sulfuric acid, hydrogen sulfide, caffeine, phenols, nitrogen dioxide, benzene, chlorine, manganese oxides and others.

3. Moderately hazardous substance – sulfur dioxide, butyl alcohol, dust and others.

4. Low-hazardous substance – carbon monoxide, ethanol, ammonia, naphthalene, acetone, turpentine etc.

Air Quality Index (AQI)

An 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.

[22] Lethal concentration 50 (LC_{50}) is the amount of a substance suspended in the air required to kills 50% of a test animals during a predetermined observation period.
[23] LD_{100} – Lethal dose for 100% of the animal test population.

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

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. The Index is based on concentration values for up to five key pollutants, including:

particulate matter (PM_{10});

fine particulate matter ($PM_{2.5}$);

ozone (O_3);

nitrogen dioxide (NO_2);

sulphur dioxide (SO_2).

The index is calculated hourly for more than two thousand air quality monitoring stations across Europe, using up-to-date data reported by EEA member countries. These data are not formally verified by the countries.

The Index indicates the short-term air quality situation. It does not reflect the long-term (annual) air quality situation, which may differ significantly.

The air quality index is not a tool for checking compliance with air quality standards and cannot be used for this purpose.

United Kingdom. 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.

Comprehension questions

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. Air pollution damages environment over (choose the right answers):

1. Acidification

2. Aesthetic damage

3. Deforestation

4. Eutrophication

5. Livestock damage

6. Crop damage

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

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

7. In Ukraine monitoring of air quality is carried out by such bodies of State environmental monitoring system as … (choose the right answers)

1. The State Emergency Service of Ukraine

2. The State Sanitary and Epidemiological Survey

3. State Service of Geology and Mineral Resources of Ukraine

4. State Ecological Inspection of Ukraine

5. State Space Agency of Ukraine

8. Are concentrations of ozone, $PM_{2,5}$ and PM_{10} not controlled in human settlements in Ukraine?

9. The pollutants that include to the program of air quality monitoring:

1. for mandatory monitoring	*A. arsenic and mercury*
2. according to local peculiarities of human settlements	*B. dust, nitrogen dioxide, sulfur dioxide, carbon monoxide, formaldehyde, lead and benzo(a)pyrene*
3. when the need arises	*C. ammonia, benzene, phenol, hydrogen sulfide, anhydrous hydrogen fluoride, toluene and other*

10. What are the main pollutants from stationary sources dominate in Ukraine now?

11. What are the main air polluters in Ukraine?

12. Is the automobile transport the major polluter from mobile sources? What is the emissions structure of the main chemical substances that came into the air during the exploitation of vehicles?

13. What does the existing network of air pollution survey include? What does selecting of site location depend on?

14. The network of air pollution survey:

1. stationary sites	*A. are designed for sampling in smoke (gas) plume to identify zone of influence of a particular source of industrial emissions*
2. route sites	*B. are intended to provide for a regular air sampling to identify and register pollution content*
3. under plume sites	*C. are intended to provide for a regular air sampling in areas where impossible or impractical to set a stationary site*

15. How many stationary sites are situated in Kyiv?

16. How many monitoring programs of regular observations at stationary sites do you know? Name them.

17. What relation should be performed between concentration (q) of pollution agent and its MPC?

1. q = MPC

2. q ≤ MPC

3. q ≥ MPC

18. What does $MPC_{o.t.}$ mean?

19. The presence in the atmosphere of several (n) PA that have the effect of summation, their dimensionless total concentration should not be greater than:

1. 0.5

2. 0.8

3. 1.0

20. The substance hazard categories:

1. Extremely hazardous substances	*A. sulfur dioxide, dust*
2. Highly hazardous substances	*B. benz(a)pyrene, DDT*
3. Moderately hazardous substances	*C. ethanol, carbon monoxide*
4. Low-hazardous substances	*D. benzene, sulfuric acid*

4. MONITORING OF LAND SURFACE WATER

Water is a scarce and incredibly valuable resource, necessary for maintaining life and agricultural and industrial development.

Protection and the ecological rehabilitation of water resources is a priority in ecological policy. During the second part of the last century and the beginning of this one, the number of unresolved problems related to water resources continuously grew. Every year, water consumption increases, and its declining quality significantly influences human health.

Available water resources in Ukraine

Ukraine has 63119 rivers, including 9 big ones (water catchment areas above 50 thous. km^2), 81 medium ones (from 2 to 50 thous. km^2, and 63029 small ones (less than 2 thous. km^2). Their total length is 206.4 thous. km, 90% of which fall on small rivers.

Geographically almost all river basins (except South Bug) as it shown on Fig. 4.1 belong to international water basins − the fact that stipulates activity of transboundary water-environmental relations and need for accelerated development of the basin water resources management.

Water stock of Ukraine includes about 8073 lakes and firths; the total watertable area of which is 4021.5 km^2, the watertable area of firths is 1073 km^2. The number of water bodies that have water volumes of 1 million km^3 and more is 944. A relatively small part of the territory is occupied by the swamps, swampy terrain and excessively humidified lands - 3.6 million ha, but they play a significant resources stabilizing role.

Ukraine belongs to the least provided with water resources European countries. Its main component is river run-off.

Local water resources − those that are formed within Ukraine − amount to 52.4 km^3 in an average water-volume year. Water resources are distributed in a very unequal way within the country's territory. Resources are higher in the north and less in the south, where the bigger water-consumers are located.

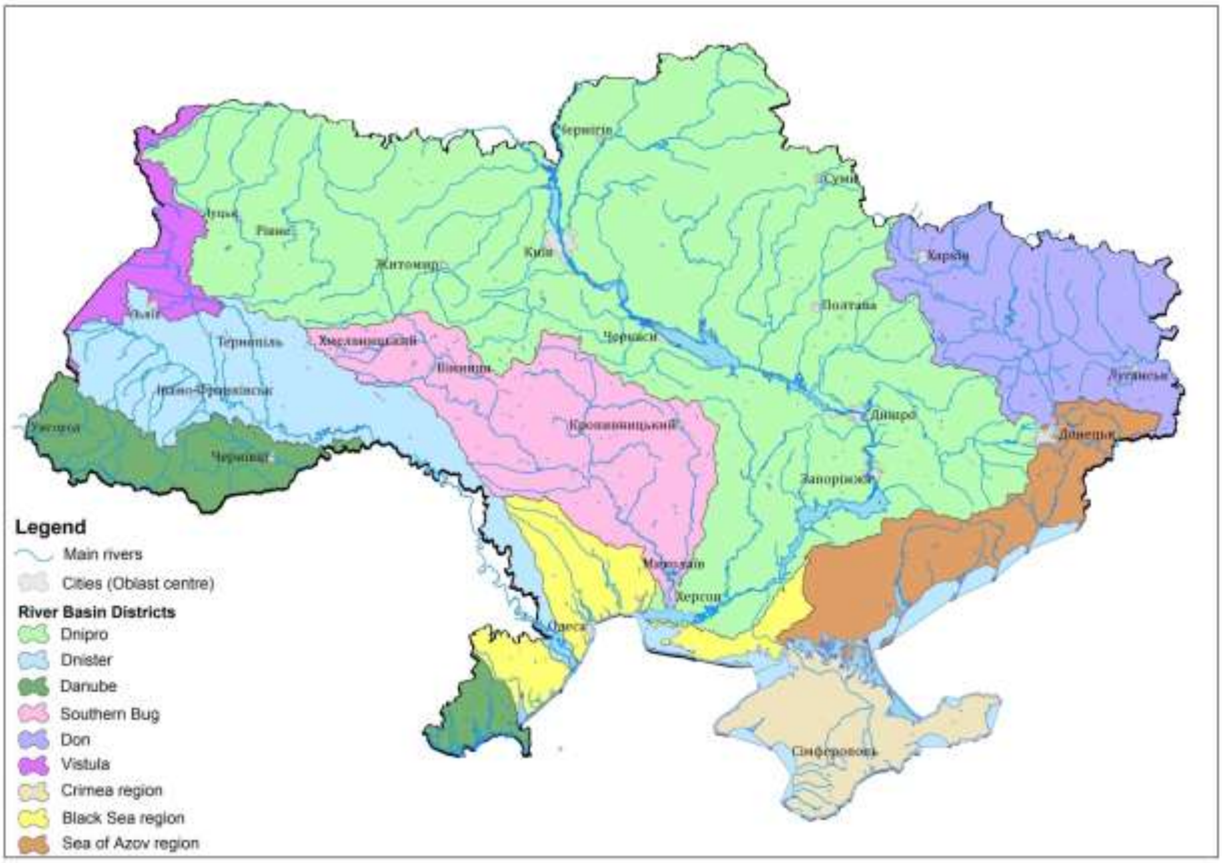


Figure 4.1 – River Basin Districts in Ukraine[24]

Ukraine also has underground water reserves. The general amount of forecasted exploitable subterranean water resources on the country's territory comes to 57.2 million cubic meters per day. The territorial division of subterranean water is uneven.

Judging by the amount of water per Ukrainian citizen, Ukraine, according to international standards, is among those countries insufficiently supplied with water resources. As a result of limited water resources and the way they are distributed, river flow is widely regulated. Reservoirs and ponds, in aggregate, hold close to 58 billion cubic meters, which exceeds the local river flow of all the country's rivers.

[24] Source: https://www.euwipluseast.eu/en/about/country-project-targets/ukraine

Table 4.1 − Renewable surface water resources by major river basin[25]

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*

Regulating the flow of the majority of rivers has reached, and even exceeded, the top-end economic- and ecology-based permissible limits. Such regulation has drastically decreased and often completely destroyed rivers' capacity to purify themselves. In addition, many reservoirs (over 1100) and ponds (around 28 thousand) have caused increases in underground water levels in large areas, and changes in underground water systems.

Water use Ukraine has multi-plan approach to water resource use. The consumer properties of water resources predetermine the possibilities for their complex and multipurpose use by many economic branches. The basic priorities of water use in Ukraine are the population, agriculture and industry.

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

[25] Source: http://www.fao.org/nr/water/aquastat/countries_regions/UKR/

quantitative and qualitative indicators. The water use situation is an intense one, and further developing it will be impossible if new stresses are added.

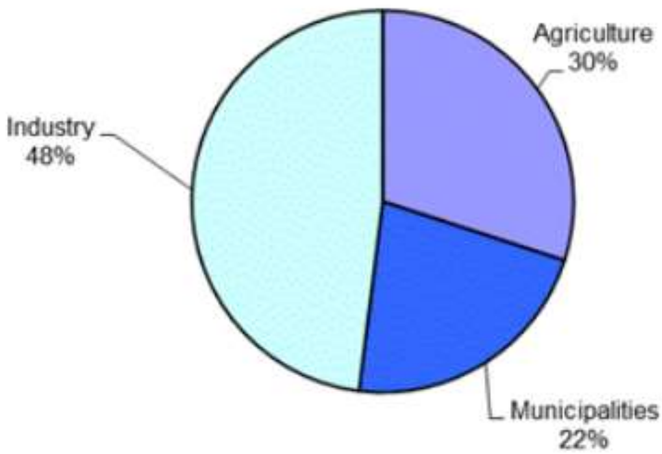


Figure 4.2 – Water withdrawal by sector (Total 14 846 million m3 in 2010)[26]

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 10-15 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.

Low forestation and a high degree of tilled landscapes in small and medium rivers' sub-watershed systems provide ideal conditions for a stable surface water resource pollution level.

With an average 70 percent of Ukraine's territory tilled, the indicators concerning reservoirs of some rivers vary between 58 and 78 percent, and the level of their agricultural cultivation reaches between 72 and 84 percent and more.

As a result of rapid anthropogenic element changes, pollution of surface water resources varies drastically, within a large range – from

[26] Source: http://www.fao.org/nr/water/aquastat/countries_regions/Profile_segments/UKR-WU_eng.stm

"mildly polluted" to "very polluted" (that is, from class II to VI, according to the current Ukrainian water quality classification system).

Calculations based on this classification show that 88% of tested rivers in Ukraine (and their basins) have ecological conditions ranging from "bad" to "catastrophic."

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.

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[27], 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

[27] UN-Water coordinates the efforts of UN entities and international organizations working on water and sanitation issues.

The key challenges to ensure water security for people in Ukraine are[28]:

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) Affordability of water supply and sanitation services is now becoming the most critical.

In a country where, according to experts assessments, more than 70 % of households unable to pay communal services bills, including water supply and sanitation, there is a real threat to ensure the human right to water and sanitation and to destroy water supplies and sanitation service provision.

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[28] T. I. Adamenko, A. O. Demydenko, M. I. Romashchenko, A. M. Tsvietkova, A. M. Shevchenko, M. V. Yatsyuk Rethinking of Water Security for Ukraine. GWP-Ukraine and UNENGO “MAMA-86”, 2016

Monitoring of surface waters in Ukraine

In Ukraine the national activity in the field of water quantity and water quality monitoring is regulated by

- Water Code of Ukraine, Law on Environmental Protection,

- Law on Hydrometeorological Activity,

and a number of Regulations of the Cabinet of Ministers of Ukraine:

"On Approving the Procedure for the Development of River Basin Management Plans"[29],

"On Approval of the Procedure of State Water Monitoring"[30])

and Orders of the Ministry of Ecology and Natural Resources of Ukraine such as "On Identification of Sub-Basins and Water Management Units within the Established River Basin Districts"; "On Approving the List of Priority Substances"; "On Approving the List of Pollutants for the identification of the Chemical Condition of Surface and Groundwater Bodies"; Draft Methodology of Ecological and Chemical Status Classification; Draft Methodology of Analysis of Pressures and Impacts and other.

In 2014, Ukraine signed the Ukraine-European Union Association Agreement. According to this Agreement Ukraine has to make approximation of the Ukrainian "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)

[29] Source: https://zakon.rada.gov.ua/laws/show/336-2017-%D0%BF
[30] Source: https://zakon.rada.gov.ua/laws/show/758-2018-%D0%BF

- 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)

The institutional activities in this field are undertaken by a number of governmental bodies. The Ukrainian institutions, currently involved in surface water issues and monitoring, are the Institute of Hydrobiology of the National Academy of Science and the Central Geophysical Observatory of Hydromet in Kyiv. Additional significant research is carried out by the Institute of Marine Biology of the National Academy of Science of Ukraine (IMB NAS UKRAINE) and the Institute of Biology of the Southern Seas (IBBS), Odessa. The State Geological Service and the State Informational Geological Fund are the institutions responsible for groundwater monitoring.

Generally, the present surface water quantity and water quality monitoring systems in Ukraine were inherited from the former Soviet Union.

1. The State Emergency Service of Ukraine (*Ukrainian Hydrometeorological Center*). Observations of surface water quality are carried out on 103 rivers, 9 reservoirs, 7 lakes, 1 channel, 1 liman in 204 points on 327 sites (stream gauges). 48 indicators of composition and properties of water as well as pollutants are determined. Samples are analyzed in 11 laboratories.

Control measurements are made once a month on 30-40 parameters that assess the chemical state of water, biogenic parameters, presence of suspended particles and organic substances, main pollutants, heavy metals and pesticides. Indicators of radioactive pollution of surface waters are also being identified.

Figure 4.2 – Surveillance points on the quality of surface water by hydrochemical indicators of the hydrometeorological service network of Ukraine in 2016[31]

Chronic toxicity of water is measured at 8 water objects; transboundary pollution is controlled at 15 sites. The samples are taken manually 4-12 times a year.

Hydrobiological samples collection is carried out by field research (by specialists of laboratories and personnel of hydrological stations) or directly by observers of hydrological sites. The water quality is determined directly by the state of the communities which live in water bodies.

Assessment of the state of hydrobiocenoses and ecosystems of controlled water bodies is determined by the results of evaluation of species composition and dynamics in abundance of phytoplankton,

[31] Source: https://docplayer.net/71391053-Ekologichniy-monitoring-stanu-zabrudnennya-prirodnogo-seredovishcha-na-merezhi-sposterezhen-gidrometsluzhbi-ukrayini.html

zooplankton, zoobenthos, perifiton, and higher aquatic vegetation and is provided by:

- bioindication − water quality assessment according to hydrobiological indicators;

- biotesting - an experimental determination of water toxicity.

2. *State Ecological Inspection of Ukraine* takes individual samples at more than 2200 sites and receives data on 60 parameters that are being measured.

3. *The State Agency of Water Resources of Ukraine* monitors the state of rivers, water reservoirs, channels, irrigation systems within multi-purpose water economy systems, water supply systems, transboundary watercourses and reservoirs, in areas affected by nuclear power plants.

Water quality is controlled according to physical and chemical parameters at 72 water reservoirs, 164 rivers, 14 irrigation systems, 1 bay and 5 multi-purpose canals.

Level of radionuclides in the surface waters is controlled by the water management organizations as part of radiation monitoring.

Number of observation sites – 435, quantity of parameters controlled – 16, frequency of observations – once a month.

4. *The State Sanitary and Epidemiological Survey* monitors centralized and de-centralized sources of drinking water supply, recreation areas along rivers and water reservoirs.

Observations are of selective seasonal character and reflect the state of water objects in summer period only as it is the most complicated from the environmental point of view.

Sanitary and epidemiological service controls chemical composition of ground waters that are designated for drinking purposes (Table 4.2).

Table 4.2 − Groups and number of safety parameters of drinking water[32]

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

According to the monitoring results of the Laboratory Center of the Ministry of Health of Ukraine due to the lack or unsatisfactory status of sanitary protection zones of water supply sources, 46.7% of communal sources and 84.1% of rural water supply sources do not meet sanitary norms.

5. *The State Service of Geology and Mineral Resources* of Ukraine monitors the state of ground waters (Figure 4.3). The depths of ground waters and their natural geochemical composition are assessed twice a year at the monitoring sites. Twenty two parameters, including concentration of heavy metals and pesticides, are being measured.

[32] Source: ДСанПіН 2.2.4-171-10

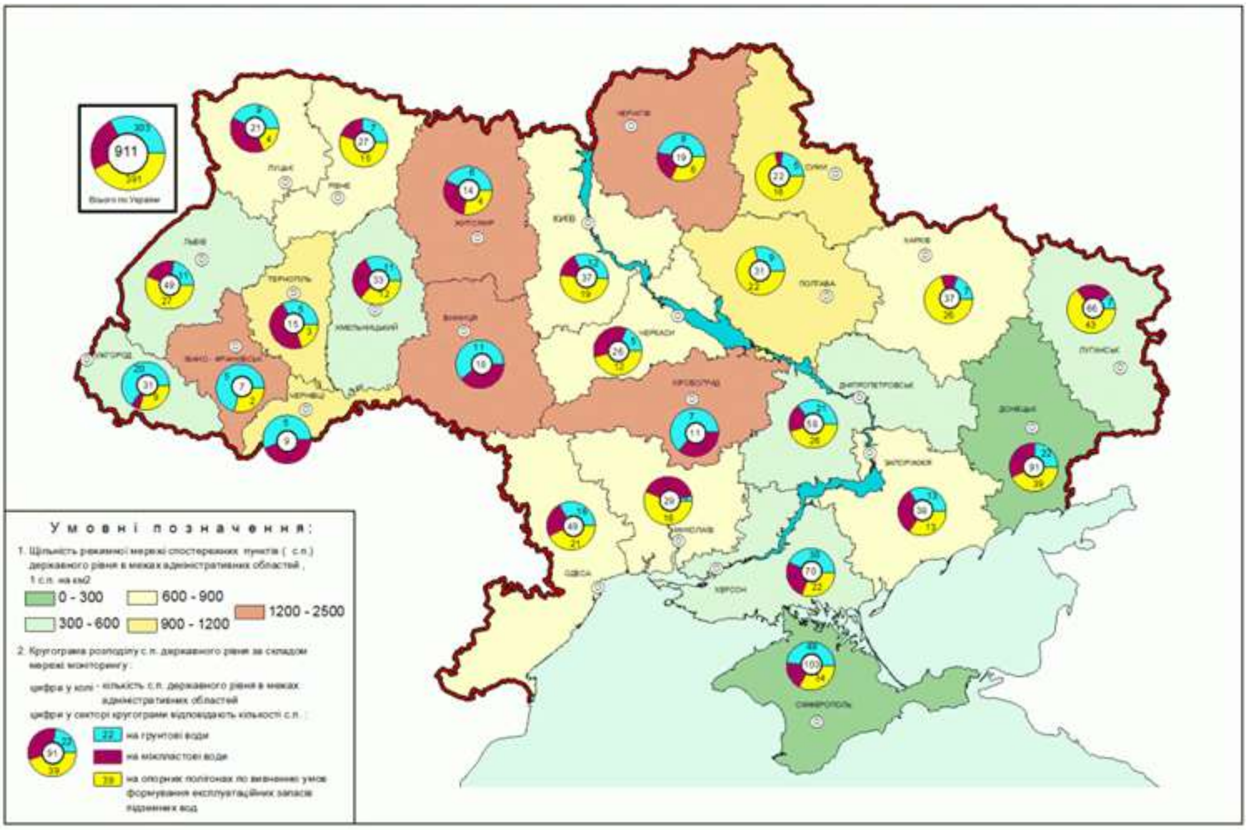

Figure 4.3 – Schematic map of the density of state-level observation points and their distribution by composition of the monitoring network within administrative areas[33]

The state monitoring network was established in the 1950s and 1960s with 8,000 wells. There are different types of monitoring, evaluations, wells (exploration wells, wells used for forecasting, etc.) and monitoring frequencies.

Monitoring wells (as they shown at Figure 4.4) allow for the measure the level of groundwater and water quality. These wells are drilled with a small diameter into the ground and extract groundwater samples for water analysis.

This permanent well collects information as the water level rises and falls in the tube sealed in the ground.

[33] Sourse: http://geoinf.kiev.ua/monitorynh-pidzemnykh-vod/

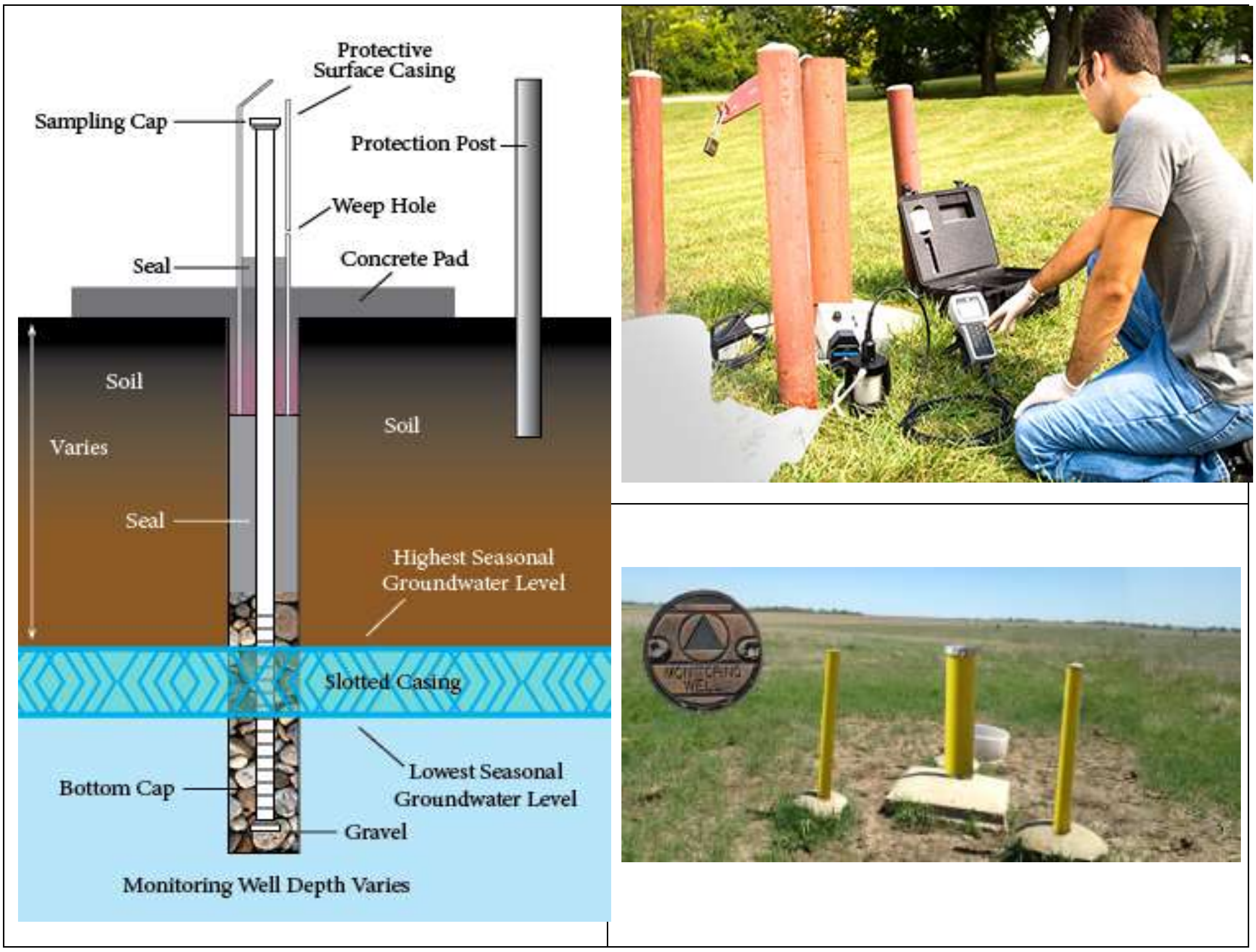

Figure 4.4 – Monitoring Wells: Installation and sampling[34]

Monitoring wells track the opportunity for contamination from surface spills of chemicals, overfilled or leaking underground storage tanks or by the overuse of fertilizer on farmed land.

A monitoring well is the key tool used to visualize how groundwater is stored and moves underground – it ensures that contaminated water is not used for consumption and keeps track of water resources that are exploited sustainably.

Follow the image shown on this page to find a greater understanding of a monitoring well and how it can help restore safe water.

[34] Sources: https://spartandrilling.com/well-installation/
https://brockerhofflc.com/services/groundwater-monitoring-and-modeling/
https://allamericanenviro.com/monitoring-well-types-and-standards/

The national groundwater experts have a very good general overview of the conditions relating to the use and exploitation of groundwater that dates from Soviet times. Moreover, the legal basis, administrative responsibilities and water management organization and monitoring are currently being restructured in a move towards WFD (Water Framework Directive) compliance.

There are different types of monitoring, evaluations, wells (exploration wells, wells used for forecasting, etc.) and monitoring frequencies. There was also a network dealing with the use and exploitation of groundwater, but this collapsed following a reduction in funding during the 1990s.

The assessment methodologies no longer functioned and the state groundwater monitoring network, which covers everything, was reduced by 120 wells (from 1,150). In 2008, the network included 929 monitoring wells (quantity), but only in theory.

There are 356 wells in the Dnipro basin, but only 50 were active in 2016 and 150 in 2015. For 2013 to 2015 there is no information available for several regions and in 2015 virtually no data was reported. There is one database with data from the past 30-40 years, but unfortunately there is no data from the last five years owing to a lack of funding[35].

The Ministry of Environmental Protection and Natural Resources of Ukraine coordinates of water quality monitoring activities of different governmental bodies. It is also responsible for organization of monitoring of sources of anthropogenic impact and zones of their direct influence, and organization of the services for special inspections of analytical control.

Each governmental body involved in water quality monitoring uses its own software and data bank.

[35] Sorce: Monitoring Assessment Report – UA/ European Union Water Initiative Plus for Eastern Partnership Countries (EUWI+): Results 2 and 3. May 2019

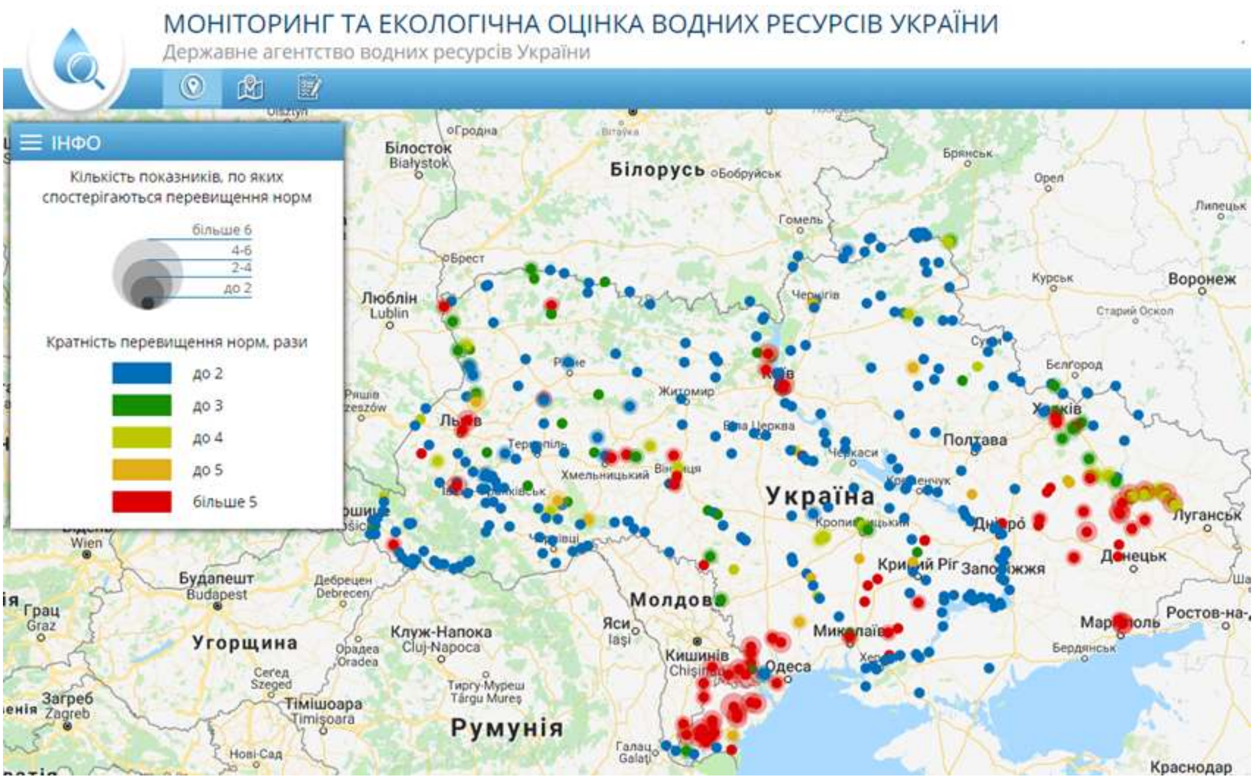

Figure 4.5 – Example of data presentation on the portal "Monitoring and Environmental Assessment of Water Resources of Ukraine"[36]

As a result, the water quality data are distributed over various sources, unintegrated, and not comparable. There is no harmonized methodology for water quality monitoring.

Basics of monitoring of water quality

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.

[36] Sourse: http://monitoring.davr.gov.ua/EcoWaterMon/GDKMap/Index

In contrast, water quality is usually determined by analyzing samples of water collected by teams of personnel visiting monitoring stations at regular intervals.

The costs associated with monitoring the many parameters that influence water quality, when compared to those associated with monitoring only a few water quantity variables, usually means that water quality monitoring is not undertaken as frequently as water quantity monitoring. However, the results of water quality monitoring are vital to being able to track both spatial and temporal trends in surface and ground waters.

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.

Some variables provide a general indication of water pollution, whereas others enable the direct tracking of pollution sources.

Physical and Chemical Characteristics of a Water Body

Temperature. Temperature affects the speed of chemical reactions, the rate at which algae and aquatic plants photosynthesize, the metabolic rate of other organisms, as well as how pollutants, parasites, and other pathogens interact with aquatic residents.

Temperature is important in aquatic systems because it can cause mortality and it can influence the solubility of dissolved oxygen (DO) and other materials in the water column (e.g., ammonia). Water temperatures fluctuate naturally both daily and seasonally.

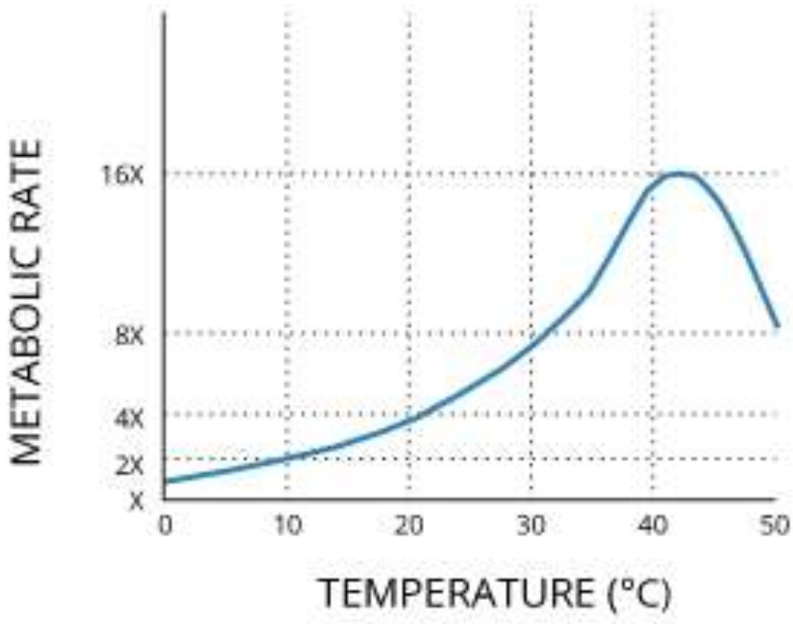

Figure 4.6 − The metabolic rates of aquatic organisms increase as the water temperature increases

Aquatic organisms often have narrow temperature tolerances. Thus, although water bodies have the ability to buffer against atmospheric temperature extremes, even moderate changes in water temperatures can have serious impacts on aquatic life, including bacteria, algae, invertebrates and fish.

Thermal pollution comes in the form of direct impacts, such as the discharge of industrial cooling water into aquatic receiving bodies, or indirectly through human activities such as the removal of shading stream bank vegetation or the construction of impoundments.

Dissolved Oxygen. Oxygen that is dissolved in the water column is one of the most important components of aquatic systems. Oxygen is required for the metabolism of aerobic organisms, and it influences inorganic chemical reactions. Oxygen is often used as an indicator of water quality, such that high concentrations of oxygen usually indicate good water quality.

Oxygen enters water through diffusion across the water's surface, by rapid movement such as waterfalls or riffles in streams (aeration), or as a by-product of photosynthesis.

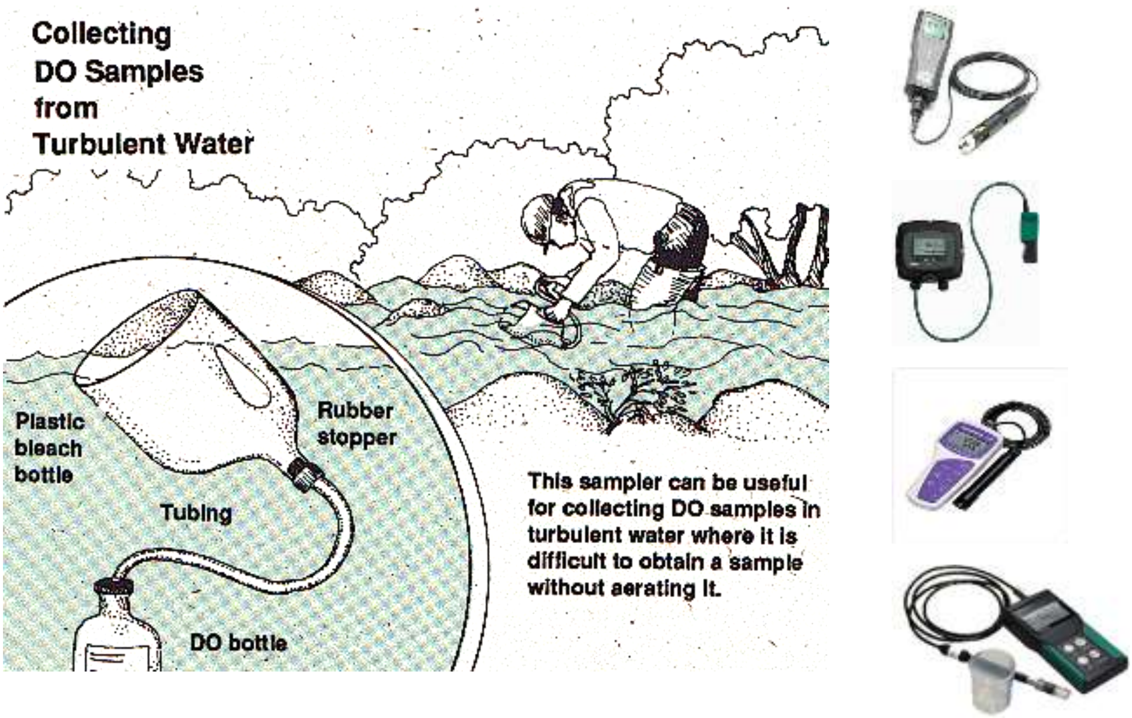

Figure 4.7 − Collecting Dissolved Oxygen sampling and DO meters

The amount of dissolved oxygen (DO) gas depends highly on temperature and somewhat on atmospheric pressure. Salinity also influences dissolved oxygen concentrations, such that oxygen is low in highly saline waters and vice versa. The amount of any gas, including oxygen, dissolved in water is inversely proportional to the temperature of the water; as temperature increases, the amount of dissolved oxygen (gas) decreases.

High algal production in the surface waters can lead to depleted oxygen concentrations at depth as cells die and settle to the bottom of the lake, where they are decomposed by bacteria. The decomposition process consumes oxygen from the water through bacterial respiration.

pH and Alkalinity. In water, a small number of water (H_2O) molecules dissociate and form hydrogen (H^+) and hydroxyl (OH^-) ions.

If the relative proportion of the hydrogen ions is greater than the hydroxyl ions, then the water is defined as being acidic. If the hydroxyl ions dominate, then the water is defined as being alkaline.

The relative proportion of hydrogen and hydroxyl ions is measured on a negative logarithmic scale from 1 (acidic) to 14 (alkaline): 7 being neutral.

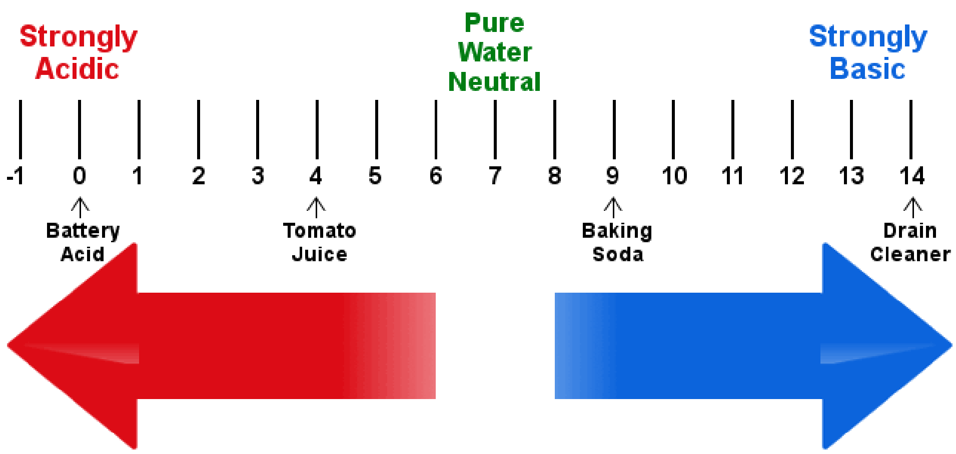

Figure 4.8 − pH scale

The pH of an aquatic ecosystem is important because it is closely linked to biological productivity. Although the tolerance of individual species varies, pH values between 6.5 and 8.5 usually indicate good water quality.

Turbidity and Suspended Solids. Turbidity refers to water clarity. The greater the amount of suspended solids in the water, the murkier it appears, and the higher the measured turbidity. The major source of turbidity in the open water zone of most lakes is typically phytoplankton, but closer to shore, particulates may also include clays and silts from shoreline erosion, re-suspended bottom sediments, and organic detritus from stream and/or water discharges.

Suspended solids in streams are often the result of sediments carried by the water. The source of these sediments includes natural and anthropogenic (human) activities in the watershed, such as natural or excessive soil erosion from agriculture, forestry or construction, urban runoff, industrial effluents, or excess phytoplankton growth.

Turbidity is often expressed as total suspended solids (TSS).

Salinity and Specific Conductance. Salinity is an indication of the concentration of dissolved salts in a body of water. The ions responsible for salinity include the major cations (calcium, Ca^{2+}; magnesium, Mg^{2+}; sodium, Na^{+}; and potassium, K^{+}) and the major anions (carbonates, sulphate, and chloride).

The level of salinity in aquatic systems is important to aquatic plants and animals as species can survive only within certain salinity ranges.

Salinity is measured by comparing the dissolved solids in a water sample with a standardized solution. The dissolved solids can be estimated using total dissolved solids (see: turbidity) or by measuring the specific conductance. Specific conductance, or conductivity, measures how well the water conducts an electrical current, a property that is proportional to the concentration of ions in solution. Conductivity is often used as a surrogate of salinity measurements and is considerably higher in saline systems than in non-saline systems.

Municipal, agricultural, and industrial discharges can contribute ions to receiving waters or can contain substances that are poor conductors (organic compounds) changing the conductivity of the receiving waters. Thus, specific conductance can also be used to detect pollution sources.

Major Ions. The ionic composition of surface and ground waters is governed by exchanges with the underlying geology of the drainage basin and with atmospheric deposition. Human activities within the drainage basin also influence the ionic composition, by altering discharge regimes and transport of particulate matter across the landscape, and by changing the chemical composition of surface runoff and atmospheric deposition of solutes through wet and dry precipitation.

There are four major cations (calcium, magnesium, sodium, and potassium) and the four major anions (bicarbonate, carbonate, sulphate, and chloride).

The ionic composition of surface waters is usually considered to be relatively stable and insensitive to biological processes occurring within a body of water. Magnesium, sodium and potassium concentrations tend not to be heavily influenced by metabolic activities of aquatic organisms, whereas calcium can exhibit marked seasonal and spatial dynamics as a result of biological activity.

Similarly, chloride concentrations are not heavily influenced by biological activity, whereas sulphate and inorganic carbon (carbonate and bicarbonate) concentrations can be driven by production and respiration cycles of the aquatic biota.

Nutrients. Nutrients are elements essential to life. The major nutrients, or macronutrients, required for metabolism and growth of organisms include carbon, hydrogen, oxygen, nitrogen, phosphorus, potassium, sulphur, magnesium, and calcium. In aquatic systems, nitrogen and phosphorus are the two nutrients that most commonly limit maximum biomass of algae and aquatic plants (primary producers), which occurs when concentrations in the surrounding environment are below requirements for optimal growth of algae, plants and bacteria.

There are many micronutrients also required for metabolism and growth of organisms, but for the most part, demands for these nutrients do not exceed supply.

Nitrogen and Phosphorus

Compounds of nitrogen (N) and phosphorus (P) are major cellular components of organisms. Since the availability of these elements is often less than biological demand, environmental sources can regulate or limit the productivity of organisms in aquatic ecosystems.

Phosphorus is present in natural waters primarily as phosphates, which can be separated into inorganic and organic phosphates.

Phosphates can enter aquatic environments from the natural weathering of minerals in the drainage basin, from biological decomposition, and as runoff from human activities in urban and agricultural areas.

Nitrogen occurs in water in a variety of inorganic and organic forms and the concentration of each form is primarily mediated by biological activity.

Phosphorus and nitrogen are considered to be the primary drivers of eutrophication of aquatic ecosystems, where increased nutrient concentrations lead to increased primary productivity.

Eutrophication The degradation of water quality due to enrichment by nutrients, primarily nitrogen (N) and phosphorus (P), which results in excessive plant (principally algae) growth and decay. When levels of N:P are about 7:1, algae will thrive. Low dissolved oxygen (DO) in the water is a common consequence.

Degrees of eutrophication typically range from Oligotrophic water (maximum transparency, minimum chlorophyll-a, minimum phosphorus) through Mesotrophic, Eutrophic, to Hypereutrophic water (minimum transparency, maximum chlorophyll-a, maximum phosphorus).

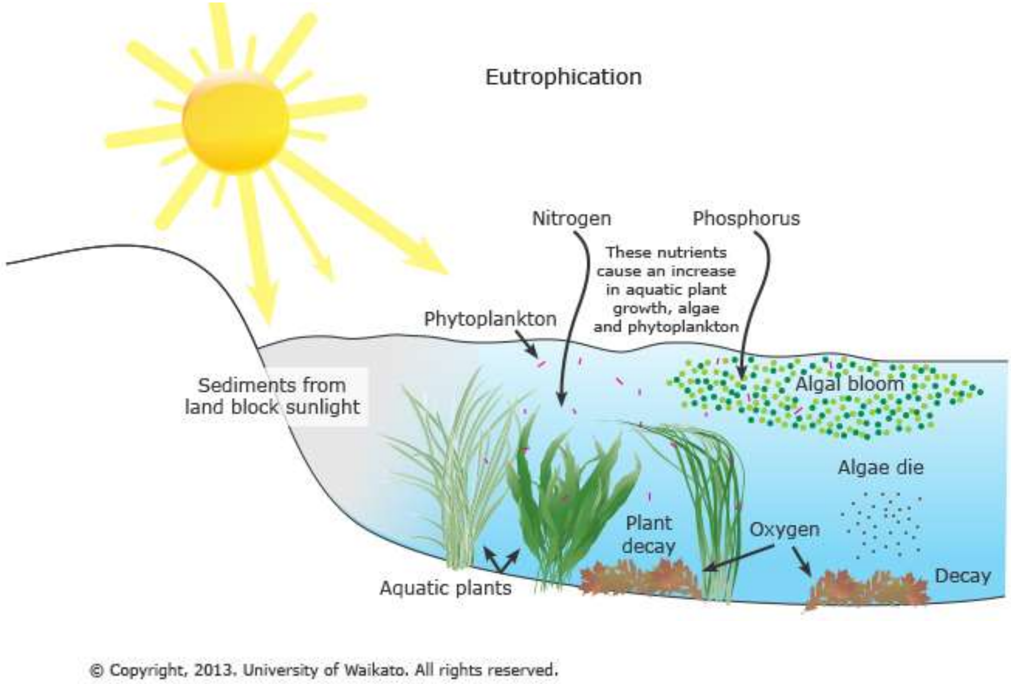

Figure 4.9 – Phosphorus and nitrogen as the primary drivers of eutrophication of aquatic ecosystems

Organic Matter. Organic matter is important in the cycling of nutrients, carbon and energy between producers and consumers and back again in aquatic ecosystems.

External subsidies of organic matter that enter aquatic ecosystems from a drainage basin through point sources such as effluent outfalls, or non-point sources such as runoff from agricultural areas, can enhance microbial respiration and invertebrate production of aquatic ecosystems.

Organic matter affects the biological availability of minerals and elements, and has important protective effects in many aquatic ecosystems, by influencing the degree of light penetration that can enter.

Biochemical Oxygen Demand and Chemical Oxygen Demand. Many aquatic ecosystems rely heavily on external subsidies of organic matter to sustain production. However, excess inputs of organic matter from the drainage basin, such as those that may occur downstream of a sewage outfall, can upset the production balance of an aquatic system and lead to excessive bacterial production and consumption of dissolved oxygen that could compromise the integrity of the ecosystem and lead to favourable conditions for growth of less than ideal species.

Biochemical Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) are two common measures of water quality that reflect the degree of organic matter pollution of a water body.

BOD is a measure of the amount of oxygen removed from aquatic environments by aerobic micro-organisms for their metabolic requirements during the breakdown of organic matter, and systems with high BOD tend to have low dissolved oxygen concentrations.

Table 4.3 – Relation between BOD Level and Water Quality

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.

Biochemical Oxygen Demand (BOD)

A measure of the quantity of dissolved oxygen, in milligrams per litre, necessary for the decomposition of organic matter by microorganisms, such as bacteria.

Chemical Oxygen Demand (COD)

A water quality measure used to indirectly measure the amount of organic compounds in water. This process converts all organic matter into carbon dioxide. It is limited in that it cannot differentiate between levels of biologically active organic substances and those that are biologically inactive.

Biological components. Organisms, populations, and communities composed of different species make up the biological diversity of aquatic ecosystems.

From single-celled microbes such as viruses, bacteria, protists, and fungi, to multi-cellular organisms such as vascular plants, aquatic invertebrates, fish and wildfowl, the community of organisms that reside within and near aquatic ecosystems simultaneously plays a vital role in regulating biogeochemical fluxes in their surrounding environment and is influenced by these same biogeochemical fluxes.

Given the importance of biological communities to water quality, water pollution should be considered as a biological issue since it impairs the ability of resident and non-resident organisms to use resources provided by the ecosystem and to maintain ecological services.

Physical loss of habitat and changes in the chemical composition of water can inhibit a species' ability to grow, reproduce, and interact with other species in the ecosystem. Various pollutants have differing effects ranging from inducing catastrophic mortality to chronic illness, in addition to the effects of bio- accumulation through the food chain.

Biomonitoring is a tool for assessing environmental quality because biological communities integrate the effects of different stressors and thus, provide a broad measure of their aggregate impact.

The monitoring of biological communities can be done at a variety of trophic levels including micro-organisms (bacteria, protists, and viruses), primary producers (algae and vascular plants), primary consumers (invertebrates) and secondary consumers (fish).

Microbes. Monitoring microbes in surface or ground waters is used to detect the presence of pathogenic organisms in order to prevent disease.

The most revealing microorganism of water pollution is coliform bacterium (*Escherichia coli,* E. coli).

The degree of biological pollution is characterized by such indexes as coli-titer (the smallest volume of water per one E. coli) and coli index (absolute number of E. coli in 1 cubic decimeter of water).

Algae and Aquatic Vascular Plants. Algae and aquatic vascular plants generally have rapid reproduction rates and very short life cycles, making them valuable indicators of short-term environmental impacts. Algae and aquatic plants, as primary producers, are most directly affected by physical and chemical factors and are sensitive to pollutants which may not visibly affect other aquatic assemblages, or that may only affect other organisms at higher concentrations.

Invertebrates: Zooplankton and Benthic Macroinvertebrates. Aquatic invertebrates are consumers that feed, primarily, on bacteria, algae, and detrital matter that is both produced within and enters from the surrounding catchment. Zooplankton is the community of invertebrates that is suspended in the water column, whereas lake and river bottoms are inhabited by benthic macroinvertebrates.

Invertebrate assemblages are good indicators of localized conditions because many have limited migration patterns or are sessile (non-motile) and, thus, are useful for examining site-specific impacts. Individual invertebrate species respond differently to environmental changes.

Changes in the environment will be reflected in changes in the species assemblage both spatially and temporally (i.e., affected and unaffected sites over time). Therefore, these assemblages can be used to help assess environmental degradation from both single and cumulative sources.

Fish. Fish communities can be used to indicate longer term or wider ranging effects of changes in the aquatic environment because many fish species are relatively long-lived and mobile. Fish are important for assessing contaminants in ecosystems since they generally represent the top of the food chain and are susceptible to bioaccumulation and bio-magnification of heavy metals and synthetic organic contaminants. They are relatively easy to collect and identify to species level.

The current level of surface water pollution is determined by complex anthropogenic factors-effects:

- Non-toxic organic pollution (saprobization);
- Organic and mineral toxic pollution (intoxication);
- Mineral substances, mainly phosphorus and nitrogen, which stimulate the growth of algae (eutrophication);
- Acid rain (acidification);
- Radionuclides (nuclidization).

Untreated waste waters and effluent waters lead to changes in physico-chemical properties of water bodies and their pollution.

By origin sewage waters divide into such groups:

1) domestic sewage,
2) industrial sewage,
3) municipal non-point runoff,
4) agricultural runoff,

5) mining water.

Each group has a specific structure, in which certain group of pollutants is dominated.

Natural purification is natural process by which an ecosystem reduces or eliminates pollutants in water.

Natural purification or self-purification is the relatively slow process. It is the result of natural physicochemical phenomena (filtration, oxidation and sedimentation) and/or the action of organisms that live in the water bacteria, algae, plants and insects) that gradually concentrate and degrade the pollution.

Water quality index and surface water quality monitoring

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.

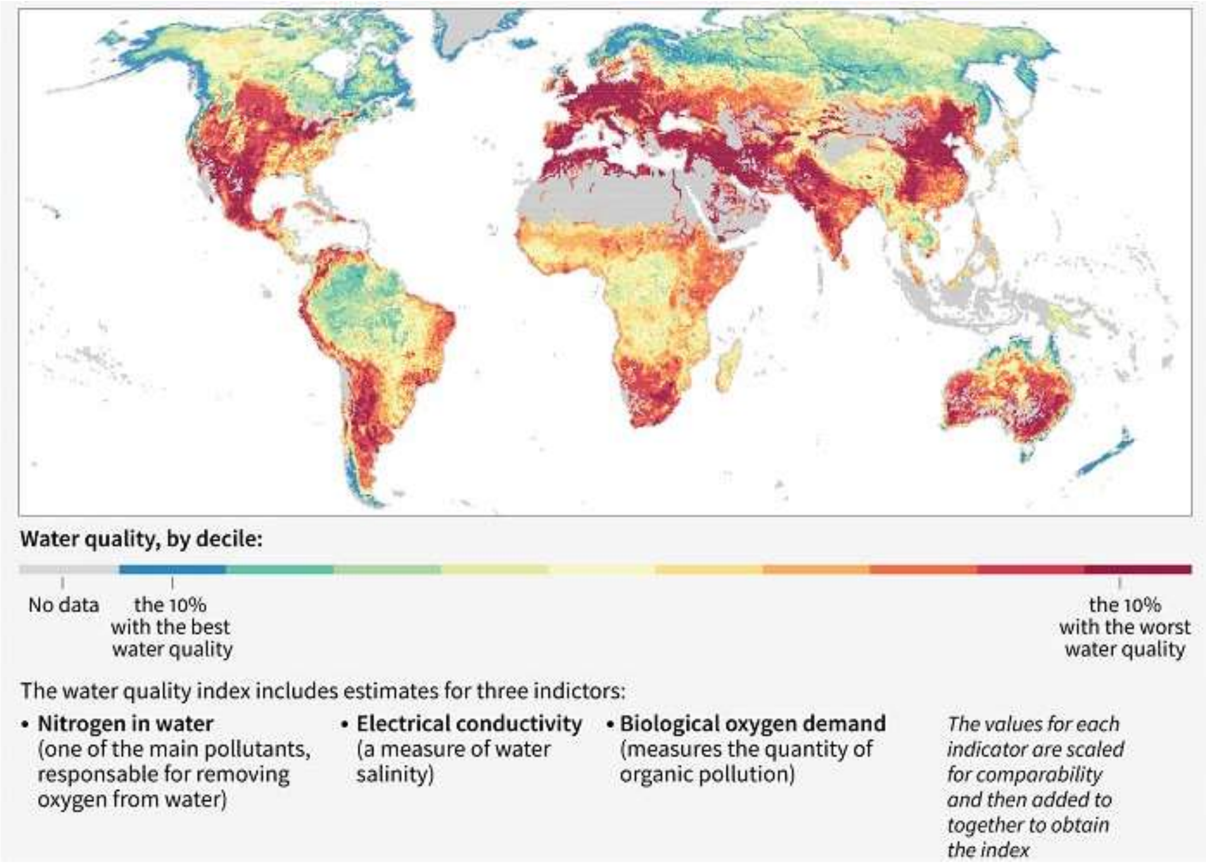

Figure 4.10 − World map of water quality around the world based on an index of key indicators from 2000 to 2010, according to a World Bank study

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.

Comprehension questions

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:

1. population

2. forests

3. agriculture

4. industry

5. nature reserves

4. The chief pollutants of surface waters in Ukraine:

1. vegetable oils

2. oil products

3. biogenic elements

4. sodium salt

5. heavy metallic salts

5. Is level of radionuclides in the surface waters controlled as part of radiation monitoring?

6. What problems can we identify in organization of water quality monitoring in Ukraine?

7. Water quality monitoring:

1. can be undertaken with a minimal amount of human intervention

2. are vital

3. is undertaken quite often

4. is not undertaken frequently enough

5. requires personnel visiting monitoring stations at regular intervals

8. Complete the sentences with a omitted word: ”The quality of any body of surface or ground water is a function of either or both … influences and … activities”.

9. Physical and chemical characteristics of a water body:

1. Physical characteristics	*A Salinity*
2. Chemical characteristics	*B Temperature*
	C Alkalinity
	D Dissolved Oxygen
	E Turbidity

10. Why the temperature is important in aquatic systems?

11. How does thermal pollution come in the form of direct impact?

12. Are the high concentrations of oxygen usually indicate good water quality?

13. The amount of dissolved oxygen gas depends on:

1. rapid movement

2. temperature

3. atmospheric pressure

4. by-product of photosynthesis

5. salinity

14. Why the pH of an aquatic ecosystem is so important?

15. Insert numerical values in the statement: The relative proportion of hydrogen and hydroxyl ions is measured on a negative logarithmic scale from … (acidic) to … (alkaline): … being neutral.

16. Salinity is an indication of the:

1. bacterial respiration

2. total suspended solids

3. concentration of dissolved salts in a body of water

4. pollution sources

17. How salinity can be measured?

18. What are the two nutrients that most commonly limit maximum biomass of algae and aquatic plants in aquatic systems? Choose the wright answers.

1. phosphorus;

2. potassium;

3. nitrogen;

4. calcium.

19. What is the cause of the eutrophication of aquatic ecosystems?

20. Put in order from high to low degrees of eutrophication:

1. Mesotrophic water;

2. Hypereutrophic water;

3. Oligotrophic water;

4. Eutrophic water.

21. What are two common measures of water quality that reflect the degree of organic matter pollution of a water body?

23. Trophic levels can be done for the monitoring of biological communities of water bodies:

1 micro-organisms	*A algae and vascular plants*
2 primary producers	*B fish*
3 primary consumers	*C bacteria, protists, and viruses*
4 secondary consumers	*D invertebrates*

24. What indexes are used for characteristic of the degree of water biological pollution?

25. Complex anthropogenic factors-effects that determine the current level of surface water pollution:

1. organic and mineral toxic pollution	*A nuclidization*
2. acid rain	*B saprobization*
3. non-toxic organic pollution	*C eutrophication*
4. mineral substances which stimulate the growth of algae	*D intoxication*
5. radionuclides	*E acidification*

26. What is the natural purification? What kinds of natural physicochemical phenomena are involved in the process?

5. MONITORING OF SEA WATERS AND OCEAN

Sea water covers approximately 71% of the total area of earth.

Sea pollution is a major problem. Many people may not realize that sea pollution affects not only the seas and oceans, but also the rest of the earth. Pollution in the ocean and seas directly affects marine organisms and indirectly affects human health and resources. Oil spills, toxic wastes, plastics, dumping of other harmful materials are all major sources of pollution in the ocean and sea.

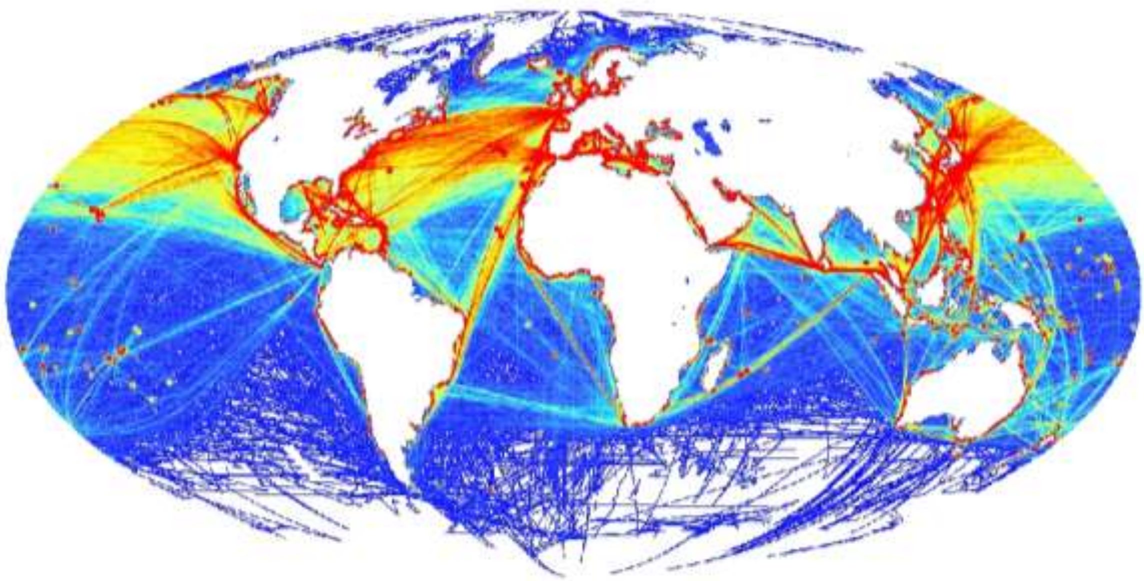

Figure 5.1 – Ocean Pollution Hotspot Map[37]

Causes of seawater pollution

Oil Pollution. Oil is such a chemical which can persist with sea water for many years. Primarily specific gravity of oil is less than water, so it can see that oil make laminar or thick layers on water surface. Then it reacts with atmospheric chemical components, products of which make effect on sea life.

[37] Source: National Center for Ecological Synthesis and Analysis, University of California Santa Barbara (raw data from NOAA)

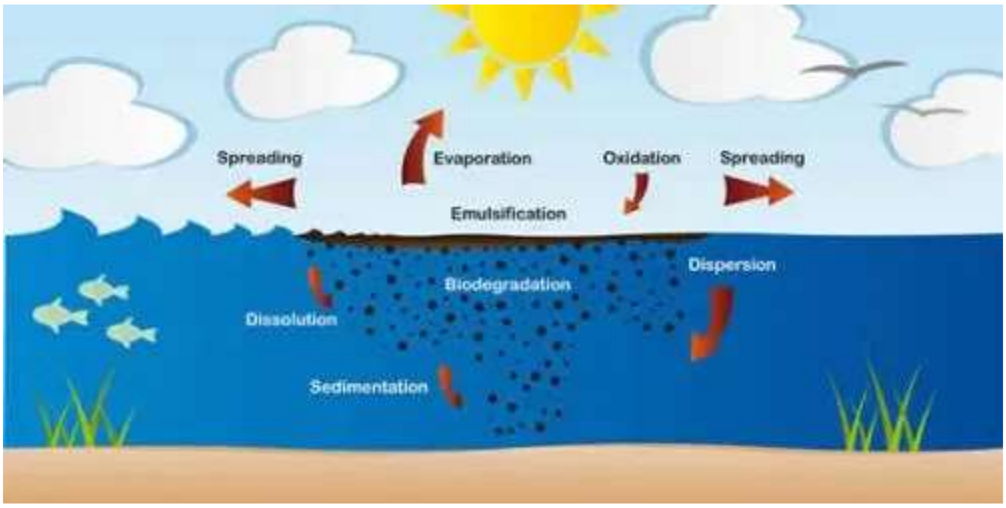

Figure 5.2 – Fate of oil spilled at sea showing the main weathering processes[38]

Large oil pollution comes from tanker accident. Land-based petroleum carried out by rain water is another cause of oil pollution. This includes drips of oils, fuels, and fluid from cars and trucks.

Effect of oil pollution is so much terrible. Oil and its constituents can change the ecology of aquatic habitat and the physiology of marine organism. Components of crude oil, called polycyclic aromatic hydrocarbon (PAHs), persist in the marine environments for years and are toxic to marine life.

Urban waste and sewage. Urban waste consists of garbage dumping, storm water, industrial waste etc. Urban waste goes through sewage pipe line to sea. Many sewage pipelines were built years ago when people did not know the negative effect of pollution. And it was thought that sea would dilute the sewage. Since then amount of sewage has been increased terribly.

Waste from garbage dump taken away by rain water mix with sea water can cause heavy pollution. Industries emits large amount of waste every day. These wastes are directly dumped to river and sea. The toxic

[38] Source: https://keywestcharters.wordpress.com/2012/09/06/the-weathering-process-of-oil/

and poisonous materials of waste can harm many plant and animals and our health also. When toxic waste harms an organism it can quickly be passed along the food chain and imbalance the ecology.

Plastic waste. The global production of petroleum-derived plastic has increased dramatically, from 1.5 million metric tons (1.7 million tons) in 1950 to more than 300 million metric tons (330 million tons) in 2014. If the current production trend − approximately 5 percent increase per year − continues, another 33 billion metric tons (36 billion tons) of plastic will accumulate around the planet by 2050, further driving the need for better methods of collection and recycling[39].

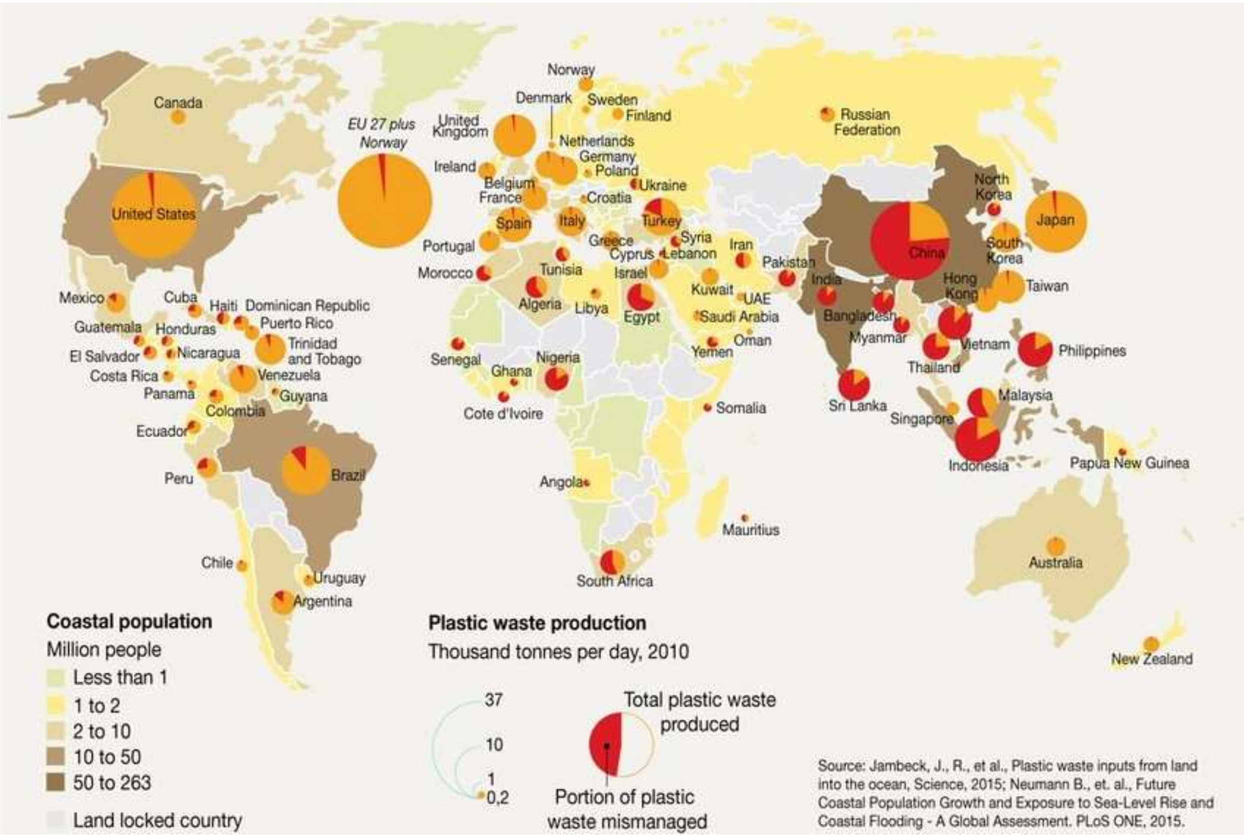

Figure 5.3 – Estimated amounts of plastic production and share of mismanaged waste[40]

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[39] Source: https://ensia.com/photos/plastics-impact-worlds-oceans-outlined-8-maps/

[40] Source: https://www.researchgate.net/figure/Estimated-amounts-of-plastic-production-and-share-of-mismanaged-waste_fig3_329424105

As Figure 5.3 shows, particularly in Asia and Africa the portion of mismanaged waste is very high, leading to massive inflows of plastic debris into waterways and ultimately into the ocean.

Gas impact. Gases have multiple effects on sea pollution. CO_2 emission in atmosphere can alter ocean chemistry. About 1/3 (one-third) of atmospheric CO_2 is absorbed by ocean surface, which make carbonic acid in sea water and damage corals. It also increases the acidity of sea water which is very much harmful for phytoplankton and zooplankton. But these are the base of food chain in marine environment.

The pH scale of seawater lowers every year drastically because of presence of CO_2 in water.

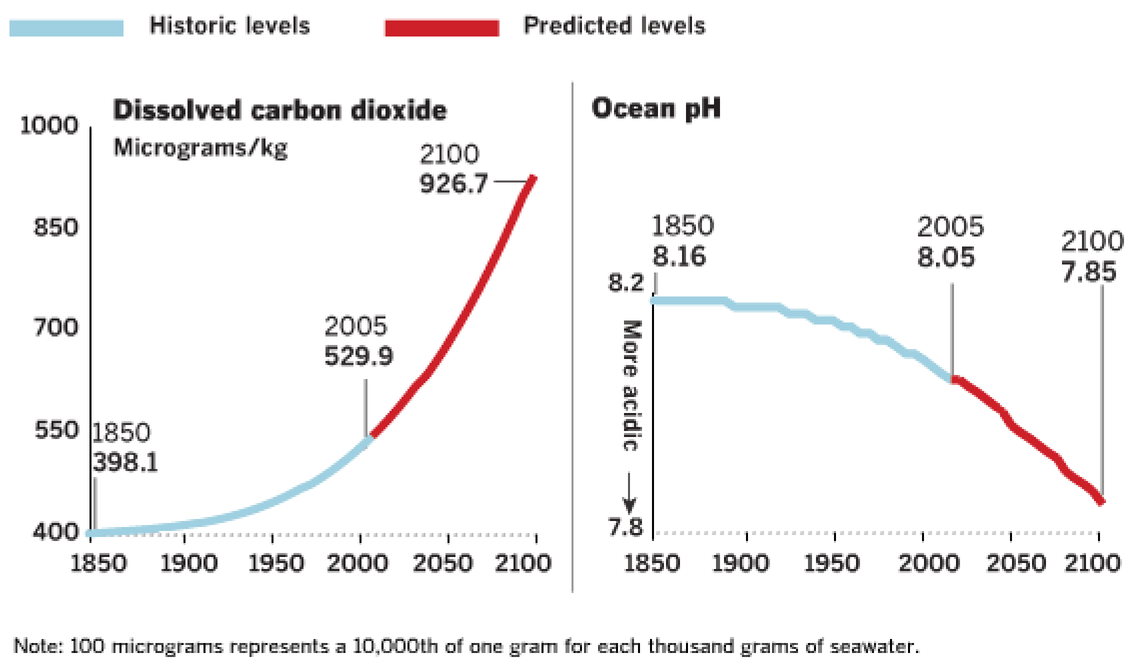


Figure 5.4 – Ocean pH Since 1850 and Projected to 2100[41]

Sulfur gas in environment coming from industrial areas and also from cars and vehicles mixed with air and then with cloud. It causes acid rain. Acid rain is dangerous for sea water. It kills fish and sea plants.

[41] Source: http://news-oceanacidification-icc.org/

NH_4 (ammonia) pollution basically comes from agricultural sectors. But living beings produce large amount of ammonia every day. This ammonia is a compound of hydrogen and nitrogen.

So ammonia can be disintegrated in to these elements causing extra amount of nitrogen in sea water. This nitrogen then gets mixed with oxygen and form NO_2. This is a strong green-house-gas.

CH_4 (methane) gas comes from industrial and garbage waste. This methane gas disintegrated to carbon and hydrogen. Extra amount of carbon give birth too many algae and other sea plant.

Agricultural waste. Agricultural waste contains harmful toxic elements which pollutes sea water. These are two types. One is fertilizers like phosphate, sulfate, nitrate, and other metallic salts. These chemicals get mixed to rivers, lakes and seas. It causes huge algae growth power in less deep water. Decomposition of algae consumes all oxygen present in water and cause massive death of sea lives.

Another type of agricultural waste is pesticides. It pollutes sea in the same way to fertilizers and cause death to fishes and also causes infection in their body. Then death fish cause another type of pollution. Many fishermen believe that toxic chemicals are killing majority of fishes. This is also a problem to our food chain as we eat fish to fulfill requirement of protein.

Radioactive Waste. Sea can be polluted by radioactive activities also. Radioactive waste has a long terrible effect on sea plans and animals. Volcanic eruption under sea is the basic cause of these wastes. When volcanoes under sea are blast, it emits lava, fumes, hard rocks and many harmful radiations. These radiations and wastes have permanent impact on sea environment.

Mining is another type of radioactive pollution. It exposes many heavy metals and sulfur compounds which were locked in earth core. Rain water washes away these compounds to sea. Nowadays mining also happened in deep sea level. And radioactive pollutants are thrown to sea water directly without any consideration.

Nuclear power plant emits large amount of nuclear waste which is highly radioactive. It is also discharged to sea water causing damage of sea lives and ecosystem.

Monitoring of sea waters in Ukraine

Ukraine is located on the cross-road of the trade routes of Eastern Europe and the Mediterranean. It is washed by the Black Sea and the Sea of Azov belonging to the Atlantic Ocean basin.

Figure 5.5 – Satellite Photograph of the Black Sea[42]

[42] Source: https://visibleearth.nasa.gov/view.php?id=75891

The total length of Ukrainian seacoast exceeds 2 500 km (Black Sea – 1 652.2 km, Sea of Azov – 874.8 km). Seagate from the Black and Azov Seas through the straits such as Bosporus, Dardanelles, Gibraltar and Suez Canal to the World Ocean allows Ukraine to use ocean resources for economic needs and ranks it together with maritime states, which according to the rules of international law possess the most favored advantages and benefits.

State Hydrometeorological Service monitors the state of coastal water at the monitoring stations that are located next to the sites of sewage water discharge, as well as scientific and research centres that are located at the coastal zones of the Azov and Black Seas. The monitoring network (as for 01.01.2013) consists of 83 monitoring sites and 14 scientific and research stations that measure 16-24 hydrochemical parameters of water and sediments.

State Environmental Inspections of the Azov and Black Seas (the Ministry of Environmental Protection and Natural Resources) have their own monitoring network. Every month they take samples and analyze the impact of the sources of pollution that are located along the coast; monitor pollutants discharge from the vessels; pollution coming from exploration and extraction activities for oil, gas and construction materials at the sea shelf; control the use of the sea resources.

State Sanitary and Epidemiological Inspection monitors sea water quality in recreation zones.

In Ukraine ecological monitoring is performed on III levels (Figure 5.6):

1-Background,

2-Regional.

3-Local

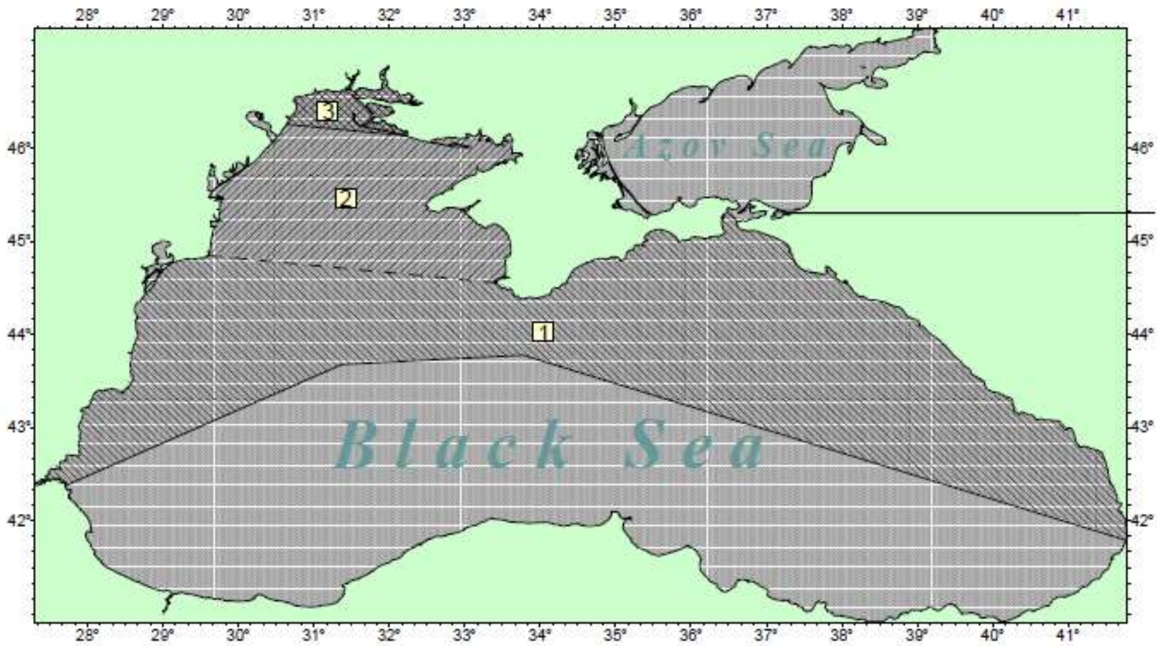


Figure 5.6 − Levels of monitoring: 1-Background; 2-Regional; 3-Local

On all levels of monitoring are investigated:

1) the main hydrochemical mode;

2) the hydrobiological parameters;

3) the main pollutants;

4) the hydrometeorological mode;

5) the radiochemical parameters in water bottom sediments, hydrobionts and surface atmosphere.

The first level is the monitoring of impact zones, i.e. most polluted water areas. The researchers are conducted every ten days. The frequency of a choice of a grid of ecological servers is chosen with a particular discretization necessary for the registration of all local processes and sources of pollution, which happen and are with in this water area.

The problems of priority at this level are:

• microbial pollution;

• hydrological, synoptic etc. conditions on allocation and transference of numerous impurities;

• eutrophication;

This (first) level of monitoring includes:

a) Inventory of land based sources (point, diffuse) with the complete chemical analysis;

b) Monitoring of beaches;

c) Monitoring of impact zones;

d) Development of water quality, bottom sediments, surface atmosphere standards.

The second level includes:

e) Monitoring of the shelf zone of the Black Sea.

The third level:

f) Background monitoring of the open part of the sea.

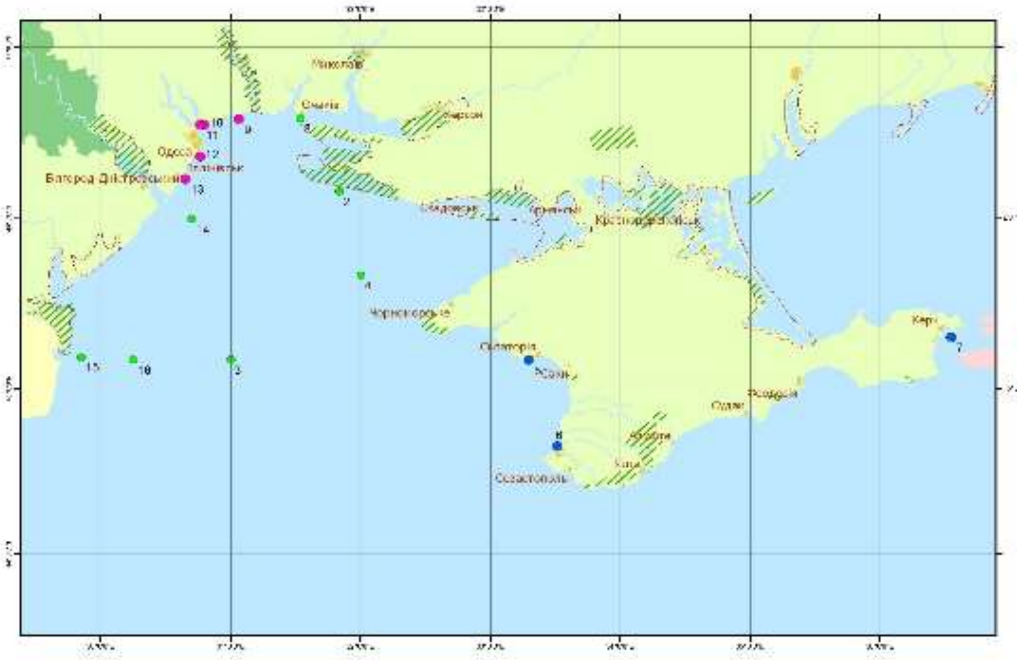


Figure 5.7 – Ukrainian Monitoring System since 1995 (the Ukrainian network had 16 stations)

The modern state of pollution of coastal (recreational) zone of the Black Sea is characterized, by the last years, as progressing anthropogenous pollution; practically many pollutants are stationary components of coastal marine waters.

Here by we have petroleum, polyaromatic hydrocarbons, phenols, organic matters, heavy metals, chlororganic pesticides, polychlorbiphenyls, synthetic surfactants and biogenic substances (nitrogen, phosphorus, silicon).

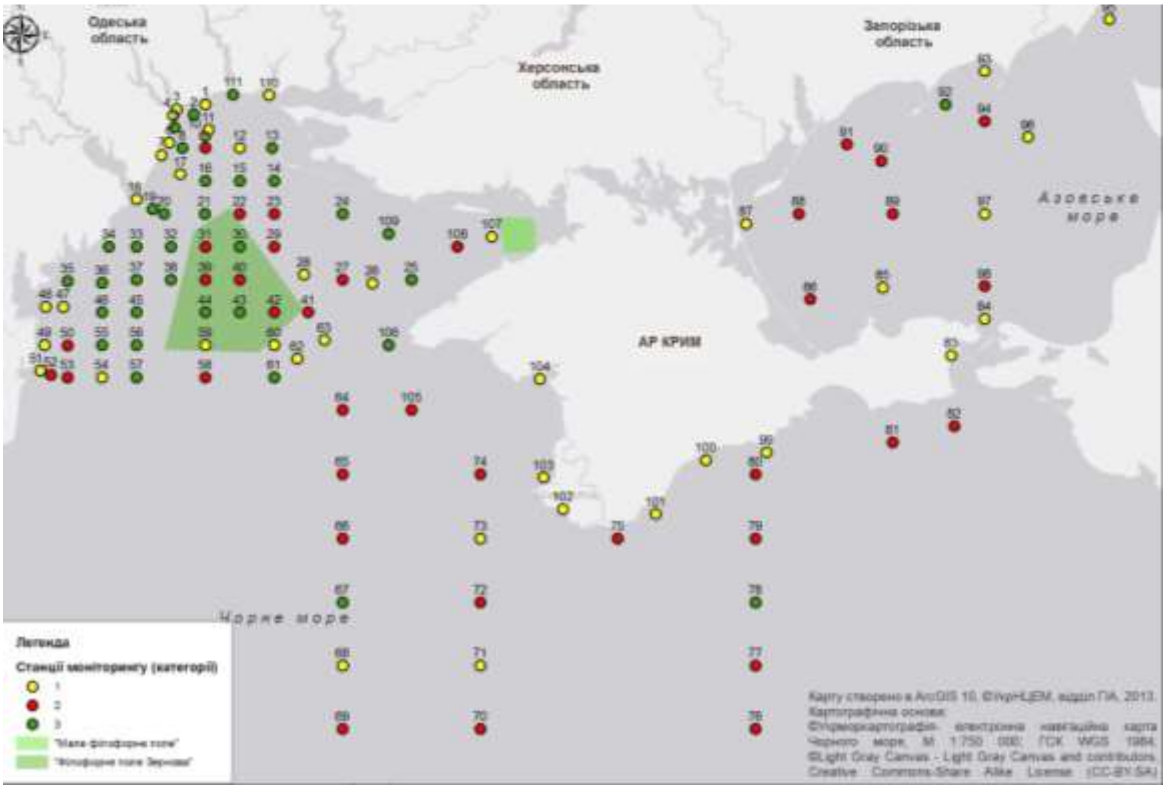


Figure 5.8 − Ukrainian Monitoring System till 2014 (the Ukrainian network had 111stations)

In compliance with the Law of Ukraine No 1207-VII of 15 April 2014 ‘On Securing the Rights and Freedoms of Citizens and the Legal Regime on the Temporarily Occupied Territory of Ukraine’, inland waterways and territorial sea of Ukraine around Crimean Peninsula, as well as the territory of exclusive (maritime) economic zone of Ukraine along Crimean coastline have been defined as temporarily occupied territories.

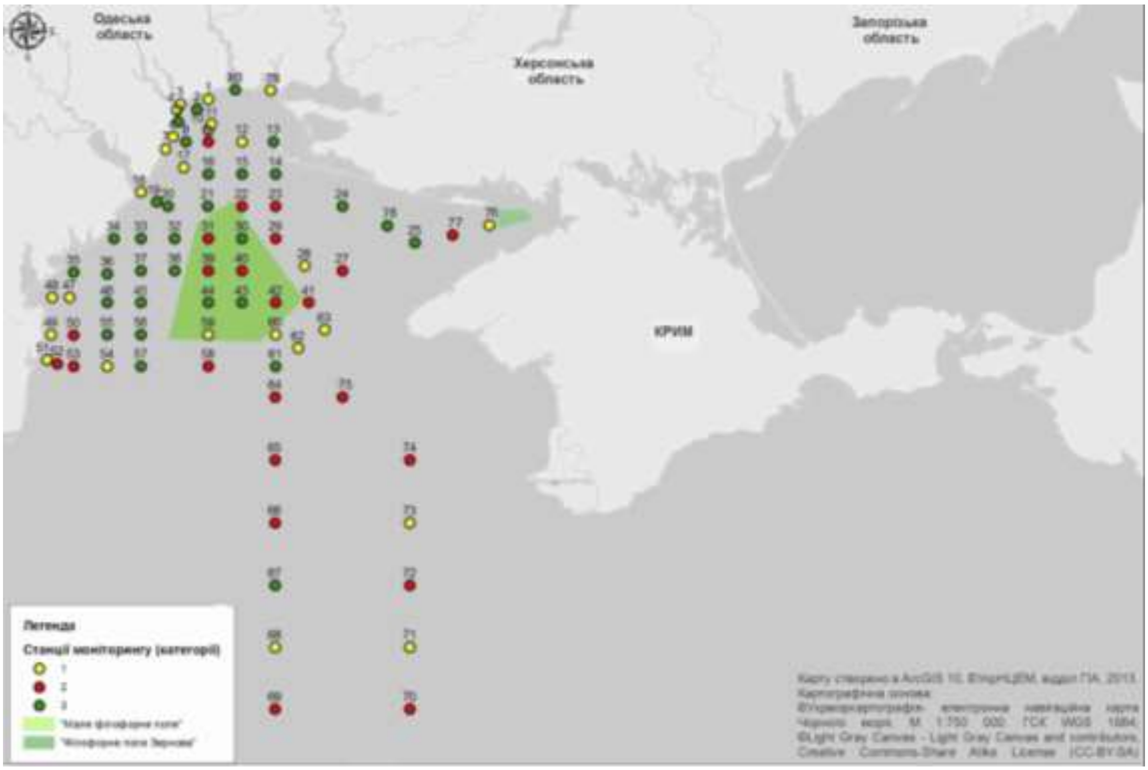


Figure 5.9 – Ukrainian Monitoring System since 2014

<u>Stations categories:</u>

- 1st rank – stations with sea water and bottom sediments (BS) and biota sampling for determination of the full complex of standard hydrophysical, hydrochemical and hydrobiological characteristic and pollution substances in water, BS and biota;

- 2nd rank - stations with sea water sampling for determination of standard hydrochemical characteristic and pollutant substances in water;

- 3rd rank - stations with sea water sampling for determination of standard hydrochemical characteristic for investigation of euthrophication and hypoxia problems.

European policy in the field of sea water quality and monitoring

The marine environment is a precious heritage that must be protected, preserved and, where feasible, restored in order to maintain biodiversity, ecosystem functioning and to ensure clean, healthy and productive seas.

The marine ecosystem is threatened by various pressures, notably pollution, eutrophication, overfishing, 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.

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 establishes 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.

The 11 Descriptors of the Marine Strategy Framework Directive (2008/56/EC) (MSFD)

To ensure that human pressures and impacts are maintained at levels which do not deteriorate the marine environment and are in line with the achievement of GES, while enabling the sustainable use of marine goods and services by present and future generations as mentioned above, the Commission has established specific methodological standards, criteria and indicators for each of the 11 Descriptors of GES.

This also ensures consistency among the Member States in fulfilling their obligations under the MSFD. The 11 Descriptors which are provided for by Annex I of the MSFD for the determination of GES are as follows:

1. Biodiversity

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. Non-indigenous species

The non-indigenous species introduced by human activities are at levels that do not adversely alter the ecosystem.

3. Commercially exploited fish and shellfish

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. Food webs

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.

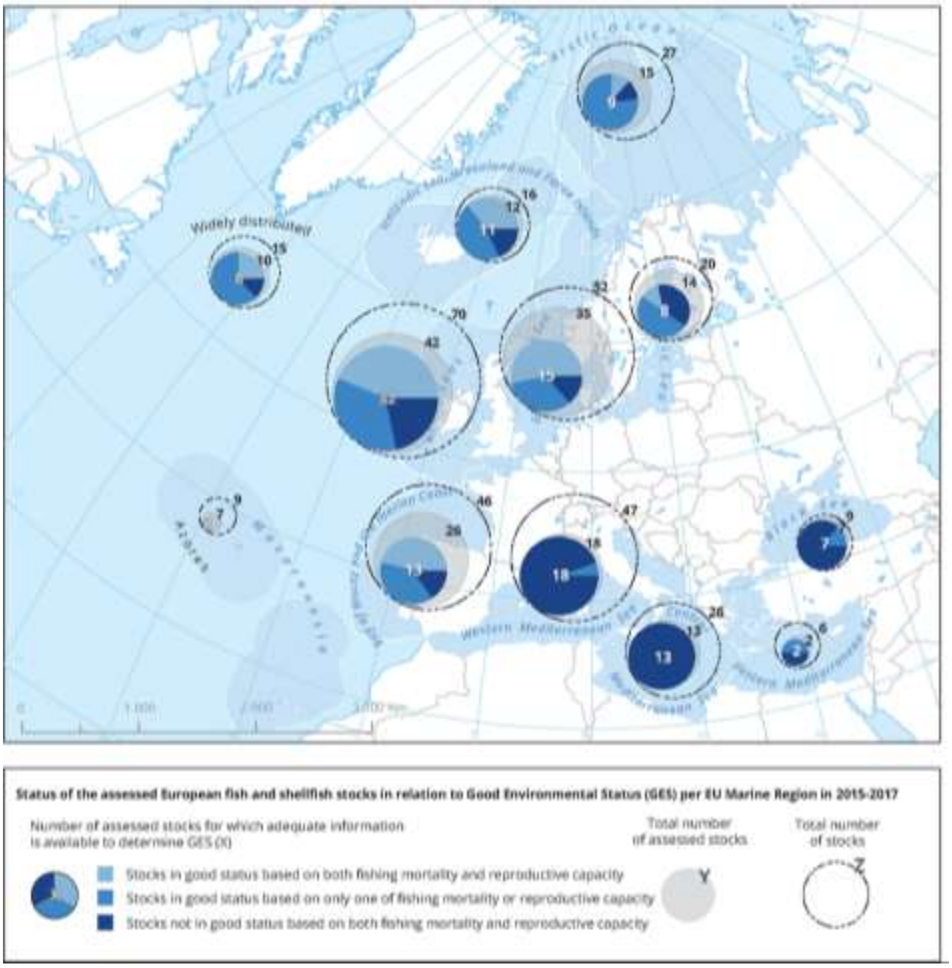


Figure 5.10 − Status of the assessed European commercial fish and shellfish stocks in relation to Good Environmental Status (GES) per EU marine region in 2015-2017[43]

5. Eutrophication

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

[43] https://www.eea.europa.eu/data-and-maps/figures/status-of-fish-stocks-in-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. Hydrographic Conditions

Permanent alteration of hydrographical conditions does not adversely affect marine ecosystems.

8. Contaminants

Concentrations of contaminants are at levels not giving rise to pollution effects.

9. Contaminants in Fish

Contaminants in fish and other seafood for human consumption do not exceed levels established by Community legislation or other relevant standards.

10. Marine Litter

Properties and quantities of marine litter do not cause harm to the coastal and marine environment.

11. Energy, including underwater noise

Introduction of energy, including underwater noise, is at levels that do not adversely affect the marine environment.

In April 2017, the Ministry of Environmental Protection and Natural Resources of Ukraine presented a draft of Ukraine's Marine Strategy and launched public consultations on it.

This is the result of Ukraine's carrying out its obligations under the Directive 2008/56 / EC which introduces a new approach to the EU environmental policy regarding the protection of the marine environment and aims at achieving Good Environmental Status (GES) in marine waters.

Implementing the requirements of the Directive, Ukraine will face a number of challenges that need to be resolved: for instance, elaborating appropriate monitoring programmes as well as carrying out the monitoring of marine environment in the exclusive (maritime) economic zone.

Given that the Directive is on various implementation stages in the EU member states, this opens new opportunities for Ukraine to develop and implement approaches of securing Good Environmental Status, in particular, in the Black Sea and the Azov Sea along and together with the EU member states.

Comprehension questions

1. Are the oil products the one of the least causes of seawater pollution?

2. What are the types of agricultural waste which pollutes sea water?

3. What gases are the major pollutants of sea water?

4. What types of radioactive pollution do you know?

5. How often do the State Environmental Inspections of the Azov and Black Seas take samples of sea water?

1) Monthly;

2) Bimonthly;

3) Twice a year;

4) Once a year.

6. Is the main hydrochemical mode investigated on all levels of sea water monitoring in Ukraine?

7. Levels of ecological monitoring of seawater in Ukraine:

1. The first level	*A background monitoring of the open part of the sea*
2. The second level	*B monitoring of impact zones*
3. The third level	*C monitoring of the shelf zone of the Black Sea*

8. Give the short characteristic of the modern state of pollution of coastal zone of the Black Sea.

6. 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.

Land, and its associated resources, comprise a stock of natural capital.

The increasing demand for land-based goods and services, and the manner in which they are today produced is adversely impacting the health and future productivity of the planet.

The misuse and over-exploitation of land resources are threatening human security on multiple fronts: diminishing food and water security as well as reduced soil health and ecosystem resilience make us more vulnerable to extreme weather events and the impacts of climate change, and even threaten stability and security within and between nations.

Keeping land in a healthy state is an essential contribution to human security – access to food and water, the stability of employment and livelihoods, resilience to climate change and extreme weather events, and ultimately social and political security.

Land classification and land use in Ukraine

Ukraine's land fund is one of the largest in Europe. If for example, arable lands occupy between 30 and 32 percent of the total area in developed European countries, in Ukraine this indicator raises to 56.1 percent.

As a result of reduced forest lands, meadows and pastures, changes occur in the microclimate and soil water deposit levels.

Additionally, land aridity and desertification occurs, and water and wind erosion develops, which causes soil fertility to decline, agricultural ecosystems productivity degradation and decline and makes sustainable development impossible, which is related to not just the country's ecology, but also food safety.

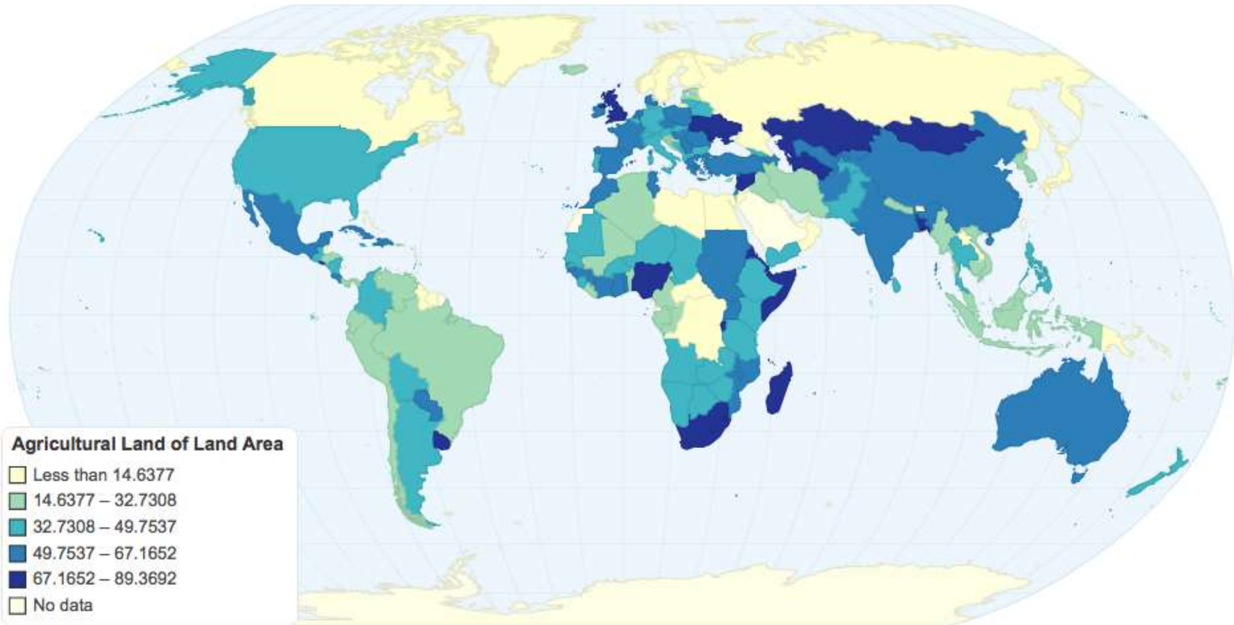


Figure 6.1 − Agricultural Land Area - as percentage of total land area[44]

The Land Code of Ukraine (of 25.10.2001 № 2768-III) regulates public relations regarding owning, use and disposal of land.

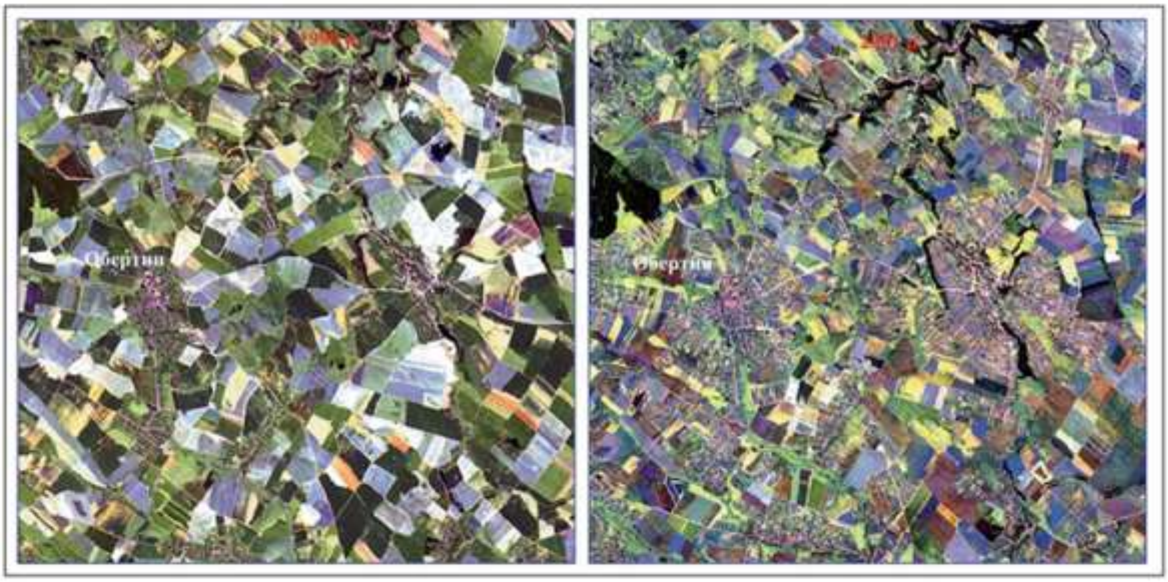
The lands of Ukraine include all lands within its territory, as well as islands and lands occupied by water objects, which are divided into the following categories by their purposeful designation:

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;

[44] Source: http://chartsbin.com/view/28797

8) Water fund lands; and

9) Lands for industrial, transportation, communications, energy, defense and other purposes.



Changes in land-use in the process of land reform *(data of Landsat satellite).*

Figure 6.2 – Changes in land-use in the process of land reform (data of Landsat satellite)

Each land fund category has its reserves. These categories, and numerous subcategories, form the basis for the definition of rights and obligations, the structure of land use and management, statistical reporting and the division of administrative responsibilities among state and municipal agencies.

The Ukrainian land fund's general territory amounts to 60.4 million hectares. The structure of the country's land fund is as follows: agricultural lands cover 70.1 % of Ukraine's territory.

The country's agricultural production resources are as follows: 78.4 % arable land; 13.1 % pastures; 5.8 % hayfields; 2.1 % multi-annual plantings; 0.6 % fallow.

Forests and other territories covered with forestation comprise 17.6% of the country's territory; lands that have been built on represent 4.2%; areas with water 4,2%; swamps 1.6%; others 3.5%.

The structure of agricultural lands, just like the structure of Ukraine's land fund, is characterized by a very high index of agricultural development (0.7 units).

Due to the abundance of very fertile land, including over 25 per cent of the world's resources of chernozem soil, the proportion of agricultural and arable land is very high, significantly exceeding the ecologically justified limit.

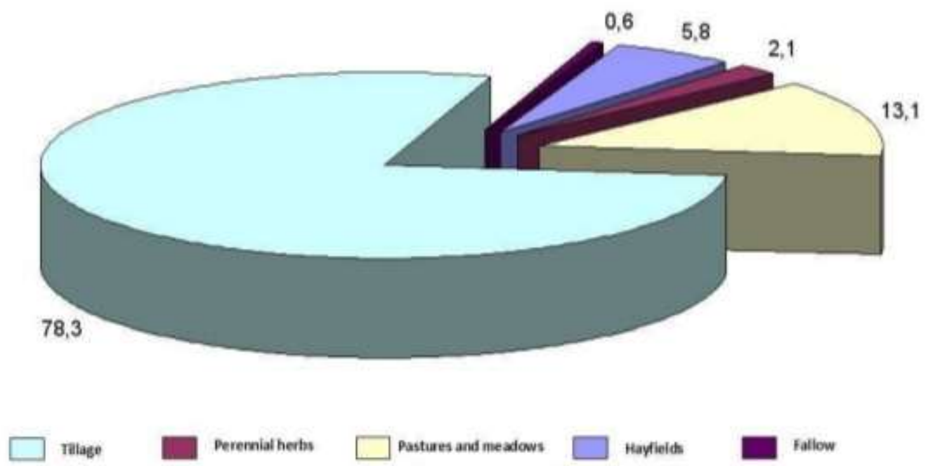


Figure 6.3 – Structure of agricultural lands[45] *in %*

According to Ukrainian scientists' evaluations, Ukrainian arable lands are located mostly in favorable natural climate conditions for growing major agricultural crops.

Around 1/10 of all arable land territory is concentrated in Polissya, around 2/5 in the forest and steppe, and ½ in the steppe zone.

Arable lands in mountainous Crimea and the brown soil forest region of the Carpathians cover an insignificant part of the soil fund, but have

[45] Source: DerzhGeoCadastre

value because tobacco, grapes, aromatic oil plants, vegetable, and feed cultures can be grown on them.

Ukraine has some of the most fertile soils in the world, including the famous Chernozems, deep black soils rich in humus (Figure 6.4 and Table 6.1). Chernozems occupy about half of the country (about 68 percent of the arable land).

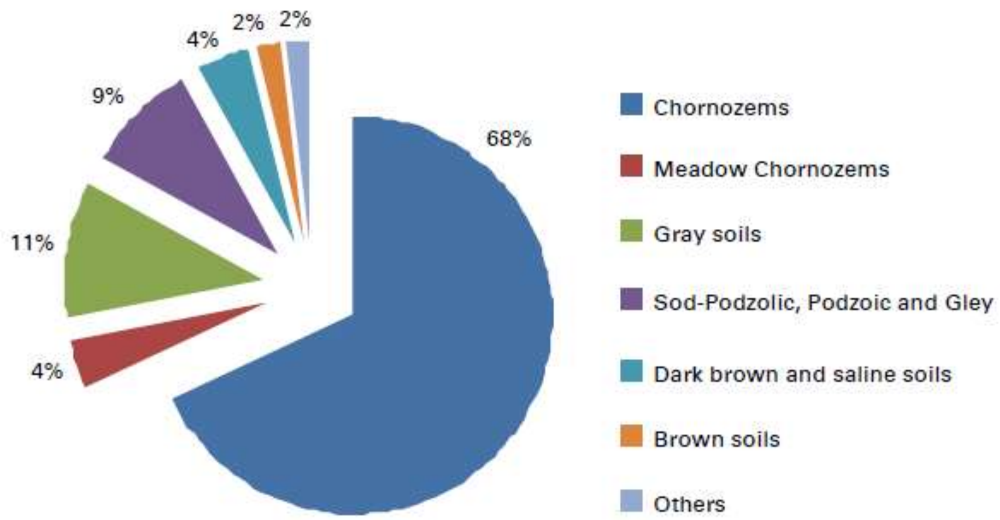


Figure 6.4 – Soils of Ukraine[46]

Physical, chemical and biological nominal data of Ukrainian soils and their classification were studied in the late 1950s (completed in 1961).

Since then no countrywide soil data update has been done.

In general, Ukraine's land fund is characterized by high bio-productive qualities. According to scientific opinion, in conditions of optimal land use and with a corresponding level of agricultural culture, the country would be able to feed up to 300-320 million people.

[46] Source: Sviatoslav Baluk, Director, Institute for Soil Science and Agro-chemistry Research during roundtable discussions in Kyiv, 23 May, 2013.

Table 6.1 − Ukraine: soil distribution[47]

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

Land and soil monitoring in Ukraine

The State Emergency Service of Ukraine monitors soil contamination with pesticides and heavy metals in 20 populated areas. Samples are taken once in every five years and sometimes on an annual basis (in the towns of Kostiantynivka and Mariupol).

The control covers 27 soil parameters.

State Ecological Inspection of Ukraine takes soil samples at industrial sites of enterprises throughout the country. The measurements encompass 27 parameters.

The State Sanitary and Epidemiological Service monitors the state of soils on the territories with potential adverse impact on people's health. Monitoring mostly covers cultivated agricultural land, areas where pesticides are applied, soil in residential areas, soil at children's

[47] Source: Sviatoslav Baluk, Director, Institute for Soil Science and Agro-chemistry Research during roundtable discussions in Kyiv, 23 May, 2013

playgrounds and on the territory of public places and social institutions. The state of soils is controlled at enterprises that store toxic waste and outside enterprises in places of toxic waste storage or disposal.

The State Agency of Water Resources of Ukraine monitors irrigated and drained agricultural lands, in particular, the degree of salinity and alkalinity of soils.

The State Agency of Forest Resources of Ukraine provides monitoring of the lands of forest fund. The control covers radiological parameters, residual level of pesticides, agrochemicals and heavy metals.

The State Service of Ukraine on Geodesy, Cartography and Cadastre (former State Land Resources Agency of Ukraine) carries out qualitative and quantitative land inventory.

Quantitative land inventory held annually for all categories of land fund. But the last comprehensive Inventory of Soil Quality has conducted in 1996.

Indicators of land qualitative state are:

- soil texture;
- saline soils;
- alkaline soils;
- soils with alkalized complexes;
- solodized soils;
- salt-affected soils (B/A soils);
- acidic soils;
- waterlogged soils;
- bogged soils;
- fragmental soils;
- deflation-dangerous soils;
- soils vulnerable to water erosion; and
- distribution of lands by degree of slope.

State institution “Soil Protection Institute of Ukraine” (Ministry of Agrarian Policy and Food of Ukraine) monitors agricultural soils. The control covers radiological, agro-chemical and toxicological parameters, residual level of pesticides, agricultural chemicals and heavy metals. Monitoring, which carries out that Institute is called *eco- agrochemical passportization (or Certification) of fields and land areas*.

This passportization is carried out since 1965 every 5 years.

Monitoring of land and soil degradation and desertification

Land degradation means 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, including processes arising from human activities and habitation patterns, such as:

- soil erosion caused by wind and/or water;
- deterioration of the physical, chemical and biological or economic properties of soil; and
- long-term loss of natural vegetation[48].

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 soil ecosystem has multiple roles in the environment, as it maintains productivity, provides habitats and buffers against pollution of

[48] Source: The United Nations Convention to Combat Desertification http://catalogue.unccd.int/936_UNCCD_Convention_ENG.pdf

adjacent water resources. Poor soil quality results in lower agricultural yields, a less resilient soil and land ecosystem and greater contamination of adjacent water bodies.

Soils can also be viewed in terms of degradation and depletion. Each has adverse effects on soil quality, plant productivity and ecosystem functions.

Degraded soils can be damaged in several ways:

− Structurally, by physical compaction and loss of aggregate stability.

Compacted soils are often slow draining, becoming water-logged when wet and as a result poorly aerated. This results in an unsuitable environment for plant roots and soil organisms. Compaction causes lower yields, higher production costs and reduced profitability. Increased run-off may reduce water quality.

− Through soil acidification, salinity, erosion and desertification. These are one of major causes of degradation in Ukraine.

Depleted soils have lost components essential for healthy plant and soil biology.

They may be:

− depleted in nutrients, because nutrient stocks are not being replaced as fast as they are removed;

− too acidic for some crops if insufficient lime is applied to counter natural acidification processes; and/or

− depleted in organic matter and therefore more prone to rapid structural decline and less able to retain nutrients in the topsoil and supply plant nutrients from organic reserves. If nutrients are not retained within soils they can contaminate surface and groundwater.

Soils low in biological activity are less able to detoxify wastes and degrade contaminants and residues.

Today's land-use situation in Ukraine is close to critical. The most comprehensive degradation processes are associated with agricultural activity.

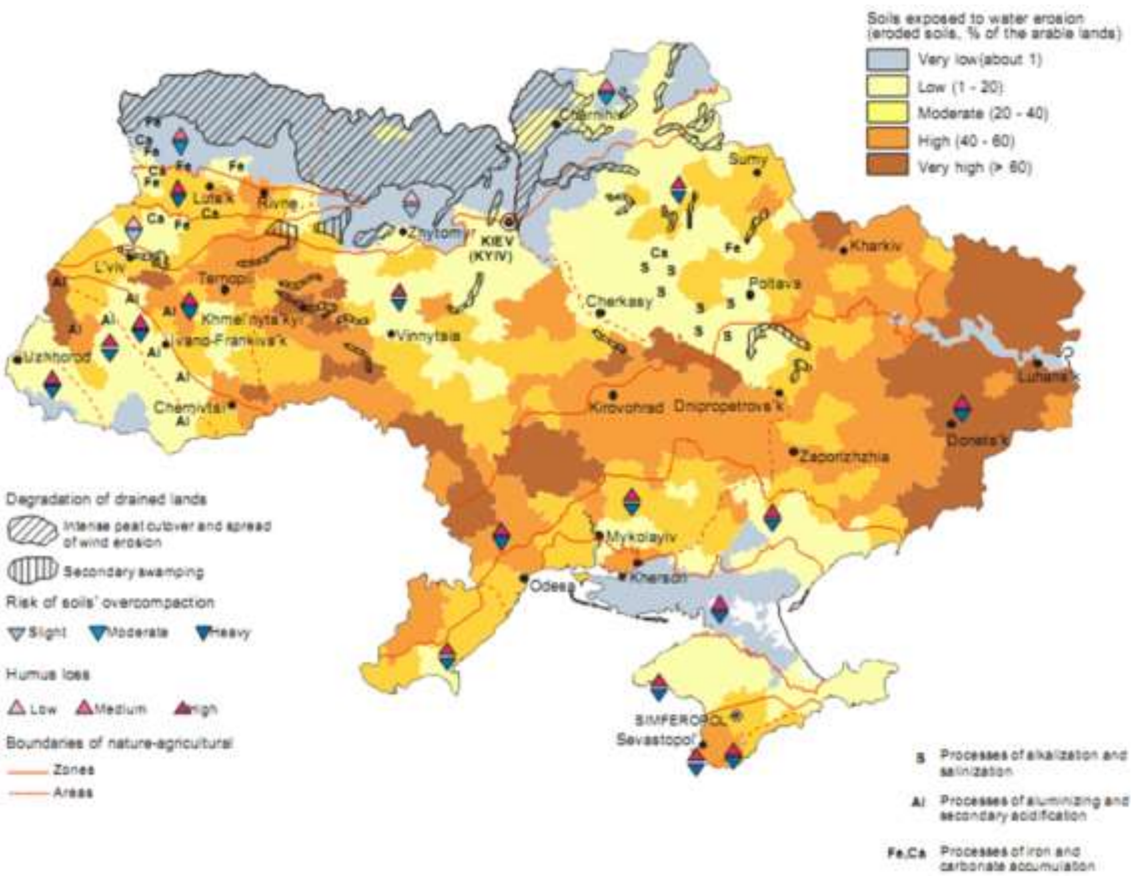


Figure 6.5 – Distribution of soil and land degradation processes in Ukraine[49]

Soil fertility is a complex characteristic and depends on several factors such as humus content and level of plant nutrients.

The ecological-agrochemical state of arable lands is regularly worsened as a result of deep ecological balance discrepancy in the ratio of the basic nutritious elements. Here, only 25 to 40 percent of *nutrients lost* harvest was accordingly returned. In such areas as Poltava, Kropyvnytskyi, Kyiv and Mykolayiv, each hectare of arable land lost on average 100 kg/hectare of NPK.

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[49] Source: http://www.fao.org/3/a-i3905e.pdf

Therefore, actual indicators are several times lower than those ecologically recommended, which has led to acceleration in agrochemical degradation and decline in soil fertility.

Therefore in the country’s farming during the last decades, flagrantly violated was the law of return, which are the natural-scientific basis of soil fertility recovery theory and a partial revelation of the general scientific law on preserving substances and energy.

Lack of compliance with this law has, in practice, led to *acidification* of the soil environment and the impoverishment of the arable soil layer’s fund of organic elements. It has also intensified the fast-progressing exhaustion of arable lands’ main nutritious elements.

Humus content is traditionally considered an integral soil fertility indicator.

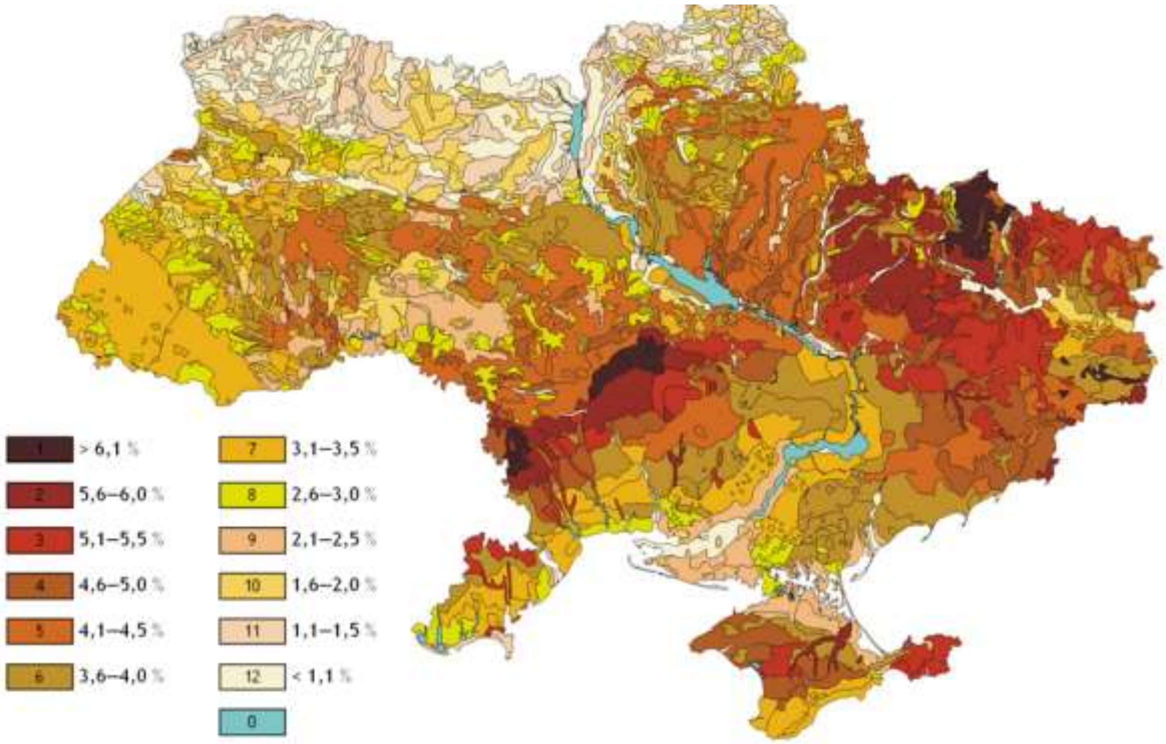

Figure 6.6 – Humus content in the arable layer of soils of Ukraine[50]

[50] Source: National Atlas of Ukraine, 2007

According to a recent soil-agrochemical monitoring cycle (2010-2015), the average humus content in Ukrainian soil amounted to 3.20%. In Polissia it was 2.18%; in forest and steppe, 3.27%; in the steppe, 3.45%.

These numbers are significantly lower than optimal humus content parameters, which are, respectively, 2.6%, 4.3%, and 4.3%.

Compared to a prior monitoring cycle, the average weighted humus content indicator decreased in Ukraine by an average of 0.007 %. Taking into account the significant decline in areas of cultivated crops where humus is actively mineralized, and also excluding low-humus, low-productive areas of land, the actual stocks of humus in Ukraine's soils have decreased even more.

Acidification is also a substantial problem. Vinnytsia and Kropyvnytskyi have large acreages of acidified land. Salinization is decreasing, as the use of irrigation has decreased substantially during the past years. Currently approximately 1.7 million hectares are identified as saline. Significant acreages of saline land are found in Kherson oblast.

Soil erosion is a significant problem which also decreases humus levels in soil. Ukraine's relief and climate and its very high proportion of arable land make erosion a widespread natural phenomenon.

About a third of the arable land is threatened by water and wind erosion. Poor land management practices, such as crop cultivation on steep slopes, excessive cutting of forests, shrubs and bushes, and overgrazing accelerate erosion. As a side effect, erosion is causing sedimentation in rivers, lakes and water reservoirs.

Erosion by wind is affecting over 13 million hectares of land. Zaporizhzhia, Luhansk and Kherson oblasts and the Autonomous Republic of Crimea are the most severely affected.

The Chernobyl accident led to significant *radioactive contamination* of the soil in Ukraine – more than 37 kBq/m^2 ^{137}Cs was deposited on 3.7 million hectares in Ukraine. Radioactive contamination is widespread on forest land as well as agricultural land mainly in the Zhytomyr, Rivne and Kyiv oblasts.

Fertilizer and pesticide use has decreased substantially, and therefore related contamination of soils has declined. But even now for example DDT residues were still found in most oblasts.

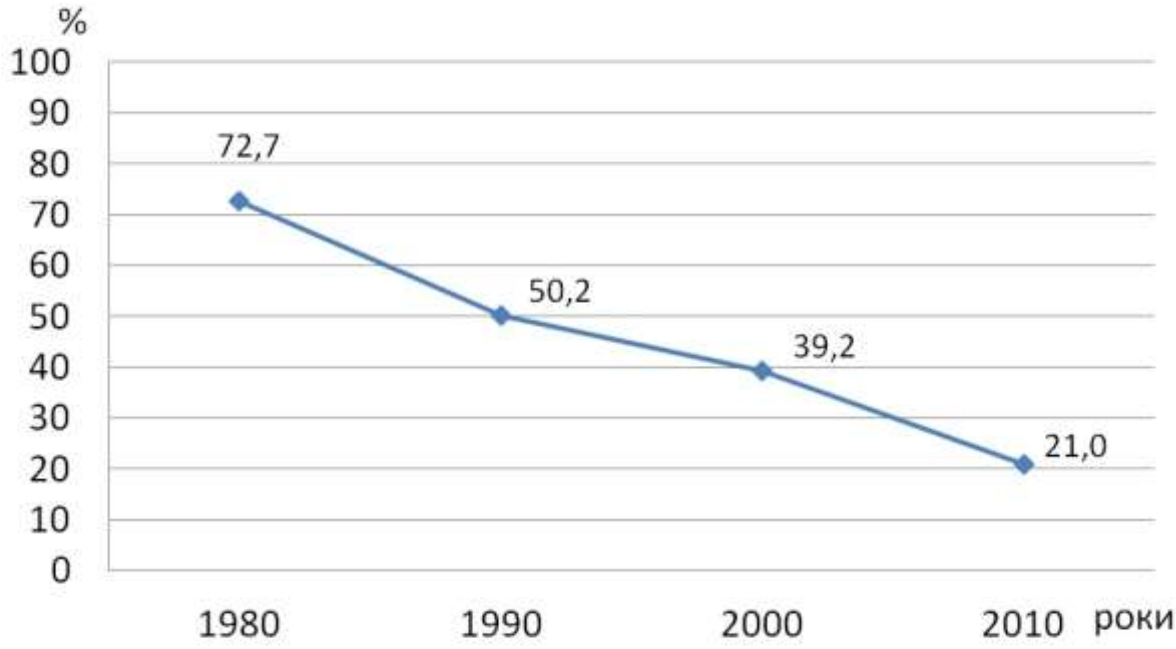

Figure 6.7 – Percentage of soil samples in which residues of 4,4-dichlorodiphenyltrichloroethane (DDT) and hexachlorocyclohexane (HCH) were detected[51]

A still unsolved problem is the contamination risk from more than 19,000 tons of often improperly stored obsolete pesticides.

There is contamination by heavy metals of soils in industrial areas such as Luhansk, Khmelnitskyi, Donetsk and Kyiv oblasts. A total of 5 million hectares are contaminated. 43 military sites are registered as potentially contaminated by toxic waste.

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[51] http://www.iogu.gov.ua/monitorynh-objektiv-dovkillya/vazhki-metaly/

Management of contaminated sites is generally weakly developed, with the exception of the areas contaminated by the Chernobyl accident.

According to various criteria, approximately 20 percent of Ukrainian lands are polluted.

Almost 23 thousand cases of landslides are registered yearly.

Abrasion is the cause of destruction of 60 percent of Azov and Black Sea coastlines and 41 percent of the Dnipro River reservoirs coastlines.

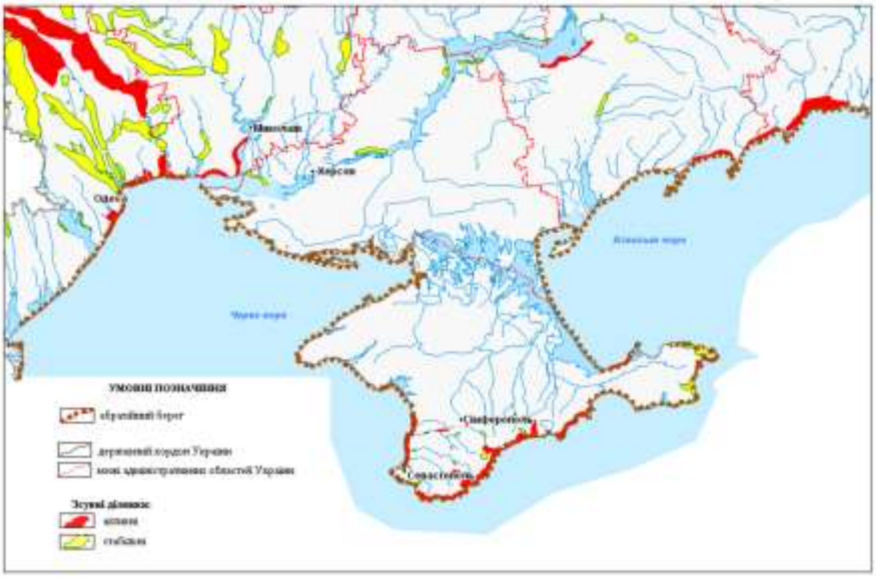


Figure 6.8 – Map of abrasive shores within Ukraine

Over 150 thousands hectares of land are disturbed by mining and other activities. The number of underground and surface karst phenomena amounts to 27 thousands hectares.

One of the main contributors to the overall negative environmental impact is the military conflict in eastern Ukraine.

The critical situation in the Donetsk and Luhansk regions, which covering an area of about 30 thousand square kilometer, is due to the fact that military activities take place in a large industrial region with a high concentration of potentially hazardous facilities, including coalmines, metallurgical, chemical and energy enterprises, storage facilities for industrial hazardous waste etc. Their destruction creates a danger to the life safety of the population and directly affects on all parameters of the environment.

A considerable part of the liberated territory of Donetsk and Luhansk oblasts with the total area of 7 thousand square kilometer is contaminated with explosive ordnance and requires measures of reconnaissance and humanitarian demining.

Substantial efforts, resources and time are required to recover damaged landscapes and restore the infrastructure of Donetsk and Luhansk oblasts.

The problems of land degradation and desertification aggravate due to the rapid climate change, accompanied by the increase of annual average temperatures, recurrence and intensity of extreme weather events including draughts, which occur every two or three years on 10 to 30 percent of country's territory and every 10-12 years on 50 to 70 percent of the total area.

Land degradation and desertification lead to biodiversity loss, deterioration or disappearance of water bodies, exacerbation of the water supply problems for population and businesses and, as a consequence, worsening of people's living conditions.

The poverty level of rural population, which traditionally depends, to a high degree, on the state of use and protection of land and other natural resources, during the recent 10 years is by 2-11 percent higher, than the country's average, which leads to overexploitation of the natural resources, their further exhaustion and degradation.

The problems are caused by:

- unjustifiably high level of economic (mainly agricultural) use of the territory and unbalanced proportion among land use types;

- violation of science-based principles of land use and basics of cropping including failure to follow the crop rotation plans, decreased volumes of applied agrochemicals, for the most part fertilizers, including organic fertilizers;

- unreasonable location of industrial and residential properties, particularly violation of the principle of locating the water demanding facilities taking into account availability of local water resources;

- insufficient area of lands designed for conservation of the environment, recreation, healing, historic and cultural purposes;

- unsatisfactory state of the land planning, particularly the development of documentation for conservation of lands and implementation of the planned measures, as well as insufficient provision of information for the State Land Cadastre system;

- insufficient functional maintenance of the state monitoring system of land and environment, of the draughts early warning and monitoring system as well as of the hydrometeorological observation network;

- insufficient level of government units' access to the material, technical and human resources as related to management of land and other natural resources;

- the necessity of wider use of modern technologies, including geoinformation technologies and remote sensing as well as innovative scientific findings in the area of making and implementing of managerial decisions;

- insufficient volume of financial resources allocated for solving of problems related to conservation and sustainable use of lands;

- insufficient coordination as well as departments' and sector's oriented measures related to combating land degradation and desertification without considering the multifactorality of the causes and consequences;

- unsatisfactory level of awareness among the population, lack of interest and capacity of the land owners and users, whose numbers exceeded 25 million, in ensuring the sustainable use of land and solving the problems of land degradation.

Improvement of soil monitoring

Generalizing international criteria and indicators of inexhaustible land use, fertility recovery and protecting the integrity and diversity of soil are the following:

• preventing water erosion development and deflation;

• ensuring appropriate phytosanitary soil conditions;

• preserving the ecological stability of soils;

• recovering soil fertility in agricultural ecosystems;

• optimizing the environment’s biosystem during agricultural use;

• maintaining the social and economic functions of lands;

• applying effective legal, economic and organizational mechanisms of ecologically sustainable land use.

The main environmental indicators in the field of soil contamination that are recommended according to the Guidelines (UNECE (the United Nations Economic Commission for Europe) Guidelines for the Application of Environmental Indicators in the Countries of Eastern Europe, Caucasus and Central Asia) and can be introduced in Ukraine are the following:

A). Indicators of the intensity of land resources usage.

A.1. Amount of land resources, thousand hectares: by main types of land areas, by agricultural lands, by types of owners and land users, by disturbed and eroded soils etc.

A.2. Volumes of mineral and organic fertilizers’ application: total amount (thousand tonnes), specific amount of applied fertilizers per unit of agricultural land (kg/ha).

A.3. Volume of pesticide application: total amount of pesticides used (thousand tonnes), specific share of applied pesticides per unit of agricultural land (kg/ha).

A.4. Data on the trends of indicators over the last 10 years (according to cl. A.1-A.3). (cl. - clause)

B). Soil quality indicators.

B.1. Share of samples not meeting the levels of maximum permissible soil contamination in the total number of samples, %: by chemical and bacterial contamination parameters.

B.2. Level of soil contamination with chemical substances, microgram/kg: cobalt, manganese, copper, nitrates, sulphates, mercury, lead, phosphorus, chrome, zinc, pesticides etc. (19 parameters in total).

B.3. Soil contamination index (hazard index):

$$I = \sum_{i=1}^{n} \frac{C_i}{MPC_i},$$

where C_i is a concentration of soil contaminating agents; MPC_i is maximum permissible concentration of contaminating agents in soil according to the national standards.

B.4. Data on the trends of indicators over the last 20 years (according to cl. B.1-B.3).

Comprehension questions

1. How many percent do arable lands occupy in developed European countries?

2. What does land degradation mean?

3. What degradation processes do arise from human activities?

1. soil erosion caused by wind and/or water;

2. deterioration of the properties of soil;

3. eutrophication of soil;

4. long-term loss of natural vegetation.

5. long-term loss of radionuclides.

4. How many categories have the land fund according to Land Code of Ukraine?

5. Are the lands of forest fund separate category according to Land Code?

6. The structure of agricultural lands is as follows:

1 78,0 %	*A pastures*
2 13,2 %	*B multi-annual plantings*
3 5.8%	*C fallow*
4 2.1%	*D arable land*
5 1%	*E hayfields*

7. Among different types of soil of Ukraine predominate:

1) regular chornozems;

2) northern chornozems;

3) typical chornozems;

4) podzolized chornozems;

5) chestnut chornozem.

8. The State Sanitary and Epidemiological Survey monitors:

1) state of soils at industrial sites of enterprises;

2) all categories of land fund;

3) state of soils on the territories with potential adverse impact on people's health;

4) irrigated and drained agricultural lands.

9. Fill the gap in the statement: "The State Service of Ukraine on Geodesy, Cartography and Cadaster carries out … and … land inventory".

10. What parameters are monitored by State institution "Soil Protection Institute of Ukraine"?

11. How frequently eco- agrochemical passportization of fields and land areas is carried out?

12. Degraded soils can be damaged in several ways:

1) by physical compaction and loss of aggregate stability;

2) in lower agricultural yields;

3) through soil acidification, salinity, erosion and desertification;

4) through higher production costs.

13. How can we describe depleted soils?

14. Give the short characteristic of the modern state of land-use in Ukraine. What are the prevailing problems of the present day land-use system in Ukraine?

15. What indicator is traditionally considered an integral soil fertility indicator?

1) level of plant nutrients;

2) ecological balance;

3) humus level;

4) overgrazing.

16. Soil fertility depends on several factors such as:

1) soil contamination;

2) humus content;

3) level of plant nutrients;

4) relief and climate.

17. What kind of soil contamination do you know?

18. Where is radioactive contamination widespread?

7. CLIMATE MONITORING

Weather and climate

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 and climate change

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 are studied by analysing ice cores, sea/lake sediments, shorelines movements, tree pollen, etc.

The knowledge of past climate can help in predicting the future. 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.

How do we know the Earth's climate is warming?

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 *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.

According to latest IPCC (the Intergovernmental Panel on Climate Change) Special Report[52] “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°C 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”.

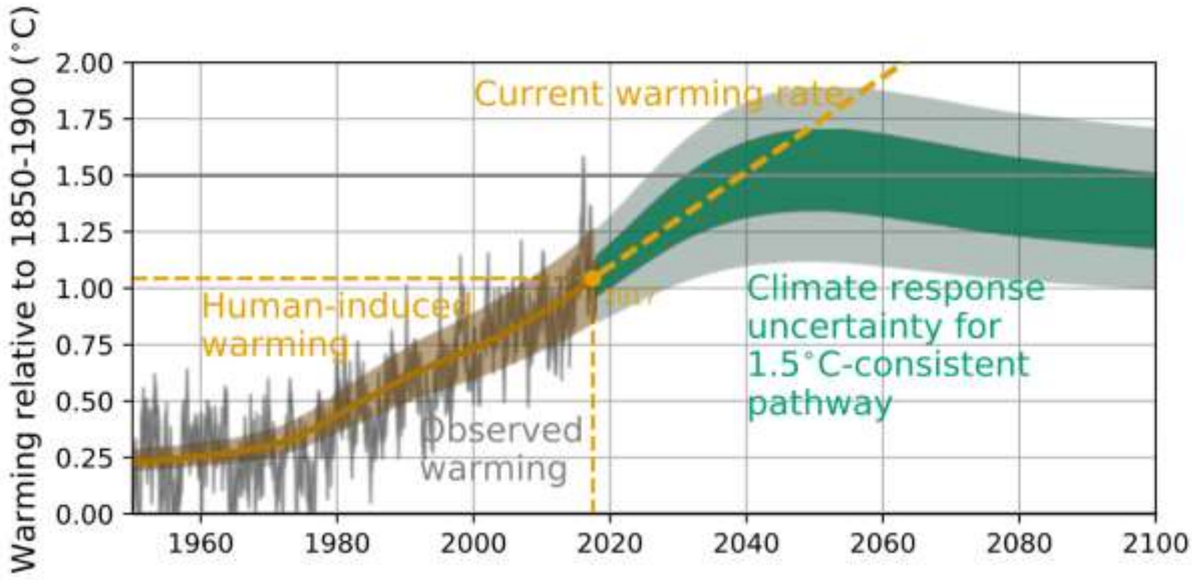


Figure 7.1 − IPCC Special Report on Global Warming of 1.5°C[53]

The global surface temperature is based on air temperature data over land and sea-surface temperatures observed from ships, buoys and satellites. Notably, the 20 warmest years have all occurred since 1981, and the 10 warmest have all occurred in the past 12 years.

Global mean *sea level* has been rising at an average rate of approximately 1.7 mm/year over the past 100 years (measured from tide gauge observations), which is significantly larger than the rate averaged over the last several thousand years. Much of the sea level rise to date is a result of increasing heat of the ocean causing it to expand. It is expected

[52] Source: https://www.ipcc.ch/sr15/
[53] Source: https://www.wcrp-climate.org/news/wcrp-news/1396-summary-for-policymakers-approved-ipcc-special-report-on-global-warming-of-1-5-c

that melting land ice (e.g. from Greenland and mountain glaciers) will play a more significant role in contributing to future sea level rise.

The data (Figure 7.2 below) have been averaged to account for long time scale variations in sea level. The average annual increase in sea level over this timeframe, depicted by the blue line, is 3.2 millimeters per year.

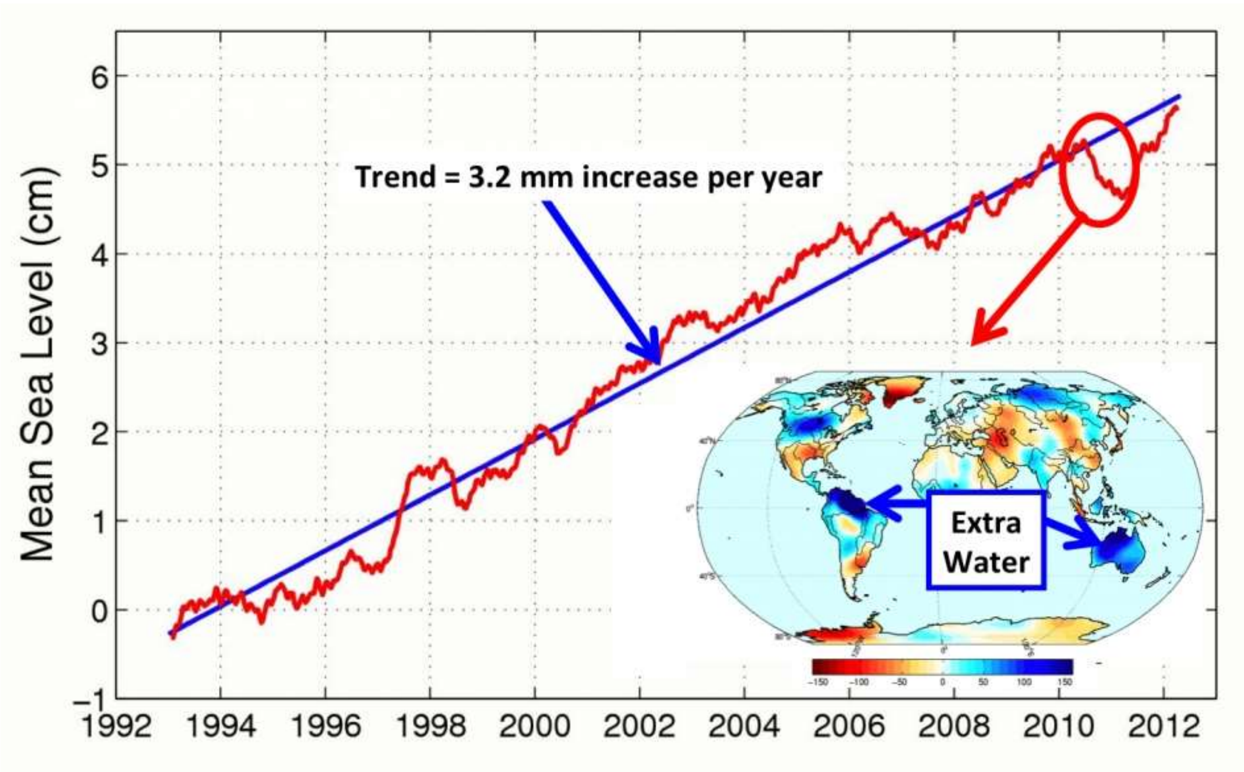


Figure 7.2 − changes in global mean sea level as measured by satellite altimetry (NASA/CNES Topex/Poseidon and Jason-1; and NASA/CNES/NOAA/EUMETSAT Jason-2) between 1992 to 2012[54]

The inset shows changes in Earth's water mass from the beginning of 2010 to mid-2011. Blue colors indicate an increase in water mass over the continents. A new NASA study shows that most of the sea level drop in 2010-11 [red circle] was related to the mass transport of water from the ocean to the continents (primarily Australia, northern South America and

[54] Source: https://www.nasa.gov/topics/earth/features/pia16294.html#.XZOB6qj7TIU

Southeast Asia [blue arrows]). While the ocean "lost" water, the continents experienced a gain because of increased rainfalls brought on by the 2010/11 La Nina. By mid-2012, global mean sea level had recovered by more than the 5 millimeters it dropped in 2010/11.

Northern Hemisphere Snow Cover is Retreating. Northern Hemisphere average annual snow cover has declined in recent decades. This pattern is consistent with warmer global temperatures. Some of the largest declines have been observed in the spring and summer months.

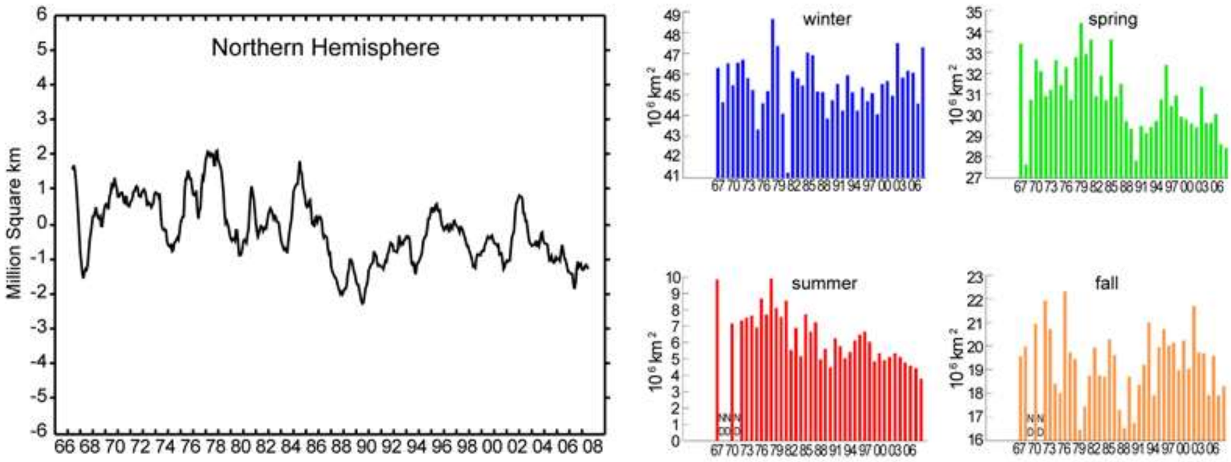


Figure 7.3 – Changes in snow cover of Northern Hemisphere

Glacier Volume is shrinking. Warming temperatures lead to the melting of glaciers and ice sheets. The total volume of glaciers on Earth is declining sharply. Glaciers have been retreating worldwide for at least the last century; the rate of retreat has increased in the past decade.

Only a few glaciers are actually advancing (in locations that were well below freezing, and where increased precipitation has outpaced melting).

The progressive disappearance of glaciers has implications not only for a rising global sea level, but also for water supplies in certain regions of Asia and South America.

A large body of evidence supports the conclusion that human activity is the primary driver of recent warming.

Global climate models clearly show the effect of human-induced changes on global temperatures (figure 7.4).

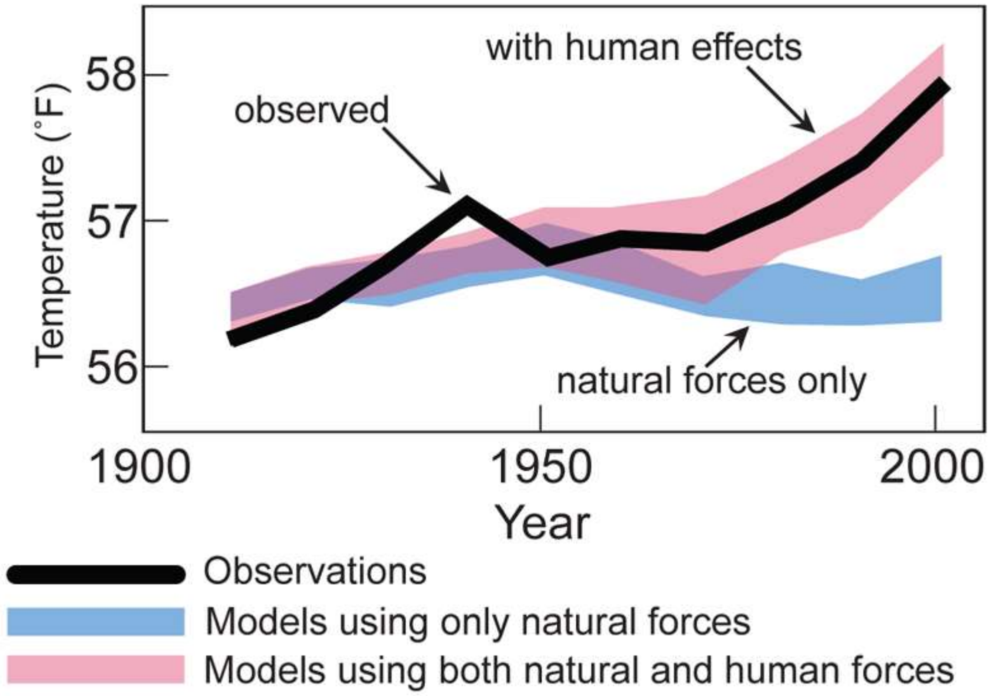


Figure 7.4 − The blue band shows how global temperatures would have changed due to natural forces only (without human influence). The pink band shows model projections of the effects of human and natural forces combined. The black line shows actual observed global average temperatures.

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.

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.

Figure 7.5 − Schematic showing a variety of observation systems[55]

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

[55] Source: Bureau of Meteorology, Australia

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.

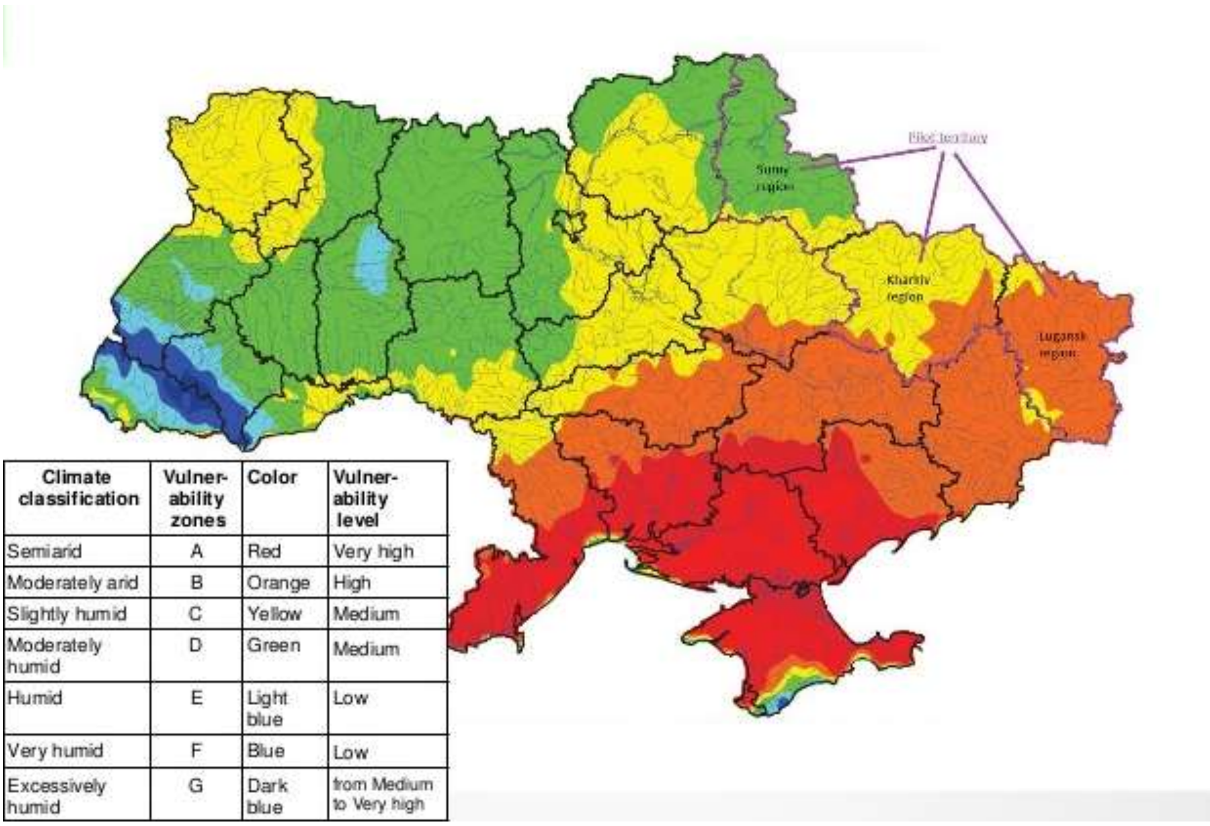
Thirdly, a climate observation should be associated – either directly or indirectly - with a set of metadata that will provide users with information, often implicitly, on how the observation should be interpreted and used. So, while climate observations serve multiple purposes beyond specific climate needs, we must ensure that they retain, and acquire, particular characteristics that serve a range of climate needs.

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.



Climate classification	Vulner-ability zones	Color	Vulner-ability level
Semiarid	A	Red	Very high
Moderately arid	B	Orange	High
Slightly humid	C	Yellow	Medium
Moderately humid	D	Green	Medium
Humid	E	Light blue	Low
Very humid	F	Blue	Low
Excessively humid	G	Dark blue	from Medium to Very high

Figure 7.5 – Vulnerability zones according climate types[56]

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.

However, in the view of most researchers, current climate changes are caused by the greenhouse effect. In its turn, the greenhouse effect is the result of excessive man-made CO_2 emissions into the atmosphere. Ukrainian scientists also guess that the most of global average warming over the past 50 years is likely due to anthropogenic GHG increases. Actually, global warming is a result of a combination of climate changes natural cycles with anthropogenic effects on climate, including GHG emission.

[56] Source: Third IDMP CEE workshop: Assessment of drought impact on forest ecosystems by Galia Bardarska

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.

The longest period of warming in Ukraine over more than 120 years of instrumental observations happened at the end of the 20th and beginning of the 21st centuries.

The average high air temperature for the year rose more in the western regions (up to 0.9 C), in the central regions, in the north, the south it is somewhat smaller (up to 0.6°C). The average minimum temperature also increased in the west by up to 0.5-0.7°C, in the east – by up to 0.4 – 0.5° C.

On average, between 1988 and 2007, the air temperature increased by 1.1-2.0°C, and according to projections a gradual increase will continue in the future. 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.

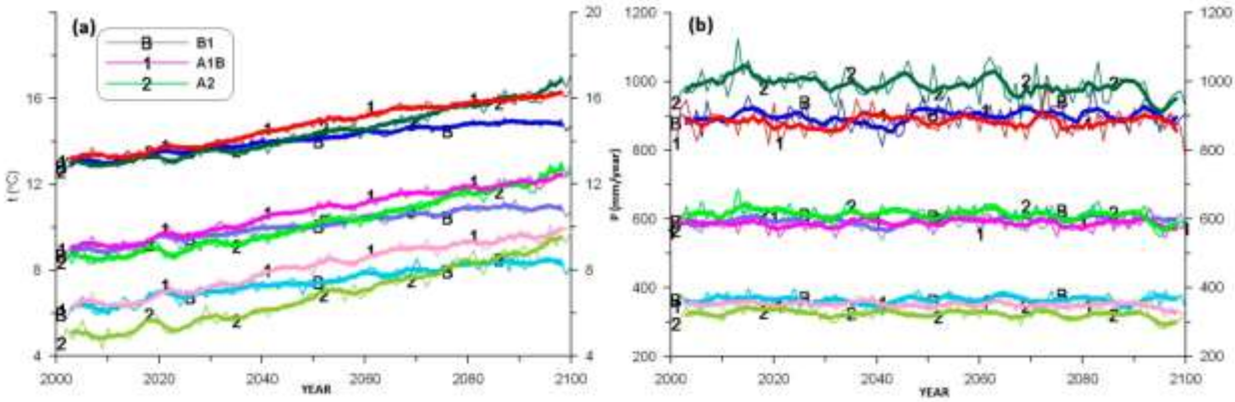


Figure 7.6 – Projections of minimal, average and maximal annual temperature (a); and amount of precipitation (b) in Ukraine for 21st century estimated by 10 GCMs for the three IPCC SRES Scenarios B1, A2 and A1B (bold lines are moving five-year averages)[57]

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 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 7.7).

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.

[57] Source: Anatoly Shvidenko, Igor Buksha,Svitlana Krakovska and Petro Lakyda. Vulnerability of Ukrainian Forests to Climate Change. https://www.mdpi.com/2071-1050/9/7/1152/htm

The repetitiveness and length of the summer heat periods (with air temperature above 25°C or 30°C) rose.

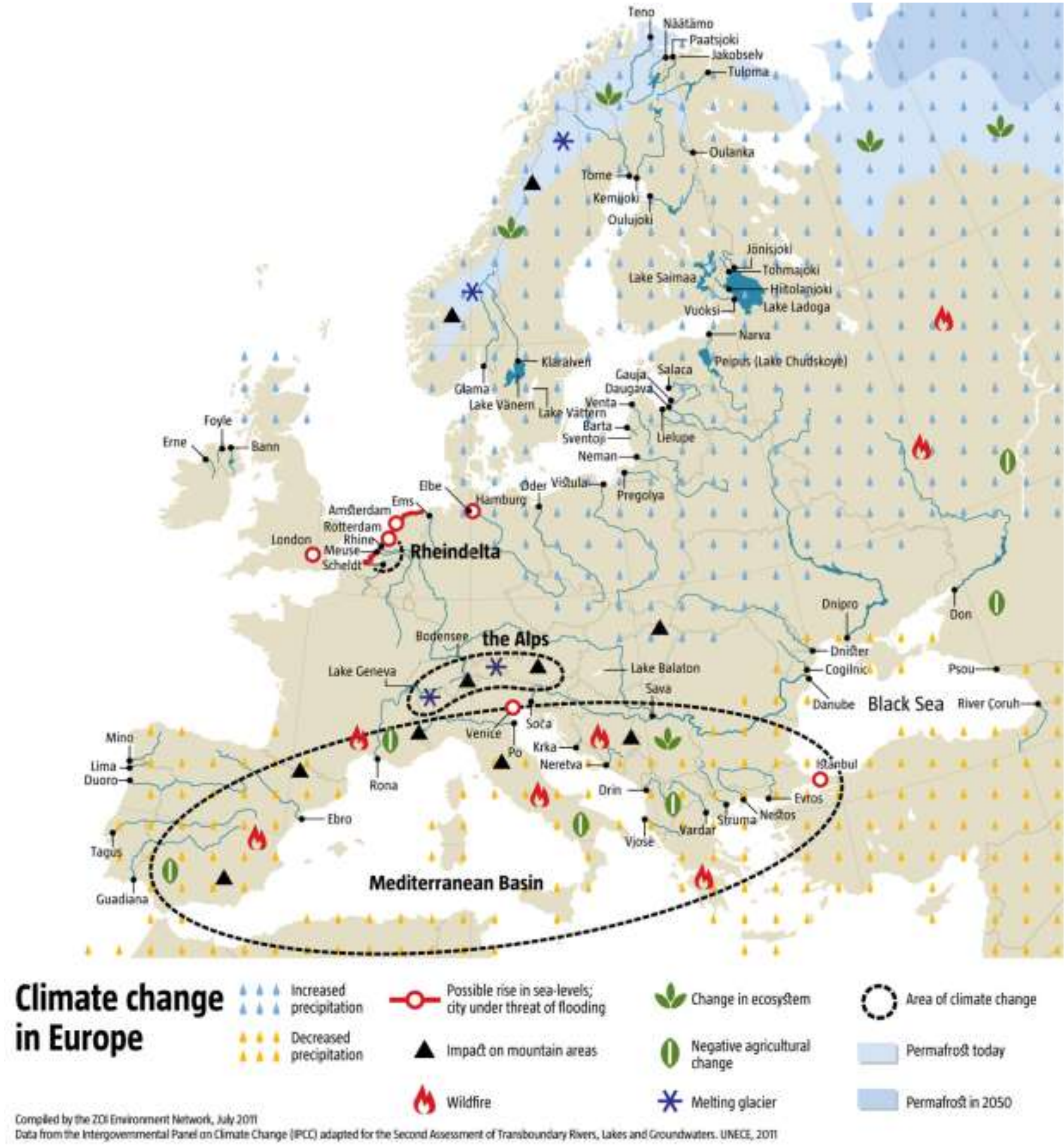


Figure 7.7 – Climate change in Europe[58] *UNECE 2011 ZOI Environmental network*

[58] Compiled by the ZOI Environmental network, July 2011

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.

Greenhouse gas (GHG) emissions in Ukraine

At international climate negotiations Ukraine is classed as an “industrial country with its economy in transition” and thus agrees to reduce its emissions by 20% by 2020 and by 50% by 2050, taking 1990 as a baseline. And as a country with a transition economy it is allowed to engage in international financial mechanisms to reduce emissions.

GHG emissions in Ukraine in 2017[59] amounted to 320.95 Mt CO_2-eq. excluding the sector Land Use, Land-Use Change and Forestry (hereinafter - LULUCF), what is 66.0 % lower than in the base 1990 level. With the LULUCF sector, emissions in 2017 amounted to 310.71 Mt CO_2-eq. and decreased in comparison with base year by 64.9 %.

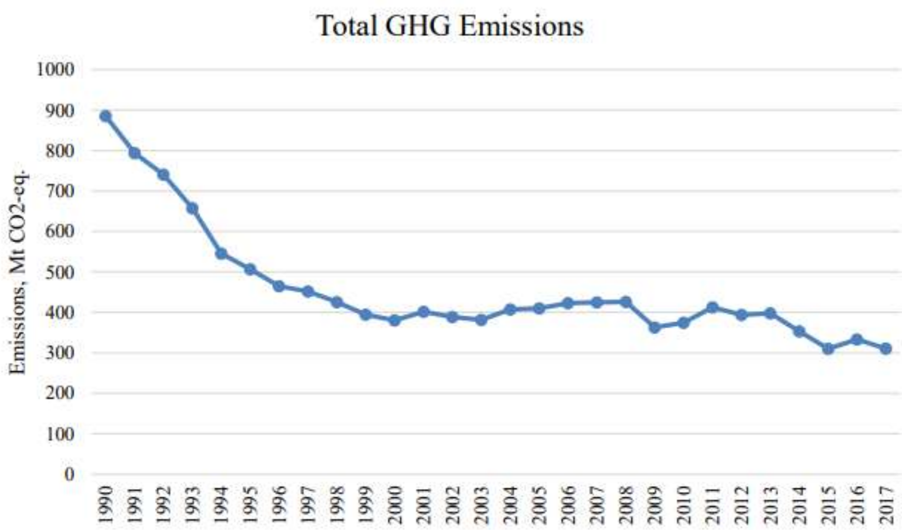


Figure 7.8 − GHG emissions in Ukraine (including LULUCF), 1990-2017, Mt CO_2-eq

[59] Source: https://menr.gov.ua/files/docs/Zmina_klimaty/kadastr2017/Ukraine_NIR_2019_draft.pdf

The largest share of GHG emissions in the base year is carbon dioxide - 73.0 % with LULUCF. Methane emissions in 1990 were 21.1 %, and those of nitrous oxide - 5.9 %. In 2017, the proportion somewhat changed - 69.7 %, 19.8 %, and 10.2 % for carbon dioxide, methane, and nitrous oxide, respectively.

The largest GHG emissions in Ukraine take place in the Energy sector. About 80% of emissions in this sector account for emissions in the Fuel Combustion category. The GHG emission structure is shown in Figure 7.9.

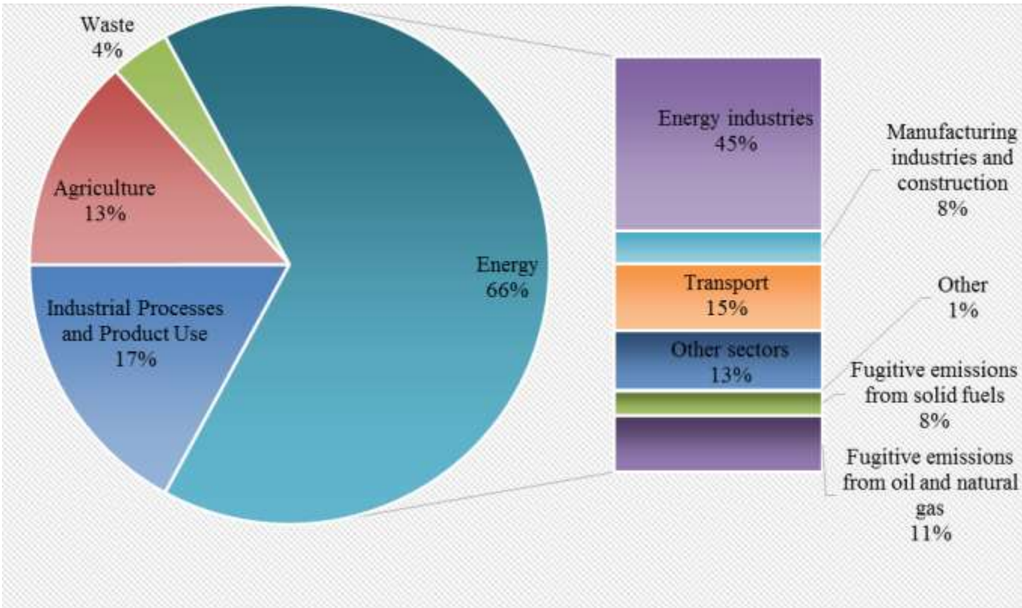


Figure 7.9 – The GHG emission structure in 2017

Possible impact of climate change on Ukraine

All transformations of climate have been affecting various areas of life in Ukraine for a while now. Their effect is particularly visible in agriculture, which accounts for over 8% of Ukraine’s GDP.

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.

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. As a result, the area under rapeseed crops being grown instead of wheat and vegetables is increasing significantly, particularly in Crimea and the Odesa, Mykolayiv and Kherson Oblasts.

In 2008, Ukraine was the top European country for area planted with rapeseed which, along with sunflower, covered 1/5 of the total area under crops. Experts have already categorized rapeseed as an environmental weapon against Ukraine, exhausting the fields and turning chornozem, the fertile black soil, into the lands that can no longer be farmed.

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.

Comprehension questions

1. What is climate? Give the short definition.

2. Past climate are studied by analyzing:

1) ice cores;

2) sea currents;

3) sea/lake sediments;

4) shorelines movements;

5) 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. The signs of global climate change:

1 average temperature	*A is rising*
2 sea level	*B is retreating*
3 land ice	*C is increasing*
4 Northern Hemisphere snow cover	*D is shrinking*
5 glacier volume	*E is melting*

6. Why the climate observations are so important?

7. Do climate observations need to account for the full range of elements that describe the climate system?

8. Fill in omitted word: "the climate of Ukraine is … continental".

9. The greenhouse effect is the result of:

1) excessive man-made dust emissions into the atmosphere;

2) excessive man-made CO_2 *emissions into the atmosphere;*

3) solar particle increase;

4) solar radiation increase.

10. Is climate of Ukraine involved or uninvolved in global climate system changes?

11. What are the signs of climate change that are apparent in Ukraine?

12. What trend can we see in average air temperature in Ukraine?

13. The biggest contribution to total GHG emissions in Ukraine is:

1) agriculture;

2) waste;

3) energy;

4) industrial processes.

14. 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

8. MONITORING OF BIODIVERSITY (BIOMONITORING)[60]

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.

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.

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.

"Goods and Services" provided by ecosystems include:

- Provision of food, fuel and fibre;

[60] In this chapter were used materials from: Kostiushyn, V.A., Gubar, S.I., Domashlinets, V.G. Strategy for developing the monitoring of biodiversity in Ukraine. — Kyiv, 2009. http://uncg.org.ua/wp-content/strategy.pdf

- Provision of shelter and building materials;
- Purification of air and water;
- Detoxification and decomposition of wastes;
- Stabilization and moderation of the Earth's climate;
- Moderation of floods, droughts, temperature extremes and the forces of wind;
- Generation and renewal of soil fertility, including nutrient cycling;
- Pollination of plants, including many crops;
- Control of pests and diseases;
- Maintenance of genetic resources as key inputs to crop varieties and livestock breeds, medicines, and other products;
- Cultural and aesthetic benefits;
- Ability to adapt to change.

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.

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 (see Table 8.1), 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.

Ecological network (Econet) is the only territorial system, which is formed to improve conditions for the creation and restoration of the environment, enhancing natural resources in Ukraine, preservation of landscape and biodiversity, places of settlement and growth of species of flora and fauna, genetic stock, migration routes of animals through a combination territories and objects of natural reserve fund and other areas that are of particular value to environmental protection.

Table 8.1 − Protected Areas of Ukraine, 2017[61]

PA Category Name (Eng/Ukr)	#	Area, ha	Percentage of PA Network	Principle Purposes	IUCN Category
National Nature Preserve/ Natsionalny Pryrodnyy Zapovednik	19	206,631	4.7	Strict protection, scientific research, education	I
Biosphere Preserve/ Biosphernyy Zapovednik	5	479,111	11.09	Strict protection, scientific research, education	I
National Nature Park/ Natsionalnyy Pryrodnyy Park	49	1,311,638	30.37	Conservation, nature recreation, science, education	II
Regional Landscape Park/ Regionalnyy Landshaftnyy Park	81	786,025	18.2	Conservation, nature recreation, education	V
Nature Reserve/Zakaznik	3,167	1,389,674	32.18	Conservation, restoration of natural habitats & species	IV, VI
Protected Site/ Zapovidne Urochyshe	812	97,860	2.27	Protect specific natural feature	III
Nature Monument/Pamyatnyk Pryrody	3441	29,769	0.68	Protect specific natural feature	III
Other categories, not natural	671	17,516	0.4	Zoos, botanic gardens, parks	N/A
Total	**8,245**	4,318,224	**100.0**		

The idea of creating the Pan-European Ecological Network (European Ecological Network or EECONET) as a system of interconnected valuable from an environmental point of view of natural areas was proposed by a group of Dutch researchers in 1993 at the International Conference "Protection of the natural heritage of Europe through the establishment of the European ecological network" (Maastricht,

[61] Source: MENR, State Department for Protected Areas, January 2017

the Netherlands). It seamlessly integrates into the idea of sustainable development and is one of the powerful tools of expression.

According to most existing views, the main goal of creating an ecological network can be considered a general improvement of the environment and the human condition, sustainability existence of the biosphere by eliminating anthropogenic fragmentation biogeocenotic cover, established in the historical development of society, the creation of its continuity and functional integrity and strengthening, due to this, the ability to heal itself.

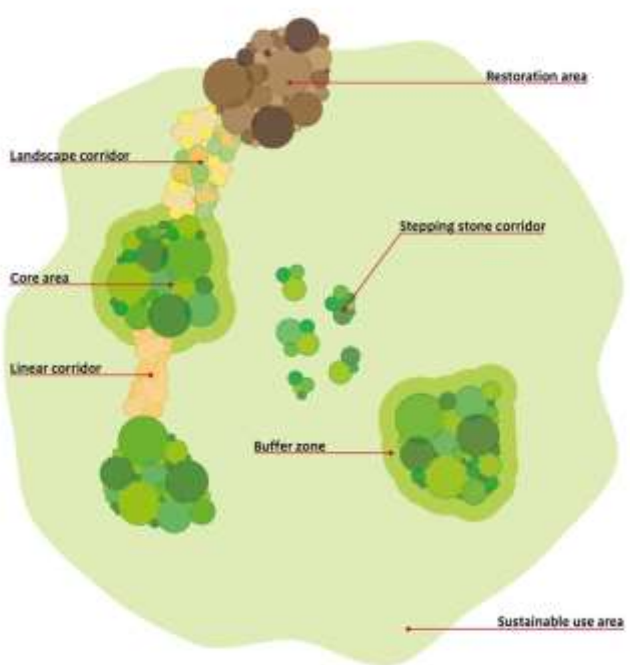


Figure 8.1 − Ecological network components mentioned in 'Making Space for Nature' report (Lawton and others 2010)

But the application of these methods for protecting and enhancing biodiversity require the evaluation of what we have achieved, were our efforts successful. The grounds for such an assessment are set by monitoring biological objects. According to Ukrainian legislation this is an integral part of the monitoring of the environment.

The monitoring of biological diversity is a system of long-term, standardized collecting, accumulation and analysis of information about biological objects.

Such monitoring establishes the basis for nature conservation policies and assessment of the efficiency of nature conservation measures, as well as for the sustainable use of natural resources. In these terms the monitoring of biological diversity integrates into international agreements and the national legislation in Ukraine directed towards nature conservation.

Among international agreements concerning biodiversity conservation (and to which Ukraine is a contracting party) the following should be mentioned:

- the Convention on Biological Diversity (CBD),
- the Convention on Migratory Species (CMS),
- the Convention on Wetlands of International Importance, especially as Waterfowl Habitat (Ramsar Convention),
- the European Landscape Convention

An important tool for biodiversity conservation is the Pan-European Biological and Landscape Diversity Strategy (PEBLDS), which is the mechanism for implementing the CBD in Europe.

According to Ukrainian legislation, biodiversity monitoring is a constituent of the monitoring of the environment of the country.

The law 'On animal wildlife' (2001) touches on issues concerning the organization and conducting of the monitoring of animals in the wild.

The law 'On plant wildlife' (1999) assign to corresponding governmental bodies the account of valuable objects of plant wildlife and maintenance of a relevant cadastre, regulation of the use of wild plant resources, and issues concerning the monitoring and protection of plant wildlife.

The law 'On the Red Data Book of Ukraine' (2002) aims to preserve and replenish rare and threatened species of plants and animals.

The law 'On the state programme for developing the national ecological network in Ukraine for the years 2000–2015' (2000) and the law 'On the ecological network of Ukraine' (2004) envisage the monitoring of the status of the ecological network, which to a large extent is monitoring biodiversity.

The 'Forest Code of Ukraine' (2006) appoints the monitoring of the status of forests to the central executive authorities responsible for forestry.

In addition, the monitoring of biodiversity in Ukraine is subjected to regulations set by the Cabinet of Ministers of Ukraine: 'On the order for maintaining the national cadastre for animal wildlife' (1994) and 'On the approval of the order for maintaining the national accounting and cadastre of plant wildlife' (2006). These cadastres are considered as a systematized assemblage of information concerning the geographical distribution of species (groups of species), their numbers and status, features characterizing their habitat and current use, other information.

A great drawback of the current environmental protection legislation is the need to elaborate and adopt various by-laws. The lack of these documents or their shortcomings hampers the practical implementation of the existing laws and quite often this is the real cause for failure.

An analysis of the current state of biodiversity monitoring in Ukraine shows that on the whole such monitoring here is in its primary stages of development, although certain orientations in this field have been fairly well developed and have a long history. Amongst these the 'Chronicles of Nature' programme should be mentioned. This programme has been maintained for decades by authorized staff of protected areas.

Game animal counts regularly carried out by managers may to a certain extent be considered a form of monitoring programme. The information collected contributes to the national statistical report.

Besides monitoring programmes involving certain animal and plant groups and financially supported by the State, there are programmes conducted by volunteers or programmes receiving support from international funding agencies (IWC (International Waterfowl Census), IBA (Important Birds Area), White Stork, Aquatic Warbler, etc.).

Out of 95 biodiversity monitoring programmes in Ukraine about a third of them are related to phytodiversity; others are devoted to monitoring animal wildlife. The monitoring of phytodiversity covers several issues:

- investigations into the population status of particular species,
- monitoring vegetation (geobotanical studies),
- forestry research,
- monitoring and research of wild plant
- resources and monitoring the flora of particular regions.

Most of the programmes focus on populations.

Creating a system for monitoring biodiversity in Ukraine will take a lot of time. Even if we take into account monitoring species we have to deal with around 70 thousand species of fungi, plants and animals in the country. Including other aspects of biodiversity − **gene pools, populations, communities and ecosystems** − makes the task almost impossible. Under these circumstances there is a need to distinguish monitoring priorities and implement the national monitoring system step by step.

Objects for the first stage of the biomonitoring development (lasting at least 10 years) should be priority biological species, plant communities and ecosystems:

a) species:

• species listed in the Red Data Book of Ukraine, international 'red' lists (European List, IUCN - International Union for Conservation of Nature etc.) and in annexes to international agreements to which Ukraine is a contracting party (Bonn Convention, Berne Convention, EUROBATS etc.);

• species subjected to legal and illegal commercial use; these are commercial fish species, game animals, medicinal plants and animals, some other groups of species;

• species indicating general changes in the biodiversity of the country (for instance, common bird species in farmland areas, forest ecosystems, etc.);

• alien species, particularly those of a hazardous character.

b) plant communities:

Priority communities are those listed in the Green Data Book of Ukraine.

c) ecosystems:

Environmental issues in Ukraine and obligations assumed under certain international agreements point out those top-priority ecosystems should be steppe, wetland and certain kinds of forest ecosystems.

Steppe ecosystems have almost entirely disappeared due to agriculture, wetlands have been reduced by millions of hectares due to drainage, or have been depleted through unwise economic use and heavy recreational pressure, most forest ecosystems are artificial and only a minor portion of them are of native origin (for instance, virgin forests in the Carpathians).

Taking into account the European vector in the development of Ukraine as a nation, the national system for monitoring biological diversity should be harmonized with the existing European initiatives and approaches towards creating a European system for monitoring, including the set of bioindicators.

The development of an efficient monitoring system is impossible without taking advantage of modern methods of field investigation, accumulation and analysis of data, and exchange of information. The development of the national system of biomonitoring must use widely as possible GIS technologies, remote sensing, relational databases, web technologies and other novel possibilities.

European indicators of biological diversity

During the past decades various international and national organizations have been developing sets of indicators to measure and assess the status of “biological resources” *("Biological resources" includes genetic resources, organisms or parts thereof, populations, or any other biotic component of ecosystems with actual or potential use or value for humanity (UN Convention on Biological Diversity, Art 2)* from both quantitative and qualitative points of view with particular attention given to biological diversity (biodiversity).

According to UN Convention on Biological Diversity, "Biological diversity" means the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems.

The European Environment Agency (EEA) has developed a set of **26 indicators SEBI** (Streamlining European 2010 Biodiversity Indicators). The Pan-European SEBI initiative was launched in 2005. Its aim was to develop a European set of biodiversity indicators – based on those already existing, plus new indicators as necessary. From its inception SEBI linked the global framework set by the Convention on Biological Diversity with regional and national indicator initiatives.

One of the principal working methods of SEBI is to build on current monitoring and available data to avoid duplication of efforts and to complement and not replace other activities to describe, model and understand biodiversity and the pressures upon it. This means that a large part of the 26 SEBI indicators originates from various external ongoing programmes and processes at the national, European and global levels.

Table 8.2 − Streamlining European 2010 Biodiversity Indicators[62]

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 socio-economic 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

[62] Source: https://biodiversity.europa.eu/topics/sebi-indicators

From the very beginning, the proposed set of indicators has been seen holistically, stressing mutual relationships among the individual indicators and their power to deal with uncertainty. Special attention was paid to the task to produce user-friendly indicators. Furthermore SEBI aimed at improving the provision of information to policy-makers along the DPSIR chain (Drivers, Pressures, State, Impact, Responses) in support of policy effectiveness.

Indicators for the Strategic Plan for Biodiversity 2011–2020 and the Aichi Biodiversity Targets (CBD). The Strategic Plan for Biodiversity 2011-2020 – A ten-year framework for action by all countries and stakeholders to save biodiversity and enhance its benefits for people. The Strategic Plan is comprised of a shared vision, a mission, strategic goals and 20 ambitious yet achievable targets, collectively known as the Aichi Targets. The Strategic Plan serves as a flexible framework for the establishment of national and regional targets and it promotes the coherent and effective implementation of the three objectives of the Convention on Biological Diversity.

The Ad Hoc Technical Expert Group on Indicators for the Strategic Plan for Biodiversity 2011-2020 identified three categories of operational indicators (see Annex B). Indicators which are ready for use at the global level are denoted by the letter (A). Indicators which could be used at the global level but which require further development to be ready for use are denoted by the letter (B).

Additional indicators for consideration for use at the national or other sub-global level are denoted by the letter (C). The set of (A) and (B) indicators are those which should be used to assess progress at the global level, while the (C) indicators are illustrative of some of the additional indicators available to Parties to use at the national level, according to their national priorities and circumstances.

The year 2020 marks the end-date of the Strategic Plan for Biodiversity 2011-2020 and the 20 global biodiversity targets (Aichi Targets).

In 2020 the Convention on Biological Diversity will adopt a post-2020 global biodiversity framework as a stepping stone towards the 2050 Vision of 'Living in harmony with nature'.

The vision of the Strategic Plan for Biodiversity 2011-2020, with its Aichi Targets was a world of "Living in harmony with nature" where "By 2050, biodiversity is valued, conserved, restored and wisely used, maintaining ecosystem services, sustaining a healthy planet and delivering benefits essential for all people.“

Comprehension questions

1. Describe the concept of biological diversity. What does biodiversity include?

2. "Goods and Services" provided by ecosystems include (choose the correct answers):

1) Provision of food, fuel and fibre;

2) Control of industrial accident hazard;

3) Purification of air and water;

4) Control of pests and diseases;

5) Ability to adapt to change.

3. What is the monitoring of biological diversity?

4. Please specify a few legislative acts in the field of biodiversity monitoring in Ukraine.

5. When was the last edition of Red Data Book of Ukraine developed?

6. The “Chronicles of Nature” programme has been maintained by: (choose the correct answer):

1) central executive authorities

2) authorized staff of protected areas

3) volunteers with supporting from international funding agencies

7. What objects should be priority for the first stage of the biomonitoring development?

8. Among the priority biological species that should be the objects for the first stage of the biomonitoring are alien species, aren't they?

9. Priority communities for biomonitoring are those listed in:

1) the Red Data Book of Ukraine;

2) the Cadastre of plant wildlife;

3) the Green Data Book of Ukraine.

10. Top-priority ecosystems for biomonitoring: (choose the correct correspondences)

1 forest	*A have almost entirely disappeared due to agriculture*
2 steppe	*B have been reduced due to drainage*
3 wetland	*C are artificial*

11. How many categories of indicators were identified on the Strategic Plan for Biodiversity 2011-2020?

GLOSSARY

Air pollutant – (1) Substance in air that could, at high enough concentrations, harm human beings, animals, vegetation or material. Air pollutants may thus include forms of matter of almost any natural or artificial composition capable of being airborne. They may consist of solid particles, liquid droplets or gases, or combinations of these forms. (2) Any pollutant agent or combination of such agents, including any physical, chemical, biological, radioactive substance or matter which is emitted into or otherwise enters the ambient air and can, in high enough concentrations, harm humans, animals, vegetation or material.

Air pollution: Introduction as a result of human activities, directly or indirectly, of substances or energy into the air that are likely to have harmful effects on human health, the environment as a whole and property.

Air quality: The degree to which air is polluted; the type and maximum concentration of man-produced pollutants that should be permitted in the atmosphere.

Aircraft - Any structure, machine, or contrivance, especially a vehicle, designed to be supported by the air, either by the dynamic action of the air upon the surfaces of the structure or object or by its own buoyancy.

Alien species - a species that has been transported by human activities, intentional or accidental, into a region where it does not naturally occur (Also known as an exotic or introduced species).

Ammonia: In its pure state and under usual environmental conditions, ammonia exists as a colorless, pungent-smelling gas. It is alkaline, caustic and an irritant. Under high pressure, ammonia can be stored as a liquid. It is highly soluble in water. It reacts with acids to form ammonium salts.

Aniline an organic base used to make dyes, drugs, explosives, plastics, and photographic and rubber chemicals.

Arable land. Land under temporary crops, temporary meadows for mowing or pasture, land under market and kitchen gardens and land temporarily fallow (less than five years).

Assessment − Formal efforts to assemble selected knowledge with a view toward making it publicly available in a form intended to be useful for decision-making (Mitchell and others 2006). By 'formal' the definition requires that the assessment should be sufficiently organized to identify components such as products, participants and issuing authority. 'Selected knowledge' indicates that the content has a defined scope or purpose and that not all information compiled and contributed is necessarily included in the report. The sources of knowledge may vary. While results from research and scientific knowledge predominate, assessments can supplement this with local, traditional or indigenous knowledge. Further, assessments can evaluate both existing information and research conducted expressly for the purpose. The definition also notes the importance of ensuring that assessments are in the public domain, as they may influence public debate and different types of decision-makers.

Benz (a) pyrene: A five-ring aromatic hydrocarbon found in coal tar, in cigarette smoke, and as a product of incomplete combustion.

Benzene: Benzene is a colorless, volatile and flammable liquid with a distinctive odour. It evaporates into the air very quickly and is a dangerous fire hazard when exposed to heat or flame. It is only slightly soluble in water, but will mix with most organic solvents. Benzene is one of the simplest organic chemicals known as 'aromatic' compounds - their carbon atoms are arranged in rings rather than chains.

Biodiversity: 1) Genetic diversity: the variation between individuals and between populations within a species; species diversity: the different types of plants, animals and other life forms within a region; community or ecosystem diversity: the variety of habitats found within an area (grassland, marsh, and woodland for instance. 2) An umbrella term to describe collectively the variety and variability of nature. It encompasses three basic levels of organization in living systems: the genetic, species, and ecosystem levels. Plant and animal species are the most commonly recognized units of biological diversity, thus public concern has been mainly devoted to conserving species diversity.

Biological contamination − The presence in the environment of living organisms or agents derived by viruses, bacteria, fungi, and mammal and bird antigens that can cause many health effects.

Biomonitoring: (1) Analysis of the amounts of potentially toxic substances or their metabolites present in body tissues and fluids as a means of assessing exposure to these substances and aiding timely action to prevent adverse effects. (2) The term is also used for an assessment of the biological status of populations and bio-communities at risk in order to protect them and to have an early warning of possible hazards to human or environmental health.

BOD: Biochemical oxygen demand. An approximate measure of the amount of biochemically degradable organic matter in water bodies. It is defined as the amount of oxygen required for the aerobic microorganisms present in a water sample to oxidise the organic matter to a stable form. BOD is often used as a measure of efficiency of treatment of urban wastewater and the permit for wastewater treatment plants often establishes the BOD of discharges. The BOD is rather time consuming to measure, and can be estimated from the chemical oxygen demand.

BOD/COD: A rough measure of the ability of bacteria to digest organic matter present, the so-called biodegradability. In natural water the BOD/COD ratio is approximately 0.7-0.8. If other organic or inorganic materials are present, the BOD/COD ratio decreases.

Body of surface water: A discrete and significant element of surface water such as a lake, reservoir, a stream, river or canal, part of a stream, river or canal, a transitional water or a stretch of coastal water.

Built-up land: Land under houses, roads, mines and quarries and any other facilities, including their auxiliary spaces, deliberately installed for the pursuit of human activities. Included area also certain types of open land (non-built-up land), which are closely related to these activities, such as waste tips, derelict land in built-up areas, junk yards, city parks and gardens, etc. Land occupied by scattered farm buildings, yards and their annexes are excluded. Land under closed villages or similar rural localities is included.

Carbon dioxide: A colourless gas with a faint tingling smell and taste. Atmospheric carbon dioxide is the source of carbon for plants. As carbon dioxide is heavier than air and does not support combustion, it is used in fire extinguishers. It is a normal constituent of the atmosphere, relatively innocuous in itself but playing an important role in the greenhouse effect. It is produced during the combustion of fossil fuels when the carbon content of the fuels reacts with the oxygen during combustion. It is also produced when living organisms respire. It is essential for plant nutrition and in the ocean phytoplankton is capable of absorbing and releasing large quantities of the gas.

Carbon monoxide: Colourless, odourless, tasteless, non-corrosive, highly poisonous gas of about the same density as that of air. Very flammable, burning in air with bright blue flame. Although each molecule of CO has one carbon atom and one oxygen atom, it has a shape similar to that of an oxygen molecule (two atoms of oxygen), which is important with regard to its lethality.

Carbon sulfide. A clear, flammable liquid, CS_2, used to manufacture viscose rayon and cellophane, as a solvent for fats, rubber, resins, waxes, and sulfur, and in matches, fumigants, and pesticides.

Climate change. Climate change refers to any change in climate over time, whether due to natural variability or as a result of human activity. This usage differs from that in the United Nations Framework Convention on Climate Change (UNFCCC), which defines 'climate change' as: 'a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods’.

COD (Chemical Oxygen Demand). COD is widely used as a measure of the susceptibility to oxidation of organic and inorganic materials in waters. Strong chemical oxidants, such as dichromate (COD-Cr) and permanganate (COD-Mn) are used in measuring COD. In unpolluted waters, COD values are in the order of 20 mg O_2/l or less. The chemical oxygen demand of the effluent indicates the more persistent chemical components in the effluent. This compares with the biochemical demand, where oxygen is absorbed through bacteria. The latter process takes quite a long time for daily operational performance checking of effluent treating plants. Provided that a waste water treatment plant has a constant input, the COD is measured as a routine analysis to estimate the BOD of the effluent once the correlation ratio has been established. See BOD, and BOD/COD ratio.

Coliform organism: Microorganisms found in the intestinal tract of humans and animals. Their presence in water indicates fecal pollution and potentially dangerous bacterial contamination by disease-causing microorganisms.

Contaminant: Any physical, chemical, biological, or radiological substance or matter that has an adverse effect on air, water, or soil.

Data base: A computerized compilation of data, facts and records that is organized for convenient access, management and updating.

Data collection: Compiling data and information to be put into databases or archives for retrieval and information purposes.

Discharge. All effluents or other materials that are put into the environment. In US, most commonly, “discharge” is considered to be the release of any liquid waste into the environment from a point source, but also can refer to air emissions.

Dissolved oxygen: The oxygen freely available in water, vital to fish and other aquatic life and for the prevention of odors. DO levels are considered a most important indicator of a water body's ability to support desirable aquatic life. Secondary and advanced waste treatment are generally designed to ensure adequate DO in waste-receiving waters.

Dissolved solids: Disintegrated organic and inorganic material contained in water. Excessive amounts make water unsuitable for drinking or for use in industrial processes.

Dumping: Disposing of waste illegally by not using bins or official recycling centres, civic amenity sites or landfills.

Emission: Any direct or indirect release of substances, vibrations, heat or noise from individual or diffuse sources of an installation into the environment (air, water or land). Emissions are generally used in relation to releases to the air, while discharges relate to releases to water.

Emission control − Procedures aiming at reducing or preventing the harm caused by atmospheric emissions.

Endangered species: Animals, birds, fish, plants, or other living organisms threatened with extinction by man-made or natural changes in their environment. Requirements for declaring a species endangered are contained in the Endangered Species Act.

Enrichment: Addition of nitrogen, phosphorous and carbon compounds or other nutrients into a water body, thereby increasing the potential for growth of algae and other aquatic plants. Most frequently, enrichment results from the inflow of sewage effluents or from agricultural run-off.

Environmental Data: 1. Any parameters or pieces of information collected or produced from measurements, analyses, or models of environmental processes, conditions, and effects of pollutants on human health and the ecology, including results from laboratory analyses or from experimental systems representing such processes and conditions. 2. Information concerning the state or condition of the environment.

Environmental Impact Assessment (EIA) is the term applied to the systematic examination of the likely impacts of development proposals on the environment prior to the beginning of any activity.

Environmental Information covers a broad range of topics, such as: the environment itself, including air, water, earth, and the habitats of animals and plants; other things that affect the environment, such as emissions, radiation, noise and other forms of pollution; policies, plans and laws on the environment.

Environmental monitoring: 1. 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. 2. Periodic and/or continued measuring, evaluating, and determining environmental parameters and/or pollution levels in order to prevent negative and damaging effects to the environment. Also include the forecasting of possible changes in ecosystem and/or the biosphere as a whole.

Environmental report: An account or statement, usually in writing, describing in detail events, situations or conditions pertaining to the ecosystem, its natural resources or any of the external factors surrounding and affecting human life.

Environmentally dangerous substance − Substance that causes undesirable change in the physical, chemical, or biological characteristics of the air, water, or land that can harmfully affect the health, survival, or activities of human or other living organisms.

Equipment: Any collection of materials, supplies or apparatuses stored, furnished or provided for an undertaking or activity.

Erosion: The general process or the group of processes whereby the materials of Earth's crust are loosened , dissolved, or worn away and simultaneously moved from one place to another, by natural agencies, which include weathering, solution, corrosion, and transportation, but usually exclude mass wasting.

European Environment Agency (EEA) was established by Regulation (EEC) No 1210/1990, amended by Regulation (EEC) No 933/1990, and has been operational since 1994. The EEA aims to support sustainable development and to help achieve significant and measurable improvement in Europe's environment through the provision of timely, targeted, relevant and reliable information to policy-making agents and the public. The Agency processes data from the member countries to knowledge at European level, and co-operates with the European environment information and observation network (Eionet) and other international partners to gather, process and distribute data and information.

Eutrophication: Excessive enrichment of waters with nutrients, and the associated adverse biological effects.

Evapotranspiration: The combined processes of evaporation and transpiration. It can be defined as the sum of water used by vegetation and water lost by evaporation.

Field sampling: On site sample taking, e.g., samples of water (effluent), soil, air pollution. Sample taking requires experienced, well trained and qualified inspectors or laboratory technicians and equipment in order to be able to proceed with an enforcement action if and when needed.

Fine dust. Air-borne solid particles, originating from human activity and natural sources, such as wind-blown soil and fires, that eventually settle through the force of gravity, and can cause injury to human and other animal respiratory systems through excessive inhalation.

Forecast: An estimate or prediction of a future condition.

Fossil fuel: Coal, natural gas and petroleum products (such as oil) formed from the decayed bodies of animals and plants that died millions of years ago.

Fresh water: Water that generally contains less than 1,000 milligrams-per-liter of dissolved solids.

Gaseous air pollutant: Uncondensed or volatile gases, usually comprised of chemical compounds, discharged to the atmosphere.

Genetic diversity - the diversity of genes within and among populations of a species. This is the lowest level of biological diversity. - variation in the genetic composition of individuals within or among species; the heritable genetic variation within and among populations.

GHG: Greenhouse gas. A gas such as carbon dioxide or methane that reflects infrared radiation emitted by the earth, thereby helping to retain heat in the atmosphere.

GIS (Geographic information system): A collection of computer hardware, software, and geographic data designed to capture, store, update, manipulate, analyze, and display geographically referenced data.

Global Environmental Monitoring System (GEMS). A global environmental monitoring system that was established in 1973 under the United Nations Environment Programme, which collects data relating to atmosphere, climate, pollution, and renewable resources.

Ground-level ozone is ozone present as a secondary pollutant in the lower atmosphere, where its formation can be enhanced by other pollutants. It is highly toxic at levels above 0.1 parts per million (p.p.m.).

Hazardous substance: Any material that poses a threat to human health and- /or the environment. Typical hazardous substances are toxic, corrosive, ignitable, explosive, or chemically reactive.

Heavy metal: Metallic elements with high atomic weights, e.g., mercury, chromium, cadmium, arsenic, and lead; can damage living things at low concentrations and tend to accumulate in the food chain.

Hydrogen chloride. Hydrochloric acid, solution is a colorless watery liquid with a sharp, irritating odor. Consists of hydrogen chloride, a gas, dissolved in water. Sinks and mixes with water. Produces irritating vapor.

Hydrogen cyanide is a colourless gas or liquid that has a faint, bitter, almond-like odour. Its water solution is a weak acid, commonly known as hydrocyanic or prussic acid. Hydrogen cyanide melts at 14 ^{0}C and boils at 26 ^{0}C. It is very flammable and a potentially explosive hazard on exposure to air, sources of ignition, including heat, or open flame; and when stored for long periods of time.

Hydrogen fluoride is an atmospheric contaminant derived from industrial emissions, such as aluminum and steel smelting, ceramic production, and the fabrication of phosphorus fertilizer.

Hydrogen sulfide: Flammable, poisonous gas with characteristic odour of rotten eggs, perceptible in air in a dilution of 0.002 mg/l. It is used as a reagent in chemical analysis; extremely hazardous; collapse, coma and death from respiratory failure may come within a few seconds after one or two inspirations; low concentrations produce irritation of conjunctiva and mucous membranes. Headache, dizziness, nausea, lassitude may appear after exposure.

Land cover reflects the (bio) physical dimension of the earth's surface and corresponds in some regard to the notion of ecosystems. Typical examples for land cover categories are built-up areas, grassland, forests or rivers and lakes.

Land degradation is the reduction or loss of the biological or economic productivity and complexity of rain-fed cropland, irrigated cropland, or range, pasture, forest or woodlands resulting from natural processes, land uses or other human activities and habitation patterns such as land contamination, soil erosion and the destruction of the vegetation cover.

Land use is based on the functional dimension of land for different human purposes or economic activities. Typical categories for land use are dwellings, industrial use, transport, recreational use or nature protection areas.

Level (monthly, quarterly, annual) **data**. Data expressed as levels are expressed in absolute terms (values, numbers, units) for a given period (month, quarter, year).

Load: An amount per unit of time emitted.

Map resolution: The accuracy with which the location and shape of map features are depicted for a given map scale.

Map scale: A statement of a measure on the map and the equivalent measure on the earth, often expressed as a representative fraction of distance, such as 1:10 000.

Marine pollution refers to direct or indirect introduction by humans of substances or energy into the marine environment (including estuaries), resulting in harm to living resources, hazards to human health, hindrances to marine activities including fishing, impairment of the quality of sea water and reduction of amenities.

Maximum allowable concentrations means the quantity of a hazardous substance present in the environment and calculated per unit of volume or weight of a certain media that does not influence adversely human health or ecosystems during a permanent or limited time exposure. Maximum allowable concentrations are established for air, water and soil pollutants, and have been developed mostly based on human health safety criteria. These standards take into consideration both acute and chronic exposure. Standard setting process, originating in the Soviet period, did not take into account available control technology, economic feasibility, and ability in practice to measure emission levels and ambient concentrations of pollutants. Furthermore, in relation to water bodies, two types of MACs are applied. If a water body is used for drinking water supply, recreation and household or industrial purposes, sanitary MACs are applied. If a water body is used for fishery purposes, fishery MACs are applied. The list of regulated substances is extensive comprising thousands of substances. On the basis of these MACs, volumetric norms are calculated individually for each industrial facility.

Mobile source: Any non-stationary source of pollution such as cars, trucks, motorcycles, buses, aircrafts, etc.

Monitoring. The observing, sample collection, analysis and reporting of information on, for example, emissions from installations or the ambient air quality in a particular location. It includes determining the actual state of the environment (often published in State of the Environment Reports on a regular basis).

Monitoring programme: A documented account of the facilities, activities and timetable for measurement work which is needed for compliance monitoring purposes.

Monitoring wells. Wells drilled at a site to collect groundwater samples for the purpose of physical, chemical, or biological analysis to determine the amounts, types, and distribution of contaminants in the groundwater beneath the site.

Multilateral environmental agreements are the agreements between states which may include obligations varying from more general principles about a particular environmental issue, through to definitive actions to be taken to achieve an environmental objective.

Natural pollutant is a pollutant created by substances of natural origin such as volcanic dust, sea salt particles, photochemically formed ozone, and products of forest fibers, among others.

Nitrogen dioxide: A reddish-brown gas; it exists in varying degrees of concentration in equilibrium with other nitrogen oxides; used to produce nitric acid.

Nitrogen oxides. Oxides formed and released in all common types of combustion; they are formed by the oxidation of atmospheric nitrogen at high temperatures. Introduced into the atmosphere from car exhausts, furnace stacks, incinerators, power stations and similar sources, the oxides include nitrous oxide, nitric oxide, nitrogen dioxide, nitrogen pentoxide and nitric acid. The oxides of nitrogen undergo many reactions in the atmosphere to form photochemical smog.

Nitrogenous oxygen demand (NOD) is a quantitative measure of the amount of dissolved oxygen required for the biological oxidation of nitrogenous material, for example, nitrogen in ammonia, and organic nitrogen in waste water.

Observation. An observation is the value, at a particular period, of a particular variable.

Oil spill. An oil spill is oil, discharged accidentally or intentionally, that floats on the surface of water bodies as a discrete mass and is carried by the wind, currents and tides. Oil spills can be partially controlled by chemical dispersion, combustion, mechanical containment and adsorption. They have destructive effects on coastal ecosystems.

Ozone depletion is the destruction of ozone in the stratosphere, where it shields the earth from harmful ultraviolet radiation. Its destruction is caused by chemical reactions in which oxides of hydrogen, nitrogen, chlorine and bromine act as catalysts.

Particulate matter: Fine solid or liquid particles that pollute the air and are added to the atmosphere by natural and man-made processes at the Earth's surface. Examples of particulate matter include dust, smoke, soot, pollen and soil particles.

Particulates − Liquid or solid particles such as dust, smoke, mist, or smog found in air emissions.

Phenol. A very poisonous chemical substance made from tar and also found in some plants and essential oils (scented liquid taken from plants). Phenol is used to make plastics, nylon, epoxy, medicines, and to kill germs. Also called carbolic acid.

Plume − A concentration of contaminants in air, soil, or water usually extending over an area from a distinct source.

Pollutant: Any substance (or effect) introduced by humans which adversely affects the environment.

Pollution. 1. presence of substances and heat in environmental media (air, water, land) whose nature, location, or quantity produces undesirable environmental effects; 2. activity that generates pollutants.

Qualitative data is data describing the attributes or properties that an object possesses. The properties are categorized into classes that may be assigned numeric values. However, there is no significance to the data values themselves, they simply represent attributes of the object concerned.

Quantitative data is data expressing a certain quantity, amount or range. Usually, there are measurement units associated with the data, e.g. metres, in the case of the height of a person. It makes sense to set boundary limits to such data, and it is also meaningful to apply arithmetic operations to the data.

Real-time instruments of monitoring − This involves making direct measurements of pollutant concentrations in situ with instruments that give immediate and continuous readings. This method gives information with high time resolution and virtually no time delay, but instruments are difficult and costly to calibrate and require special maintenance under possibly adverse or difficult field conditions.

Release: Any spilling, leaking, pumping, pouring, emitting, emptying, discharging, injecting, escaping, leaching, dumping, or disposing into the environment of any pollutant.

Remote sensing is the process of detecting and monitoring the physical characteristics of an area by measuring its reflected and emitted radiation at a distance from the targeted area. Special cameras collect remotely sensed images of the Earth, which help researchers "sense" things about the Earth.

Sampling: The obtaining of small representative quantities of material for the purpose of analysis.

Soil degradation refers to the process(es) by which soil declines in quality and is thus made less fit for a specific purpose, such as crop production.

Soil organic matter is carbon-containing material in the soil that derives from living organisms.

Source: A facility, installation or individual from where the pollution or information etc. originates.

Spatial data is any data with a direct or indirect reference to a specific location or geographical area.

State Environmental Monitoring System is an open information system, priority operations of which are the protection of vital important ecological interests of human and society; preservation of natural ecosystems; prevention crisis changes in the ecological state of the environment and prevention of emergency environmental situation.

Statistical data refers to data from a survey or administrative source used to produce statistics.

Sulphur dioxide: Heavy, pungent, colourless gas formed primarily by the combustion of fossil fuels. It is harmful to human beings and vegetation, and contributes to the acidity in precipitation.

Turbidity. 1. Haziness in air caused by the presence of particles and pollutants. 2. A similar cloudy condition in water due to suspended silt or organic matter.

Volatile organic compound (VOC): Organic chemical compounds that under normal conditions are gaseous or can vaporise and enter the atmosphere. VOCs include such compounds as methane, benzene, xylene, propane and butane. Methane is primarily emitted from agriculture (from ruminants and cultivation), whereas non-methane VOCs (or NMVOCs) are mainly emitted from transportation, industrial processes and use of organic solvents.

Wastes. 1. Unwanted materials left over from a manufacturing process. 2. Refuse from places of human or animal habitation.

Water pollution. The presence in water of enough harmful or objectionable material to damage water quality.

Water quality criteria. Specific levels of water quality that, if reached, are expected to render a body of water suitable for its designated use. The criteria are based on specific levels of pollutants that would make the water harmful if used for drinking, swimming, farming, fish production, or industrial processes.

Wetlands. An area that is regularly saturated by surface water or groundwater and is subsequently characterized by a prevalence of vegetation adapted for life in saturated soil conditions. Examples include swamps, bogs, fens, marshes, and estuaries.

Individual work

(indicative directions for choosing the topic of course work)

- Monitoring of protected areas: soil and water pollution, air monitoring, biomonitoring, background monitoring, monitoring of radioactive pollution, etc.
- Monitoring of urban areas: soil and water environment, air monitoring, biomonitoring, sanitary and hygienic monitoring, monitoring of radioactive contamination, socio-ecological monitoring, etc.
- Monitoring of industrial territories: soil and water environment, air monitoring, biomonitoring, sanitary and hygienic monitoring, monitoring of radioactive contamination, socio-ecological monitoring.
- Monitoring agricultural areas: soil and water environment, poultry farm, pig farm, livestock farms and so on. There are different variants: biomonitoring, sanitary and hygienic monitoring, monitoring of radioactive contamination, socio-ecological monitoring.
- Monitoring of agro-industrial complexes: soil and water environment, sanitary and hygienic monitoring, biomonitoring, monitoring of radioactive contamination, socio-ecological monitoring, air monitoring, soil and land monitoring, surface water monitoring etc.

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