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TM2.1 Environmental Quality – Air, Water and Soil

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Introduction

The learning unit "Environmental quality - water, air and soil" proposes a presentation of the main concepts used to describe environmental problems. In developing the material, the authors have aimed to form an image of what is meant by the environment, environmental pollution and environmental quality monitoring. The main institutions responsible for assessing and maintaining environmental quality are also introduced.

2.1.1 Environment and Environmental Pollution

The environment is defined as the set of conditions and natural elements of the Earth: air, water, soil, subsoil, characteristic aspects of the landscape, all atmospheric layers, all organic and inorganic matter, as well as living beings, natural systems in interaction, comprising the elements listed above, including material and spiritual values, quality of life and conditions that can influence human well-being and health (Decision, 2002).

The definition reflects the complexity of this concept and includes the physical, biological and social environment in which an organism, an individual or a group of individuals exists and interacts. The environment comprises:

- **natural elements**, for which the term "natural environment" is often used, and includes the biotic and the abiotic environment. In the environmental science, the term environmental factors is assimilated to that of environmental components, the "-spheres" that together make up the ecosphere: air – atmosphere, water – hydrosphere, the soil and the subsoil - the lithosphere, biota (plants and animals) - biosphere.
- **the man-made systems**, elements created by man (anthroposphere), for which the term "built environment" is often used, which includes, for example, buildings, infrastructure, cultural systems in which humanity lives, interacts, and carries out its activity.

In Figure 1, the concept of "environment" understood as a "global mega-system" that brings together the natural and the built environment is shown schematically, also highlighting the interactions between the components. The environment is a dynamic and interconnected system, changes in one part of the system can have effects on other parts. Understanding the environment is crucial to the health and well-being of all living things, including humans.

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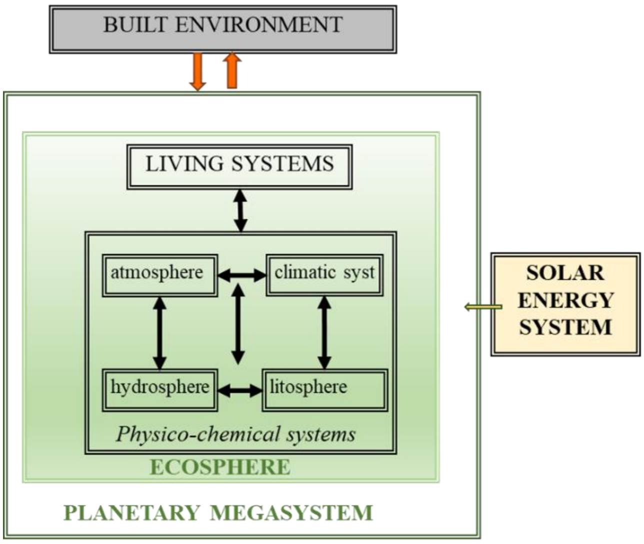

Figure 1. The concept of the environment as a mega-system

The existence and functioning of the environment, as a whole, based on natural balance, constitutes the primary resource for human civilization, providing it with the necessary opportunities to ensure the functioning of man-made systems. Material and energy resources taken from the natural environment are necessary for the development and operation of man-made systems. On the other hand, the operation of man-made systems leads to the generation of substances, materials, products, which are not created by the natural environment, or are created in much smaller quantities, so that the natural balance is seriously disturbed. In this way, the natural balances are affected, and the natural environment generates constraints for the functioning of the built environment.

As mentioned, the natural environment is constituted as a system that includes living components (biotic - animals, plants, microorganisms) and non-living components (abiotic - water, air, soil, climate system) in a complex network of interactions. The community of living organisms, together with their living environment, make up an ecosystem, of varying size and complexity, such as a forest, a body of water (lake, river), or even an open sea or rainforest.

Ecosystems are essential for sustaining life on Earth and provide ecological services which are defined as the tangible and intangible benefits that ecosystems provide to support human life and well-being. These services are essential for the functioning and survival of human and natural communities, as well as for supporting biological diversity and essential ecological processes, and fall into the following categories:

- life support services, essential for the maintenance of life on the planet, such as the production of oxygen through photosynthesis, the provision of the nutrient circuit, the formation and maintenance of the soil;
- regulatory services that control ecological and climate processes and maintain balance in ecosystems, such as water and air quality regulation, as well as climate regulation;
- production support services that provide goods and resources for both the natural and the built environment, such as the production of food, construction materials and other natural resources (such as food, drinking water, fuels);

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- cultural services that include cultural, spiritual, non-material aspects such as recreational and aesthetic experiences.

Understanding and properly managing ecosystem services is essential because the balance of the environment as a whole depends on their maintenance.

The quality of the environment is given by the quality of all the natural factors of the environment, in interaction with the anthropogenic ones, resulting in influencing the ecological balance.

The atmosphere (atmospheric air, air) is composed of a mixture of gases, water vapor and solid particles in suspension, which are unevenly distributed around the planet under the influence of gravity and other external forces (air currents, winds).

Usually, by air is meant the lower layer of the atmosphere (troposphere), up to about 10 km altitude (18 km at the Equator and 8 km at the Poles). Approximately 90% of the atmospheric mass is found in this layer, it is the seat of meteorological phenomena and the area where human activity is most strongly felt.

The natural gaseous composition of dry air in the troposphere, expressed in volume percentages, is: N_2 (78-79%), O_2 (20-21%), Ar (0.92%), CO_2 (0.03-0.04 %), He, Ne, CH_4, Kr, Xe, O_3, H_2, Rn (together 0.01%). Atmospheric air is the main source of oxygen for living things on earth (people, fauna), and, respectively, of carbon dioxide for green plants (flora).

Along with the gaseous components, in the atmosphere are present, in variable quantities, depending on the location, the season, species in solid state (material particles or particles in suspension) or liquid (aerosols). These coagulate as very fine particles often expressed as $PM_{2.5}$ (particulate matter that have an average diameter of less than 2.5 µm) or PM_{10} (particulate matter with diameter of less than 10 µm). Solid particles, aerosols, and hydrosols have different compositions, containing inorganic ions, anions of aliphatic organic acids (with low molecular weight), organic compounds known as volatile organic compounds (VOC).

The atmospheric layer immediately above the troposphere is the stratosphere. In the stratosphere, between 16 and 48 km altitude, stratospheric ozone is found, the gas that is responsible for trapping ultraviolet (UV) radiation from the Sun. Ozone is the triatomic form of oxygen (O_3, as opposed to the diatomic form, O_2 that sustains life on Earth), is an unstable substance and is found in variable amounts depending on geographic location and season. It should be noted that at the level of the stratosphere ozone is essential for the protection of terrestrial life, but at the level of the troposphere ozone is a main pollutant, a component of photochemical smog.

The hydrosphere (water) comprises the entire mass of free water on the planet, regardless of its state of aggregation, vapor, liquid or solid.

From Law 107 of 1996, the classification of waters can be derived, according to multiple criteria, such as:

- chemical composition: fresh water/saline water/transient water,
- positioning with respect to the ground surface: surface water, which can be standing or flowing/groundwater,
- possibility of use: waters intended for human consumption/non-potable waters

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- passing through an anthropic activity: natural waters/wastewater (which can be purified or not)

The composition of natural waters is complex, depending on the type of water, and may include:

- chemical species of different origin – mineral (inorganic) or organic;
- dissolved gases – in natural waters, the most important are oxygen and carbon dioxide;
- particles with variable sizes – forming solutions, suspensions (colloids) or coarse dispersions;
- living organisms.

Dissolved salts from the mineral components of the soil with which the water comes into contact predominate in surface and underground waters, and precipitation waters bring an input of dissolved gases from the atmosphere. After use, the water changes its initial properties, becoming residual/waste water.

The soluble mineral (inorganic) compounds present in water can be:

- cations: H^+, Ca^{2+}, Mg^{2+}, Na^+, K^+, Fe^{2+}, Fe^{3+}, Cu^{2+}, Cd^{2+}, Al^{3+}, Zn^{2+}, NH_4^+;
- anions: HO^-, Cl^-, HCO_3^-, NO_3^-, NO_2^-, CO_3^{2-}, SO_4^{2-}, S^{2-}, PO_4^{3-}, polisilicates, borates, etc.

The organic compounds in natural waters are biological in nature and result from metabolic processes in which plant and animal organisms are involved. They can be: methane, organic compounds with nitrogen, with phosphorus, with sulfur, or other organic compounds soluble in water.

In natural waters there are many living organisms, whose existence is dependent on the quality of the water.

The geosphere is the solid part of the earth. The part of the geosphere directly involved in environmental processes, in contact with the atmosphere, the hydrosphere and the biosphere, is called the lithosphere.

Soil is the most important component of the lithosphere, the depth of which depends on its usefulness for human activities: the environment for plant culture and food production, support for forests and infrastructure. Thus, establishing the depth of the layer in the lithosphere corresponding to the soil depends on its use. The soil is a polydisperse, structured and porous system, a mixture of minerals, organic substances and biochemical compounds, which are found in the soil, in the three states of aggregation: gaseous (soil air), liquid (soil solution) and solid. In general, one kilogram of soil contains:

- approx. 0,70-0,90 kg mineral solid compounds, mainly salts and oxides (clay, fine sand, quartz, mica, feldspat) or organic compounds (humus, lignine, cellulose, raisins, pectines, semicellulose, hydrocarbons, enzimes);
- approx. 0,15 kg water (containing dissolved substances, and forming the soil solution);
- approx. 0,015 kg gazes (soil air).

The biosphere (the living systems) represents the living matter distributed over the entire surface of the Earth, forming an area with variable thickness and density. The biosphere is composed of all living entities on Earth. Living organisms belong to the biotic environment, while the components of the lifeless environment are called abiotic (Drăghici et al., 2022).

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The natural composition of the environment is affected by human activity. In the natural environment, chemical compounds or products are released that have diverse, complex effects on humans, on the components of the natural and/or built environment. It should be noted that many of the effects of these compounds may still be under the spectrum of uncertainty.

The impact of harmful compounds on humans began to be studied only after their effect on human health was realized. To explain the new observed phenomena, terms such as "xenobiotic", "contaminant", "contamination", "pollutant", "pollution" or "environmental damage" were introduced into the current language (Drăghici et al., 2022).

Deterioration of the environment represents the alteration of the physical-chemical and structural characteristics of the natural and anthropogenic components of the environment, the reduction of the biological diversity or productivity of natural and anthropogenic ecosystems, the damage to the natural environment with effects on the quality of life, mainly caused by water, atmosphere and soil pollution , the over-exploitation of resources, their deficient management and capitalization, as well as through improper planning of the territory (Decision, 2005).

Xenobiotic (from the Greek xenos, "foreign") is any chemical compound that is found in organisms, but which is not a product of the organism's metabolism, and therefore not recognized by it.

Contaminants are xenobiotics or biological agents that contaminate a system by contacting or mixing the initial components of the system with them (contamination).

Pollutant is any solid, liquid, gas, vapor or energy form (electromagnetic, ionizing, thermal, sound or vibration radiation) which, introduced into the environment, changes the balance of its constituents and living organisms, causing damage to material assets (Decision, 2005).

Pollution (from the Latin polluere, "to pollute, degrade ") represents the direct or indirect introduction of a pollutant that can cause damage to human health and/or the quality of the environment, damage to material assets or cause damage or an impediment to use the environment for recreational or other legitimate purposes (Ordonantă, 2005). Pollution leads to the degradation of the quality of the environment due to natural or anthropogenic processes that make it less suitable for ensuring the conditions necessary for life. Pollution is determined by the accumulation and unfavorable interaction of contaminants with the environment (Dumitru and Manea, 2011).

Figure 2 schematically describes environmental pollution, a model which can be used to describe a pollution event. The pollution starts from the source of pollutants, their emission into the environment (air, water, soil, biota), followed by their transport into the environment, polluting it, producing negative effects on living organisms, the built environment, ecosystems , or even of the global environment.

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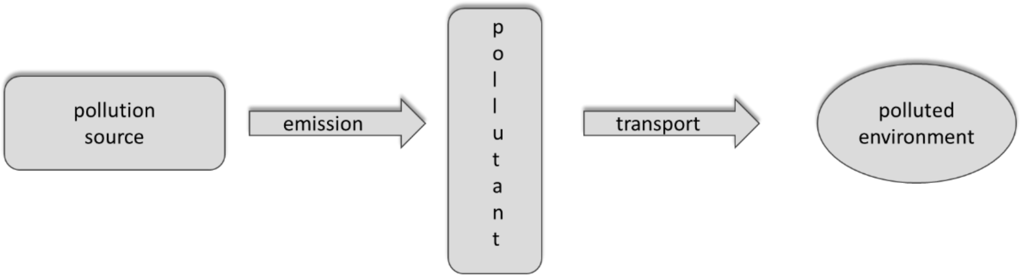

Figure 2. Environmental pollution – schematic presentation

The simplest classification of pollution differentiates two categories, based on the sources that produce it:

- natural pollution - which is due to natural sources,
- artificial (anthropic/ anthropogenic) pollution - which is due to anthropic (human) activity.

The Air Pollution

By air pollution is meant the process of introducing into the atmosphere some substances foreign to the natural composition of the air, which, depending on their concentration, alter the human living environment, cause health disorders, or affect the flora and fauna. The quality of the atmospheric air is difficult to keep under control, due to the fact that the pollutants emitted into the atmosphere, from different sources, dissipate quickly and can no longer be captured to be subjected to a purification process.

Emission means any direct or indirect discharge, from point or diffuse sources, of substances, vibrations, heat or noise into air, water or soil (Decision, 2005). As a result, the analysis of pollutants in the atmospheric air, their qualitative and quantitative evaluation starts from the establishment of pollutant emissions from various sources.

Air pollution sources can be natural or anthropogenic. The natural ones are:

- cosmic dust – from the upper layers of the atmosphere;
- volcanic eruptions - release gases, vapours, solid particles into the atmosphere;
- the soil - under the influence of temperature variations, rains, air currents, the soil erodes, with the release of gases, vapours or fine particles into the atmosphere;
- extreme meteorological phenomena – storms, strong winds including tornadoes, which can cause the lifting and transport of particles in the atmosphere;
- plants - contribute with pollen, volatile organic compounds emitted by deciduous or conifers;
- **animals - eliminate excretion** metabolites, hair, feathers, flakes.

Anthropogenic sources of air pollution can be mobile or stationary (Drăghici et al., 2022):

- pollution from mobile sources is most often due to combustion processes from means of transport (road, rail, sea, air);
- pollution from stationary sources is due to:

- combustion processes in industrial and/or domestic activities;
- industrial processes, such as the extractive industry, the chemical industry, the metallurgical industry, the steel industry, the construction materials industry, the energy industry, the food industry;
- non-compliant storage of waste;
- agricultural and animal husbandry activities.

Polluted air has a complex composition that differs by location and pollution sources. According to the size of the particles, atmospheric pollutants can be suspensions (powders, dust), aerosols (smoke, fog) and gases, and according to their nature they can be inorganic or organic.

For example, particulate matter/ suspended particles, PM may contain carbon, silicon, metal oxides (of Fe, Zn, Cd, Ni), polycyclic aromatic hydrocarbons (PAH). On the other hand, gaseous pollutants can be: NO_x (NO, NO_2), SO_2, CO, H_2S, O_3, volatile organic compounds (VOC).

Water pollution

By water pollution is meant any physical, chemical, biological or bacteriological alteration of water, above an established admissible limit, including exceeding the natural level of radioactivity produced directly or indirectly by human activities, which make it unsuitable for normal use for the purposes for which this use was possible before alteration took place (Lege, 1996). Water can be contaminated either by pollutants from the atmosphere that reach the waters, or by pollutants from different sources, emitted/discharged directly into natural waters.

The sources of pollution of surface waters (rivers, lakes, seas...) and underground waters are:

- polluted air from industrial areas carried to the water surface by atmospheric currents;
- water from precipitation that carries atmospheric pollutants;
- waste water, sludge, leachate;
- compounds used for agricultural purposes by applying pesticides;
- disinfection agents introduced for the purpose of eliminating pathogens;
- waste from industrial processes, from agricultural and/or domestic activities.

Water pollutants can be of mineral (inorganic) or organic nature, either dissolved in water (including gases) or in suspension phase.

Soil Pollution

Soil pollution represents any disturbance that affects the quality of soils from a qualitative and/or quantitative point of view (Dumitru and Manea, 2011).

The degree of pollution is assessed in 5 classes, either depending on the percentage of reduction of the harvest from a quantitative and/or qualitative point of view compared to the production obtained on unpolluted soil, or by exceeding in different proportions the accepted thresholds (Decision, 1997).

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As in the case of air or water pollution, anthropogenic soil pollution is a direct result of non-compliant economic activities:

- polluting substances carried by the air;
- radioactive materials;
- emissions/ evacuations on the ground of liquid residues from industrial activities;
- inadequate purified industrial or domestic waste water, used for irrigation;
- chemical fertilizers, pesticides, household waste or sludge from water treatment plants (used as fertilizers in agriculture) improperly stored and distributed;
- waste from industrial, agro-zootechnical, forestry or household activities, landfills, settling ponds, flotation tailings deposits, waste deposits, ash deposits, sludge deposits;
- ballast yards, quarries, oil extraction, daily mining operations.

The main inorganic and organic chemical pollutants that affect all components of the environment are synthetically presented in Table 1.

Table 1. Types of inorganic and organic chemical pollutants.

Pollutant cathegory	**Type**	**Examplex**
Inorganic	Simple substances	Cl2, O3 (tropospheric ozone)
	Gazeous oxides (nonmetallic oxides)	CO, NOx, SO2
	Volatile acids and bases	HCl, H2S, NH3
	Anions	AsO32-, CrO42-, NO3-, NO2-, PO43-, SO32-, S2-
	Heavy metal cations	Cd2+, Cu2+, Hg2+, Mn2+, Pb2+, Zn2+
Organic	Volatile organic compounds (VOC)	hydrocarbons, halogenated compounds, alcohols, ethers, aldehydes, ketones, esthers
	Persistent organic pollutants (POP)	polycyclic aromatic hydrocarbons (PAH)
		Policlorinated byphenils (PCB)
		Pesticides
		Dioxines, furans

In conclusion, air, water and soil are polluted from various activities:

(a) industrial processes, the movement of means of transport, or agricultural activities, as follows:

- SO_2 and NO_x emissions come from mobile (transport) or stationary (non-ferrous metal industry) sources;
- emissions containing cations of heavy metals (Pb, Cd, Cu, Zn, Hg) that pollute the environment mainly come from areas with extraction activities (mining operations) or from the metallurgical and steel, chemical and petrochemical industries;

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- ashes from thermal power plants or from cement production;

(b) non-compliant waste deposits:

- household, street and industrial;
- oil tankers near oil wells or oil refineries, pipelines for transporting crude oil or oil products;
- droppings from livestock farms, or sludge from sewage treatment plants, spread on the soil as fertilizers, without adequate pretreatment;

(c) the use in too high concentrations of pesticides with a beneficial action for crops, with side effects harmful to the soil and vegetation.

2.1.2 Biogeochemical cycles

The components of the natural environment, water, air, soil, (also called environmental factors) contain a series of chemicals (in different forms) that make life possible and provide the previously mentioned services (Lupea et al., 2008). There are naturally exchanges of matter (chemicals) and energy between the components of the environment.

The natural exchanges, in the form of circuits, through which essential chemicals are transferred between the biological, geological and atmospheric components of our planet, are called bio-geo-chemical cycles (or bio-geo-chemical circuits). These circuits are regulated by biological factors, such as bacteria that decompose organic matter, as well as by abiotic factors, such as the climate system or geological processes.

The main bio-geo-chemical cycles are:

- **the carbon cycle** through which the concentration of carbon dioxide in the atmosphere is naturally regulated, an essential process of the climate system;
- **the nitrogen, phosphorus and sulfur cycles** - essential elements in the production of nutrients that maintain soil fertility;
- **the hydrological cycle**, also called the water cycle/ circuit is the one that describes the transport of water between the different components of the environment;
- **the oxygen cycle** describes how oxygen is produced, transported, consumed in the different components of the environment;
- **the iron cycle** reproduces the transport of iron compounds between the components of the environment, with importance in the production of essential substances and energy for living organisms.

Knowledge of bio-geo-chemical circuits is important because they are, as mentioned, the processes by which substances and energy are transferred and transformed in natural ecosystems. At the moment, these circuits are disrupted due to the functioning of the built environment, which has and may in the future have serious consequences on the natural environment, that is, on ecosystems and human health, both on an individual scale and on a global scale.

Next, the carbon, nitrogen and water circuits are exemplified, which are directly influenced by the activity specific to the rural environment and whose disruption has led to major environmental imbalances at the level of the planetary

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megasystem. By understanding the functioning of ecosystems, how human activities can influence natural interactions, the effects of these activities on the environment can be understood and strategies can be developed that lead to preserving the quality of the environment, preventing and reducing pollution where it exists.

The Carbon Cycle

In environmental factors (water, air, soil), carbon is found in inorganic or organic compounds. Examples of inorganic compounds include carbon dioxide, CO_2 (in air, water or soil), salts in the form of carbonates and acidic carbonates (in water or soil). Examples of organic compounds include methane (in water, soil, or even air), saccharides, proteins, amino acids (components of living organisms). Large amounts of carbon, in the form of compounds, are found in fossil fuels (natural gas, oil, coal), which contain organic compounds and are formed from the fossil remains of plants and animals. Fossil fuels are an important resource for the energy needed to carry out human activities.

The natural carbon cycle is based on two processes:

- **combustion** - which consists in the transformation of organic carbon compounds into carbon dioxide, a process that results in the release of energy; combustion takes place either in living organisms (the natural process by which the organic matter in a living organism is transformed into energy and carbon dioxide), or in the built environment, by burning fossil fuels to obtain the energy needed for various activities such as transport, industry (which, along with energy, generates water, CO_2 and other chemicals, known as pollutants).
- **photosynthesis** - the process by which, in plants, in the presence of light radiation, carbon dioxide is transformed into oxygen, organic matter and chemical energy necessary for plant development.

Naturally, the carbon dioxide generated by combustion is taken up by plants through the process of photosynthesis, processes on which the climate system of the planet is based, through the **greenhouse effect**. The greenhouse effect is the natural phenomenon that keeps the Earth's temperature constant at a level suitable for supporting life. The earth is warm due to the retention of solar radiation by certain gaseous substances, naturally existing in the earth's atmosphere, called **greenhouse gases** such as: water vapor, carbon dioxide, nitrous oxide, methane.

However, the climatic balance is disrupted at the planetary level, due to the disruption of the bio-geo-chemical cycle of carbon. Carbon dioxide emissions resulting from the excessive burning of fossil fuels can no longer be processed by the "green mass" which is massively diminished due to, for example, deforestation. This imbalance manifests itself through the disruption of the climate system through global warming, the phenomenon known as **climate change**.

Climate change is produced not only by carbon dioxide but also by other natural gases in the atmosphere, or by some devloped by humanity. Along with the presented categories, tropospheric ozone (the pollutant, component of photochemical smog) and water vapor also have a greenhouse effect. Figure 3 presents the main categories of greenhouse gases, together with examples of activities that lead to emissions of these gases. Since most of these contain the element carbon, greenhouse gas emissions are often referred to as "carbon emissions".

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The most aggressive activity, which contributes massively to climate change, is the consumption of energy from fossil fuels. Whether it's about transport (transportation of people, goods, or the operation of various machines), whether it's about the energy needed to carry out various industrial or socio-economic activities, carbon dioxide emissions are significant, globally, even if at at the individual level this is not noticed.

Greenhouse gases (carbon dioxide, methane, hydrofluorocarbon compounds) are also emitted from activities in the agro-zootechnical field. Along with emissions from energy consumption for transport and/or the production and processing of animal feed, CO_2 emissions are generated during the fermentation and composting processes of animal waste. Methane (CH_4) emissions are generated during fermentation and digestion processes in animal stomachs, as well as during the storage and disposal of animal waste. Methane is a much stronger greenhouse gas than CO_2, meaning a greater contribution to climate change.

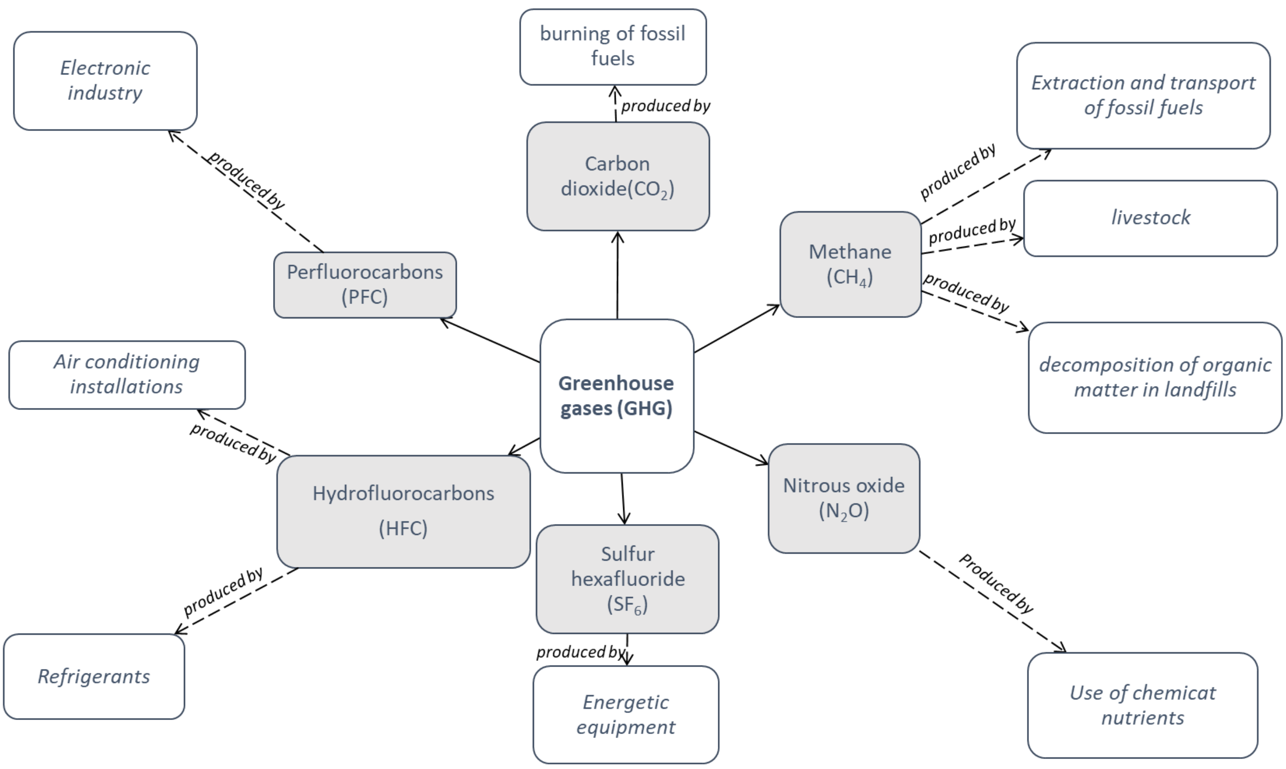

Figure 3. Greenhouse gases and examples of their sources

The major consequence of climate change is the increase in global average temperature. According to the data of the Intergovernmental Institute of Climate Change, IPCC, (IPCC, 2019), the average global temperature is approximately 1°C higher than that of the pre-industrial period, and an average increase of 1.5°C is estimated for the period 2030-2050. Global warming leads to the melting of glaciers and the rise of sea levels, to extreme weather events, but also to changes in the distribution of plant and animal species at the planetary level and even the disappearance of some of the species.

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Changes can have significant negative effects on natural systems and human society, by increasing the risk of natural disasters, affecting natural resources and human health. These are just a few examples, and risks depend on the magnitude and speed of temperature increase, geographic location, level of development and vulnerability, as well as the choices and implementation of the climate change adaptation and mitigation option.

Tackling the disruption of the carbon cycle primarily involves reducing greenhouse gas emissions, increasing the capacity of natural ecosystems to absorb carbon dioxide, and developing clean and sustainable technologies.

The Nitrogen Cycle

The nitrogen cycle is a natural bio-geo-chemical process by which nitrogen (as a simple substance or in the form of compounds) is transported between the atmosphere, waters, soil and living organisms, especially plants and microorganisms, and changes in this cycle can have effects significant impact on soil quality, water quality and ecosystem health.

The bio-geo-chemical cycle of nitrogen consists of four major stages:

- **nitrogen fixation**, the first step in the cycle, involves the transformation by bacteria and microorganisms of nitrogen from the atmosphere into forms usable by plants and other organisms (eg proteins);
- **ammonification** is the process by which bacteria and other organisms break down organic nitrogen compounds in the soil, as well as excrement and other animal products, into ammonia; ammonia, in large quantities, is toxic to plants and animals, but is transformed, through oxidative chemical processes, into less harmful compounds;
- **nitrification** is the process by which bacteria convert ammonia into nitrites (nitrogens) and then into nitrates (nitrogens), which are more easily assimilated by plants and constitute the nutritional components, which is why these chemical species are also known as "nutrients"; this process occurs in two distinct steps: in the first step, the bacteria oxidize ammonia to form nitrites, and in the second step, the nitrites are oxidized to nitrates; when chemical fertilizers are applied to the soil, the natural processes of nitrogen fixation, ammonification and nitrification are suppressed, the plants receiving the nutrient species "ready-made" - for example nitrates;
- **denitrification** is the process by which bacteria convert nitrates into nitrogen gas and transfer it to the atmosphere; this process takes place under anaerobic conditions, that is, in the absence of oxygen, and occurs in water-saturated soils or in sediments from lakes or rivers; during denitrification, bacteria use nitrates as a source of oxygen, thus producing gaseous nitrogen but also other gases, such as nitrous oxide (N_2O);

As a whole, the bio-geo-chemical cycle of nitrogen contributes to maintaining balance in ecosystems and ensuring sufficient amounts of nitrogen for plants and other organisms to have a balanced rate of growth and development.

Disruption of the nitrogen cycle can be caused by human activities, such as excessive use of nitrogen-based fertilizers in agriculture, which can lead to soil and water pollution with nutrients. The main effect of the disturbance of the

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nitrogen cycle due to the excess of nitrates and nitrites (nutrients), which from the soil reach the groundwater and surface waters, consists in the eutrophication of water bodies which is manifested by the excessive growth of algae.

Other examples of environmental problems caused by the disruption of the nitrogen cycle are: deterioration of soil quality and soil acidification, as well as emissions of greenhouse gases such as nitrous oxide (N_2O), which contribute to climate change.

The Water Cycle

On Earth, water is constantly in motion, due to evaporation, condensation, precipitation, runoff, and seepage. Thus a continuous cycle is achieved, with water passing through transformations that involve both water in liquid state and water in gaseous state (vapour) or in solid state (ice, snow). The hydrological cycle (as the water cycle is called) is a process that is naturally essential for sustaining life on Earth and ensures the availability of water for all living organisms.

The circuit can be explained starting with the evaporation of water from surface waters (oceans, rivers, lakes) and from the soil through the action of solar heat. Water vapor rises in the atmosphere and condenses forming clouds, and through precipitation the water reaches back to the Earth's surface. Water from precipitation can flow directly into rivers and lakes or seep into the soil, feeding groundwater.

The transport of water through the soil is an important process, it is based on complex mechanisms, diffusion, osmosis, which ensures the supply of water to plants for growth and survival. The process also depends on the physical properties of the soil, such as texture, structure and density. For example, finer textured soils such as clays can hold more water than coarser textured soils such as sand. Soil structure can also affect water circulation through soil pores and air channels.

Due to its physico-chemical properties, water is a good solvent and dispersion medium for various chemical species. Naturally, there are dissolved in water a number of chemical species that make possible, on the one hand, underwater life and, on the other hand, the use of water for human use, or in other socio-economic sectors, including agro-zootechnical activities. Water is also an excellent transport medium for life-supporting substances (nutrients, oxygen), microbiological species, but also polluting species.

Below are some examples of activities that correlate with life in the countryside and contribute significantly to the disruption of the water circuit, most likely affecting the quality of the water to be used as drinking water.

Climate change, manifested primarily by rising temperatures compared to periods when human activities were much less complex, may result in water evaporating from the soil and surface waters much more rapidly than in the past, which may lead to drought and to other problems related to water consumption.

The construction of dams and canals for irrigation, beyond the beneficial effect it has, changing the way water flows in a certain area, disrupts the natural water cycle. For example, dams can prevent water from flowing naturally into rivers and affect water quality, and irrigation canals can reduce water levels in rivers and wetlands, thus affecting ecosystems.

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Deforestation and changes in land use generate changes in the way water is absorbed by soil and vegetation. For example, cutting down forests can reduce the soil's ability to retain water, resulting in flooding and surface water runoff.

The presence of chemicals, waste and other materials in surface waters can affect the quality and integrity of aquatic ecosystems, thereby disrupting the water cycle. For example, pesticides and other chemicals (such as chemical fertilizers) used in agriculture can reach groundwater and surface water, affecting aquatic life and reducing the water's ability to be used for human or agricultural purposes.

Pesticides are chemical substances with complex and stable structures in the natural environment, non-biodegradable and widely used in agriculture to prevent or control pests and, implicitly, plant diseases. Pesticides include insecticides, fungicides, rodenticides, herbicides and other pest control agents. Although the use of pesticides can be effective in protecting agricultural crops against pests, in high concentrations, or following bioaccumulation in living organisms, these substances can have negative effects on the environment and human health, primarily due to the fact that they are non-biodegradable. Pesticides can pollute soil, water and air, thus affecting flora and fauna and even contributing to climate change.

An important category of products that contribute to environmental pollution, as their presence leads to disturbances in natural circuits, is waste. The topic of waste is very widely addressed today, primarily due to legislative pressures. Currently, waste can be viewed from two opposite points of view: on the one hand, waste is an environmental problem, and on the other hand, it is, or can be, a source or raw material for other processes.

In the countryside, it is well known to use waste from food scraps and especially from animals as soil fertilizers. But it is also known that the excessive "fertilization" of the soil with animal droppings can lead to the contamination of surface and underground waters with nutrients, bacteria and viruses, or to the acidification of the soils on which they are applied.

Regardless of their origin, of the class in which they fall from a legislative point of view, waste can lead to serious environmental problems due to the substances they contain, or which are formed as a result of the (bio)chemical processes that occur as a result of storage .

Waste that is incinerated produces emissions of carbon dioxide and other gases that can be toxic, affect air quality and contribute to climate change. An example in this case is the burning of waste containing plastics, which by burning form extremely toxic chemical compounds, in the category of dioxins and furans.

Uncontrolled disposal of waste can lead to soil or surface water contamination with chemicals. For example, heavy metals or other hazardous substances can enter the soil and/or surface water from the waste, which can be absorbed by plants and affect the animals that feed on these plants. This can also lead to a decrease in soil fertility and serious environmental damage.

Improperly disposed waste can pollute groundwater by diffusing through the soil and leaching toxic substances into drinking water sources, leading to a decline in water quality, with negative impacts on human health and animals that

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depend on these water sources. Waste can affect wildlife by encouraging pests and other organisms that feed on waste. Animals can also be injured or killed by waste objects such as plastic or metal.

A category of waste materials should be mentioned in this context, which attracts more and more attention due to the problems it raises. It is about microplastics, those materials from products that are based on components belonging to plastic masses, and have small dimensions, below 5 mm. They can be released directly into the environment as a result of human activities (for example debris from the abrasion of tires while driving, from water resulting from washing clothes or from the use of personal care products) or they can be formed as a result of destruction, degradation or the decomposition of plastic products that already exist in the environment (for example "plastic" bags, various "plastic" containers or objects, improperly stored). Thanks to natural circuits, microplastics end up in natural waters, even in the oceans, where they are assimilated by living things and even by humans through the food chain. The effects of these microplastics are not yet fully known, but the alarm is being sounded, and efforts are being made at the European level to identify and prevent them.

(https://www.europarl.europa.eu/news/ro/headlines/society/20181116STO19217/microplasticele-surse-efecte-si-solutii).

The environment is therefore a very complex system, in which there are multiple interactions between natural components, interactions that are disturbed due to human activities, the knowledge of which is essential in preventing negative effects on the environment, in adopting practices that prevent or reduce (where if applicable) deterioration of environmental quality.

2.1.3 Institutions Responsible for Environmental Monitoring

Environmental monitoring is a complex activity that involves surveillance, forecasting, warning and intervention to systematically assess the dynamics of the qualitative characteristics of environmental elements, in order to know their quality status and ecological significance, their evolution and the social implications of the changes produced, followed by the necessary measures (Ordinance, 2005).

The environmental monitoring activity is a complex one, which follows well-established stages, schematically shown in Figure 4.

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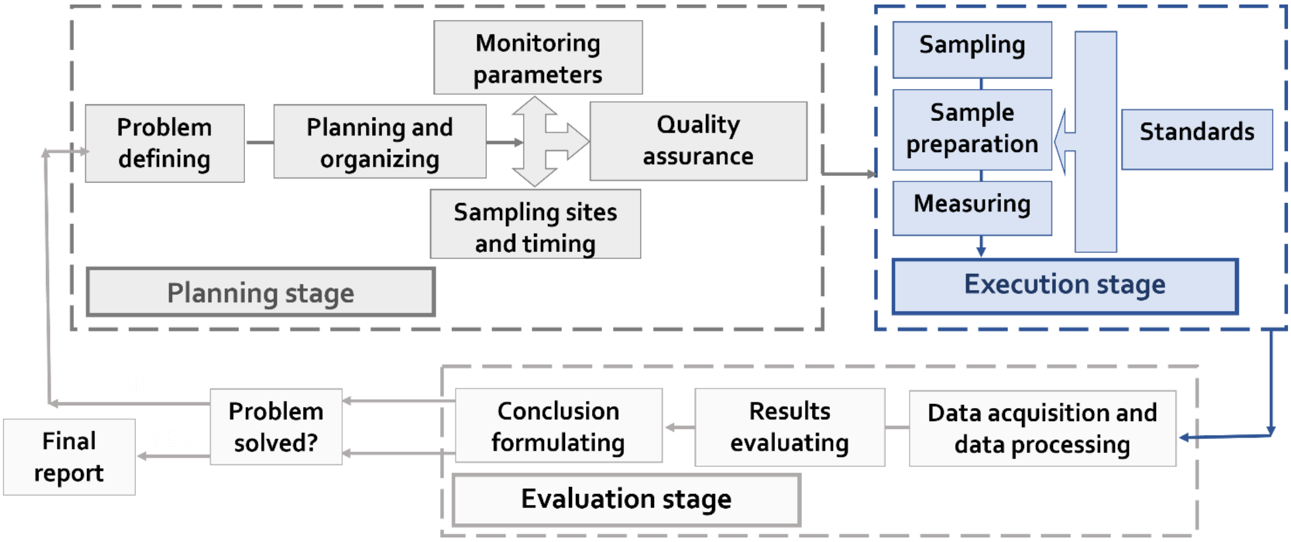

Figure 4. Stages of a monitoring programme (adaptted after https://toxoer.com/).

The planning stage comprises in activites like problem definition, planning and organisation. The monitoring parameters, sampling sites and sampling campaigns are established, based on the problem definition. All these activities are subject of quality assurance.

The execution stage envisages activities related to the environmental sample: sampling, sample preparation and measuring/ analyzing. For all these activities, specific standards are available and used.

The evaluation stage of environmental monitoring consists of studies to assess the presence and content of pollutants in the various environmental components (water, air, soil), by:

- data acquisition of on environmental quality, obtained by analysing parameters and indicators, on the basis of systematic measurements, with spatial and temporal coverage;
- data processing obtained from measurements and entering them into databases;
- after data processing, the results are evaluated and conclusions are formulated.

Institutions Responsible for Environmental Monitoring in Romania

Environmental monitoring programmes started from the need to know the relationship between the presence of pollutants in the environment and their influence on living organisms, dose-response studies. The processing of the information recorded in the monitoring databases, correlated with the results of toxicological studies, allowed the establishment of limit values for pollutant concentrations in the environment. As a result, it is extremely important to have databases that provide reliable information on environmental quality, which can be obtained from the implementation of a monitoring system at institutional/government level, or from research studies carried out by groups in research institutes, higher education institutes or non-governmental organisations. Of all these potential

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holders of information on environmental quality, only governmental institutions with responsibilities in this field will be presented.

The national authority responsible for environmental monitoring is the *Ministry of the Environment*, under the various names it has had under different governments (see references for examples of legislation issued), currently the **Ministry of the Environment, Water and Forests** (MMAP). In addition to the Ministry of the Environment, the main institutions responsible for environmental monitoring are:

- National Environmental Guard (GNM),
- National Agency for Environmental Protection (ANPM),
- National Administration of Romanian Waters (ANAR),
- National Research and Development Institute for Pedology, Agrochemistry and Environmental Protection (INCDPAPM).

The Ministry of the Environment, Water and Forests is the state authority for synthesis, coordination, regulation, monitoring, inspection and control in the areas of competence. At the level of MMAP, the national policy in the fields of environmental protection is carried out. The MMAP's areas of interest include those for the protection of environmental components (http://www.mmediu.ro/):

- industrial pollution control;
- air quality and environmental noise;
- water management;
- contaminated sites;
- soil and subsoil protection;
- nature protection.

The Ministry of the Environment is organized into several directorates, of which those with responsibility for the quality and monitoring of environmental components have been selected:

1. *General Directorate for Impact Assessment, Pollution Control and Climate Change*, with services for pollution control and air quality;
2. *General Directorate for Water*, with the departments for Water Protection and for International Waters;
3. *General Directorate for Waste, Contaminated Sites and Hazardous Substances*, with the Department for Contaminated Sites;
4. *General Directorate for Biodiversity*.

The **National Environmental Guard** is a public institution with legal personality, and operates as a specialized body of the central public administration, under the Ministry of Environment. The National Environmental Guard is a specialized inspection and control body that can take measures to sanction, suspend or close down activities, respectively, as a result of pollution and deterioration of the environment for failure to comply with the conditions imposed by regulatory acts. Although it has no direct activity in monitoring the quality of environmental factors, the National Environmental Guard is presented due to its responsibilities on inspection and control of compliance with quality conditions.

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The National Environmental Guard has the following units (https://www.gnm.ro/index.php):

- Bucharest Municipal Commissariat;
- the Commissariat of the Danube Delta Biosphere Reserve;
- 41 county commissariats.

The **National Agency for Environmental Protection** is a public institution with legal personality, which operates under the Ministry of Environment, Water and Forests and carries out activities for the protection of the principles and implementation of environmental protection legislation. ANPM monitors the status of the fulfilment of commitments in the field of environmental protection (those negotiated with the European Commission in the process of accession to the European Union), and monitors the fulfilment of reporting targets, in accordance with the European Union Directives, within the deadlines and with the targets set for this purpose (http://www.anpm.ro/).

ANPM subordinates 41 County Environmental Protection Agencies (APM), responsible for monitoring the air quality and certain categories of soils.

The National Environmental Protection Agency has the following structures that are responsible for environmental quality and monitoring:

- Pollution Control and Regulation Directorate, with the Industrial Emissions Service;
- *General Monitoring Directorate*, with the Directorate of Air Quality Assessment Centre and the Directorate of National Reference Laboratories (air, radioactivity, waste, noise and vibrations);
- Waste and Hazardous Chemicals, Soil and Subsoil Directorate, with the Soil and Subsoil Protection Office;
- Directorate for Nature Conservation, Biodiversity.

The organizational structures of the two institutions, MMAP and ANPM, show the areas of competence and responsibilities they have for environmental quality and monitoring.

The **National Administration of Romanian Waters (ANAR)** is a public institution of national interest, under the coordination of the central public authority, namely the Ministry of Environment, Waters and Forests. Unlike ANPM and GNM, which subordinate units at county level, ANAR is geographically organized, with 11 Water Basin Administrations (ABA), corresponding to the 11 river basins and their catchment areas (Figure 5) (https://rowater.ro/).

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Figure 5. Romanian river basins.

From the point of view of monitoring the quality of the environment, the National Administration of Romanian Waters is responsible for monitoring the quality of surface, underground, coastal, transboundary or waste waters on the territory of Romania.

Even though it is not a government agency, we have also included in this presentation The **National Research and Development Institute for Pedology, Agrochemistry and Environmental Protection** (also known by its old name and acronym, Research Institute for Pedology and Agrochemistry Bucharest - ICPA Bucharest).

The institute carries out research, technological development, technical assistance and consultancy, training, technology transfer, information services, documentation in the field of agriculture and environmental protection (https://icpa.ro/).

The inclusion of the institute in this presentation is due to the fact that its responsibilities include combating soil pollution, pedological and agrochemical studies, physical, chemical and microbiological analyzes of soil, plant material, sludge and water.

ICPA subordinates the National Network of Soil and Agrochemical Studies Offices (OSPA), 37 offices (https://icpa.ro/ospa/).

The National Agency for Environmental Protection, the National Administration of Romanian Waters and the National Research and Development Institute for Soil Science, Agrochemistry and Environmental Protection are responsible for issuing and submitting reports on environmental quality in Romania to the European Environment Agency - EEA (https://www.eea.europa.eu/en).

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Institutions Responsible for Environmental Monitoring in Iceland

Similar to the institutions responsible for monitoring the quality of the environment, at the governmental level in Romania, institutions also operate in Iceland. The responsible ministry is called the **Ministry of the Environment, Energy and Climate** (https://www.government.is/ministries/ministry-of-the-environment-energy-and-climate/), and has a series of agencies under its authority, from which we have selected those with responsibilities for monitoring the quality of the environment:

- Meteorological Office of Iceland (https://en.vedur.is/),
- Environment Agency of Iceland (https://ust.is/english/),
- National Planning Agency of Iceland (https://www.skipulag.is/en).

The Ministry of Environment, Energy and Climate formulates and implements the Icelandic government policy for environmental affairs and oversees nature-related affairs in Iceland. Among these concerns, we have selected the following:

- conservation and outdoor recreation,
- the national parks of Iceland,
- climate change,
- the protection of animals and wildlife management,
- pollution prevention,
- fire prevention,
- weather forecast and avalanches protection,
- forestry and soil conservation,
- and last but not least environmental monitoring and surveillance.

The previously mentioned concerns also define the fields of interest of the ministry, from which we have selected those that particularly respond to the surveillance of the quality of environmental factors (air, water, soil):

- air quality,
- biodiversity,
- environmental impact assessment,
- meteorology and natural hazards,
- prevention of pollution,
- soil conservation,
- waste management,
- waters.

The fields of activity and responsibilities of the governmental institutions in Romania and Iceland differ, adapted to the geographical, climatic and socio-economic conditions of the two countries.

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2.1.4 Environmental Monitoring – Air, Water and Soil

Complexity of characterizing environmental samples

Environmental quality is determined by analyzing samples taken from environmental components.

The **environmental sample** is a portion of a system (environmental component), representative of the place and time of sampling. Sample characterization consists of determining the components based on measurements:

- qualitative analysis (identification) - what components/substances are found in the sample;
- quantitative analysis - how much component/substance is present in the sample.

The qualitative characterization of environmental samples containing pollutants is complex, due to differences in the origin/ nature, state of aggregation, composition or solubility of the substances in the sample:

- nature of environmental samples can be mineral (inorganic) or biological (organic);
- aggregation state of environmental samples can be gaseous (atmospheric air, emissions, indoor air), liquid (surface or ground water, leachate) or solid (soil, biota, sludge, sediment);
- the composition of environmental samples can be mono-component (extremely rare/ utopian) or multi-component, i.e. relatively homogeneous (air, water) or heterogeneous mixtures (aerosols, smoke, water, sludge, sediment, soil, biota);
- solubility (hydrophobicity) refers to samples containing substances soluble in water or polar solvents (hydrophilic) or insoluble in water, soluble in non-polar organic solvents (hydrophobic).

The quantitative characterization of environmental samples consists of determining the concentration of the components (pollutant) in the environmental sample. The expression of the concentration is done by any form of reporting of the pollutant to the sample. As a rule, the pollutant is expressed in units of mass (nano grams - ng, micro grams - μg, milli grams - mg, or grams - g) and the sample is expressed in units of volume (cubic metres - m^3), capacity (litres – L) or mass (kilo grams - kg).

For environmental analyses, the pollutant concentration expression is used, according to regulations, such as:

1. mg pollutant/ m3 sample (mg/m3) - for gaseous, atmospheric air or indoor air samples;
2. mg pollutant/ mL sample (mg/mL) - for liquid, water samples;
3. mg pollutant/ kg sample (mg/kg) - for soil or biota samples, sediment, sludge.
4. parts per million - ppm, equivalent to mg/kg; μg/g (soil, biota...) or mg/L; μg/mL (water, other liquid samples);
5. parts per billion - ppb, equivalent to μg/kg; ng/g (soil, biota...) or μg/L; ng/mL (water, other liquid samples).

Given the different characteristics of the environmental components (propagation vectors, contact interfaces or biotransformation environment) the assessment of pollutants during the environmental quality surveillance (monitoring) programme is carried out following different assessment indicators (Table 2).

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Table 2. Assessment of environmental components.

No	Environmental components	Characteristics of environmental components	Evaluation of pollutants
1	air and water	vectors of propagation (transport of pollutants)	concentration, flow, dispersion speed
2	soil and subsoil	contact interfaces (among environmental components)	concentration, retention times, other retention indicators
3	biota	environment of biotransformation, bioaccumulation, biomagnification	concentration, age, bioaccumulation rate

The concentration of pollutants in environmental samples is a complex concept, which needs to be approached differently, depending on the source of the pollutants. Thus, for air and water, the concentration of pollutants released into the environment from different sources (called emissions), or the concentration of pollutants resulting from exposure to a combination of sources (called immissions) is assessed differently.

Emission monitoring networks assess direct discharges of pollutants to the atmosphere or wastewater discharges to natural sources (natural receptors).

Immission monitoring networks assess the presence of pollutants in atmospheric or indoor air as well as in water receiving streams.

As a result, domain-specific regulations apply, both at EU and national level (Romania). Monitoring of emissions or immissions differs by: parameters of interest, monitoring frequencies or accepted concentrations.

Consequently, there are different networks for monitoring emissions or immissions.

- networks intended for emissions monitoring evaluate the direct discharges of pollutants into the atmospheric air, or the discharges of waste waters into the natural ones, called natural receptors;
- networks intended for immissions monitoring evaluate the presence of pollutants in the atmospheric or indoor air, as well as in receiving natural water courses.

In the Romanian legislation, the term immission is not used, being evaluated as air/ water quality.

Air monitoring

Air monitoring – emissions

Air quality is determined by air emissions from stationary and mobile sources, mainly in urban agglomerations, and by long-range transport of air pollutants. At international level, Romania has signed the Convention on Long-Range Transboundary Air Pollution (CLRTAP) and the European Pollutant Release and Transfer Register (E-PRTR).

At national level, the protection of atmospheric air and prevention of its pollution is based on the provisions of Directive 2010/75 (Directive, 2010) on industrial emissions (Integrated Pollution Prevention and Control - IPPC), transposed into national legislation by Law 278/2013 (Law, 2013). Table 3 shows the total emission limit values (selection) according to Law 278/2013.

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Table 3. Total emission limit values (mg/Nm^3).

No.	Pollutant	Total emission limit value
1.	total particulate matter	30
2.	HCl	10
3.	HF	1
4.	NO_x (expressed as NO_2 equivalent)	500
5.	Cd+Tl	0.05
6.	Hg	0.05
7.	Sb+As+Pb+Cr+Cu+Mn+Ni+V	0.5
8.	dioxins and furans	0.1*
9.	SO_2	50
10.	gaseous or vaporous organic substances, expressed as total organic carbon (TOC)	10

* – ng/Nm^3 (nano grams per normal cubic meters)

Air quality monitoring

Directive 2008/50/EC on ambient air quality and cleaner air for Europe (Directive, 2008) is the framework legislation for air protection. The Directive was transposed into Romanian law by Law 104/2011 on ambient air quality (Law, 2011).

Law 104/2011 established the National System for Integrated Air Quality Assessment and Management (SNEGICA) to provide the organizational, institutional and legal framework for cooperation between public authorities and institutions with competences in the field, in order to assess and manage ambient air quality in a uniform manner throughout Romania, as well as to inform the population and European and international bodies on ambient air quality. (http://www.mmediu.ro/categorie/calitatea-aerului/56).

SNEGICA comprises two sub-systems, designed to assess immissions and emissions respectively: the National Atmospheric Pollutant Emissions Inventory System (SNIEPA) and the National Air Quality Monitoring System (SNMCA) http://www.anpm.ro/calitatea-aerului:

- SNIEPA provides the organisational, institutional and legal framework for carrying out inventories of pollutant emissions into the atmosphere, in a uniform manner, throughout Romania;
- SNMCA provides the organisational, institutional and legal framework for carrying out atmospheric air quality monitoring activities, in a unified manner, on the Romanian territory.

The assessment of atmospheric air quality is carried out by the following structures of the SNMCA:

- The National Network for Automatic Monitoring of Air Quality (RNMCA);
- Air Quality Assessment Centre (CECA) (www.calitateaer.ro).

The National Network for Automatic Monitoring of Air Quality comprises 148 continuous air quality monitoring stations. The stations have equipment for automatic measurement of concentrations of the main air pollutants: sulphur dioxide (SO_2), nitrogen oxides (NO_2/ NO, assessed as NO_2 equivalent), particulate matter (PM_{10}), carbon monoxide (CO), ozone

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(O_3), heavy metals (lead, arsenic, cadmium, nickel), benzene (C_6H_6), polycyclic aromatic hydrocarbons (PAH (as benzo[a]pirene equivalent), (https://www.calitateaer.ro/public/assessment-page/pollutants-page/? locale=ro) (Table 4).

Table 4. Air quality standards for atmospheric air (Law 104/2011).

Pollutant, um	Indicator	Value
SO_2, µg/m^3	hourly limit value for the protection of human health (1 hour average)	350
	daily limit value for the protection of human health (24 hours average)	125
	critical level for vegetation protection (average over 1 calendar year)	20
	alert threshold	500
NO_2 and NO, µg/m^3	hourly limit value for the protection of human health (1 hour average)	200
	daily limit value for the protection of human health (24 hour average)	40
	critical level for vegetation protection (average over 1 calendar year)	30
	alert threshold	400
PM_{10}, µg/m^3	daily limit value for the protection of human health (24 hour average)	50
	annual limit value for the protection of human health (average per 1 calendar year)	20
CO, mg/m^3	limit value for the protection of human health (maximum value of 8-hour averages)	10
O_3, µg/m^3	alert threshold	240
lead, µg/m^3	annual limit value for the protection of human health (average per 1 calendar year)	0.5
arsenic, ng/m^3	target value	6
cadmium, ng/m^3	target value	5
nickel, ng/m^3	target value	20
benzene, µg/m^3	annual limit value for the protection of human health (average per 1 calendar year)	5
benzo[a]piren, ng/m^3	target value	1

The Air Quality Assessment Center administers the information and data provided by the RNMCA. The measured data on air quality are collected and transmitted to the public information panels, and after the primary validation in the county centers (APM) they are transmitted for evaluation and certification to the CECA.

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Water monitoring

The quality of water is determined by its organoleptic, physical, chemical, biological and bacteriological characteristics. Similar to air quality monitoring, water quality in Romania is also monitored at the level of immissions (natural waters) and emissions/effluents (discharges from different emissions, as residual water, waste water), for which there are different regulations, both at EU and national level.

Romania's accession to the EU required the implementation of 18 Directives and 2 Decisions in the water sector. According to the EU Directives and implementing rules, a new monitoring and assessment strategy for surface and groundwater is applied, based on a new concept of integrated water monitoring.

Water monitoring – emissions

The Directive 91/271/EEC (Directive, 1991) concerning urban waste water treatment was transposed into Romanian legislation with the Government Decision (GD) 188/2002 (Decision, 2002) for the approval of some rules on the conditions for the discharge of wastewater into the aquatic environment (with the annexes of interest NTPA-001/2002 and NTPA-002/2002).

For the assessment of the wastewater subsystem, GD 188/2002 (Decision, 2002) approving some rules on the conditions of discharge of wastewater into the aquatic environment is applied, which has two components of interest for this study: The Regulation on the establishment of pollutant load limits of industrial and urban wastewater at discharge into natural receptors (NTPA-001/2002, updated in 2007) and the Regulation on the conditions of wastewater discharge into sewerage networks of municipalities and directly into treatment plants (NTPA-002/2002, updated in 2007). From Table 5 it can be seen that the assessment of quality indicators differs in the two regulations, both in indicators type and values.

Table 5. Quality standards for wastewater discharge into the aquatic environment (GD 188/2002).

Quality indicators	MU	NTPA 001/2002	NTPA 002/2002
temperature	°C	35	40
pH	units	6.5-8.5	6.5-8.5
suspended solids	mg/L	35 (60) *	350
CBO_5	mg O_2/L	25	300
CCOCr	mg O_2/L	125	500
ammoniacal nitrogen (NH_4^+)	mg/L	2 (3) *	30
total nitrogen (N)	mg/L	10 (15) *	NN**
nitrates (NO_3^-)	mg/L	25 (37) *	NN
nitrites (NO_2^-)	mg/L	1 (2) *	NN
sulfides and hydrogen sulfide	mg/L	0.5	1
sulfites (SO_3^{2-})	mg/L	1	2
sulfates (SO_4^{2-})	mg/L	600	600
water vapor extractable phenols	mg/L	0.3	30

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substances extractable with organic solvents	mg/L	20	30
petroleum products	mg/L	5	NN
total phosphorus (P)	mg/L	1 (2) *	5
synthetic detergents (biodegradable)	mg/L	0.5	25
total cyanides (CN^-)	mg/L	0.1	1
free residual chlorine (Cl_2)	mg/L	0.2	0.5
chlorides (Cl^-)	mg/L	500	NN
fluoride (F^-)	mg/L	5	NN
filtered residue at 105°C	mg/L	2000	NN
arsenic (As^{3+})	mg/L	0.1	NN
aluminum (Al^{3+})	mg/L	5	NN
calcium (Ca^{2+})	mg/L	300	NN
lead (Pb^{2+})	mg/L	0.2	0.5
cadmium (Cd^{2+})	mg/L	0.2	0.3
total chromium (Cr^{3+}. Cr^{6+})	mg/L	1	1.5
hexavalent chromium (Cr^{6+})	mg/L	0.1	0.2
total iron (Fe^{2+}. Fe^{3+})	mg/L	5	NN
copper (Cu^{2+})	mg/L	0.1	0.2
nickel (Ni^{2+})	mg/L	0.5	1
zinc (Zn^{2+})	mg/L	0.5	1
mercury (Hg^{2+})	mg/L	0.05	NN
silver (Ag^+)	mg/L	0.1	NN
molybdenum (Mo^{2+})	mg/L	0.1	NN
selenium (Se^{2+})	mg/L	0.1	NN
total manganese (Mn)	mg/L	1	2
manganese (Mg^{2+})	mg/L	100	NN
cobalt (Co^{2+})	mg/L	1	NN

* values to be respected for discharges in sensitive areas; ** - NN is not standardized.

Water quality monitoring

By the Ordinance of the Minister of Environment and Water Management 31/2006 (Ordinance, 2006), the Integrated Water Monitoring System in Romania (SMIAR) was established, which supervises the quality of water through the territorial units of the Romanian National Water Administration (https://rowater.ro/). The system includes 6 monitoring subsystems, of which those corresponding to 1-5 are from natural sources and the 6 one is from pollution sources (emissions):

1. flowing surface waters;
2. lakes (natural and reservoirs);
3. transient waters (rivers and lakes);
4. coastal waters;
5. underground waters/ groundwater;

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6. waste waters/ sewage/ effluents.

For water quality monitoring, the **Directive 2000/60/EC** establishing a framework for Community water policy (Directive 2000) was transposed into the Romanian legislation by the **Law 107/1996** – Romanian water law (Law, 1996) and the **Order of the Ministry of the Environment and Water Management 161/2006** (Order, 2006) for the approval of the Normative on the classification of surface water quality in order to establish the ecological status of water bodies. The Order 161/2006 establishes 5 ecological statuses for rivers and natural lakes: very good (I), good (II), moderate (III), poor (IV) and bad (V), based on biological, hydromorphological and physico-chemical quality elements (Table 6).

Table 6. Classification of surface waters into quality classes according to limit values of physical-chemical indicators.

Physical-chemical indicators	**MU**	**Limit values per quality class**				
		I	**II**	**III**	**IV**	**V**
physical indicators						
temperature	°C	it is not normalized				
pH	units	6.5 – 8.5				
oxygen regime						
dissolved oxygen	mg O_2/L	9	7	5	4	< 4
CBO_5	mg O_2/L)	3	5	7	20	> 20
CCO-Mn	mg O_2/L	5	10	20	50	> 50
CCO-Cr	mg O_2/L	10	25	50	125	> 125
nutrients						
ammonium (NH_4^+)	mg N/L	0.4	0.8	1.2	3.2	> 3.2
nitrites (NO_2^-)	mg N/L	0.01	0.03	0.06	0.3	> 0.3
nitrates (NO_3^-)	mg N/L	1	3	5.6	11.2	> 11.2
total nitrogen (N)	mg N/L	1.5	7	12	16	> 16
orthophosphate (PO_4^3)	mg P/L	0.1	0.2	0.4	0.9	> 0.9
total phosphorus (P)	mg P/L	0.1	0.2	0.4	1	> 1
chlorophyll A	µg/L	25	50	100	250	> 250
Salinity (general ions)						
dry filterable residue at 105^{0}C	mg/L	500	700	1000	1300	> 1300
chlorides (Cl^-)	mg/L	25	50	250	300	> 300
sulfates (SO_4^{2-})	mg/L	60	120	250	300	> 300
Ca^{2+}	mg/L	50	100	200	300	> 300
Mg^{2+}	mg/L	12	50	100	200	> 200
Na^+	mg/L	25	50	100	200	> 200
Specific toxic pollutants of natural origin						
total Cr ($Cr^{3+.}$ Cr^{6+})	µg/L	25	50	100	250	> 250
Cu^{2+}	µg/L	20	30	50	100	> 100
Zn^{2+}	µg/L	100	200	500	1000	>1000
As^{3+}	µg/L	10	20	50	100	> 100
Ba^{2+}	mg/L	0.05	0.1	0.5	1	> 1
Se^{4+}	µg/L	1	2	5	10	>10
Co^{3+}	µg/L	10	20	50	100	>100

Pb^{2+}	µg/L	5	10	25	50	> 50
Cd^{2+}	µg/L	0.5	1	2	5	> 5
total Fe (Fe^{2+}, Fe^{3+})		0.3	0.5	1	2	> 2
Hg^{2+}	µg/L	0.1	0.3	0.5	1	> 1
total Mn (Mn^{2+}, Mn^{7+})		0.05	0.1	0.3	1	> 1
Ni^{2+}	µg/L	10	25	50	100	> 100
Other relevant organic chemical indicators						
phenol	µg/L	1	5	20	50	> 50
active anionic detergents	µg/L	100	200	300	500	> 500
adsorbed organic halogenated compounds (AOX)	µg/L	10	50	100	250	> 250

Soil monitoring

Among the responsibilities of the General Directorate for Waste, Contaminated Sites and Hazardous Substances, within the MMAP, we mention http://www.mmediu.ro/categorie/situri-contaminate/23:

- drafting the legislative package on soil and geological environment protection;
- identification of the financial resources needed to implement the National Strategy and the National Action Plan for the Management of Contaminated Sites in Romania.

Soil monitoring is of interest, mainly for monitoring the quality of soils on which crops are grown, i.e. agricultural soils and forest soils. As a result, soil quality studies can be carried out by the following institutions (https://www.madr.ro/calitatea-solului.html):

- Research Institute for Pedology and Agrochemistry Bucharest (ICPA);
- County Soil and Agrochemical Survey Offices (OSPA, 37 offices nationwide);
- National Forestry Research and Development Institutes (INCDS), also known as Forestry Research and Development Institutes (ICAS);
- National Agency for Environmental Protection (ANPM).

The county agencies (APM) monitor, in particular, soils in areas adjacent to landfills (waste, sludge, tailings, ashes), or areas adjacent to industrial activities, or sites with historical contamination.

The Directive 86/278/EEC on the protection of the environment, and in particular of the soil, when sewage sludge is used in agriculture is among the first EU regulations to allow for the assessment of soil quality (Directive, 1986). The Directive was transposed into Romanian law by the Order of the Ministry of Agriculture, Forestry, Water and the Environment (OM 49/2004) approving the Technical Standards for the protection of the environment and in particular of soils when sewage sludge is used in agriculture (Order, 2004).

The annexes of the Directive and OM 49/2004 respectively indicate both limit values for heavy metal concentrations in soils where sludge is applied (Table 7) and limit values for concentrations of heavy metals and other substances allowed in sludge for use in agriculture (Table 8).

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Table 7. Accepted pollutant concentrations in a representative soil sample (pH greater than 6.5).

Pollutant	Concentration (mg/kg in dry substance)	
	Directive 86/278/CEE (*)	OM 49/2004
cadmium	1-3	3
copper	50-140 (**)	100
nickel	30-75 (**)	50
lead	50-300	50
zinc	150-300 (**)	300
mercury	1-1.5	1
chromium	– (***)	100

* - Member States were able to authorise an exceedance of previously set limit values; ** - Member States were able to authorise an exceedance of limit values for these parameters for soils with a constant pH greater than 7; *** - it was not possible to set limit values for chromium at that stage.

Table 8. Accepted pollutant concentrations in sludge for agricultural use.

Poluant	Concentration (mg/kg in dry substance)	
	Directive 86/278/CEE (*)	OM 49/2004
cadmium	20-40	10
copper	1000-1750	500
nickel	300-400	100
lead	750-1200	300
zinc	2500-4000	2000
mercury	16-25	5
chromium	(*)	500
cobalt	–	50
arsenic	–	10
sum of organohalogenated compounds (AOX)	–	500
polycyclic aromatic hydrocarbons (PAH) (**)	–	5
polychlorinated biphenyls (BPC) (***)	–	0.8

* – it was not possible to set limit values for chromium at that stage; ** – sum of the following substances: anthracene, benzoanthracene, benzofluoranthene, benzoperylene, benzopyrene, chrysene, fluoranthene, indeno (1,2,3) pyrene, phenanthrene, pyrene; *** – the sum of the compounds with the numbers (congeners) 28, 52, 101, 118, 138, 153, 180.

By the joint Order of the Ministry of the Environment and Water Management and the Ministry of Agriculture, Forestry and Rural Development, OM 197/2005, the organization of the **National Integrated Soil Monitoring System** was approved, within the structures of the National Integrated Monitoring System of Water Resources and Protected Areas, managed by the National Research-Development Institute for Pedology, Agrochemistry and Environmental Protection

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(ICPA). As a result, the supervision and control program is conducted in collaboration between the institute and the Romanian National Water Administration.

On the other hand, the National Agency for Environmental Protection, among other objectives, has the Identification of contaminated sites by type of polluting activities.

Among the ANPM's powers and competences, regarding soils and subsoils, we can also mention:

- creates the database regarding the situation of contaminated areas at the national level;
- creates the database for the management of contaminated sites;
- participates in the organization of soil and subsoil monitoring activities, as well as the quality of non-renewable natural resources.

The county agencies (APM) are monitoring, in particular, the soils in the areas adjacent to some deposits (waste, sludge, tailings, ashes), or areas adjacent to industrial activities, or sites with historical contamination.

The Order of the Ministry of Water, Forests and Environmental Protection 756/1997, approving the regulation on environmental pollution assessment (Order, 1997):

- defines: alert threshold, intervention threshold, sensitive land use, less sensitive use;
- provides limits of pollutant concentration accepted for different purposes: for sensitive or less sensitive land use.

The **alert threshold** is given by pollutant concentrations in air, water, soil or in emissions/discharges that indicate that contamination exists, but within acceptable risk limits. The alert threshold warns the competent authorities of a potential environmental impact, which triggers further monitoring to define possible hazards and/ or reduce pollutant concentrations in emissions/ discharges.

The **intervention threshold** is given by concentrations of pollutants in the air, water, soil or in emissions/discharges that generate an unacceptable degree of risk to human health and the environment, indicating a state of danger that must be removed. When the intervention threshold is reached, the competent authorities will order risk assessment studies to be carried out, usually no further investigations are required to certify the state of danger, and the pollutant concentrations in emissions/ discharges are reduced directly.

Sensitive land uses (S) are residential and recreational uses, agricultural uses, protected areas or restricted health areas, as well as land areas planned for such uses in the future.

Less sensitive land uses (NS) include all existing industrial and commercial uses as well as land areas planned for such uses in the future.

Thus, OM 756/1997 indicates three categories of reference values for trace chemical elements in soil: normal value in soil, alert threshold, intervention threshold, the last two for sensitive use and less sensitive use respectively. All these limits are given for the following categories of pollutants: inorganic compounds (Table 9), aromatic and polyaromatic hydrocarbons, petroleum hydrocarbons (Table 10), or organochlorine and triazine pesticides (Table 11).

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Table 9. Reference values for trace chemicals in soils – inorganic compounds.

Compound	Concentration (mg/kg in dry substance)				
	Normal value in soil	Alert threshold/ type of use		Intervention threshold/ type of use	
		S	NS	S	NS
Ag	2	10	20	20	40
As	2	10	20	20	40
soluble B	1	2	5	3	10
Ba	200	400	1000	625	2000
Be	1	2	7.5	5	15
Cd	1	3	5	5	10
Co	15	30	100	50	250
total Cr	30	100	300	300	600
Cr VI	1	4	10	10	20
Cu	20	100	250	200	500
Hg	0.1	1	4	2	10
Mn	900	1500	2000	2500	4000
Mo	2	5	15	10	40
Ni	20	75	200	150	500
Sb	5	12.5	20	20	40
Se	1	3	10	5	20
Sn	20	35	100	50	300
Pb	20	50	250	100	1000
Tl	0.1	0.5	2	2	5
V	50	100	200	200	400
Zn	100	300	700	600	1500
cyanide (free)	<1	5	10	10	20
cyanide (complex)	<5	100	200	250	250
sulfocyanides	<0.1	10	20	20	40
Fluorine	-	150	500	300	1000
Bromine	-	50	100	100	300
elemental sulfur	-	400	5000	1000	20000
sulphides	-	200	400	1000	2000
sulfates	-	2000	5000	10000	50000

S - sensitive uses; NS - less sensitive uses.

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Table 10. Reference values for trace chemicals in soils – aromatic and polyaromatic hydrocarbons, petroleum hydrocarbons.

Traces of pollutants	Concentration (mg/kg in dry substance)				
	Normal value in soil	Alert threshold/ type of use		Intervention threshold/ type of use	
		S	NS	S	NS
I. Mononuclear aromatic hydrocarbons					
benzene	< 0.01	0.25	0.5	0.5	2
ethylbenzene	< 0.05	5	10	10	50
toluene	< 0.05	15	30	30	100
xylene	< 0.05	7.5	15	15	25
II. Hydroxylbenzenes					
phenol	< 0.02	5	10	10	40
catechol	< 0.05	5	10	10	20
resorcin	< 0.05	2.5	5	5	10
hidrochinonă	< 0.05	2.5	5	5	10
cresol	< 0.05	2.5	5	5	10
total aromatic hydrocarbons (AH)	< 0.05	25	50	50	150
III. Polynuclear aromatic hydrocarbons (PAH)					
anthracene	< 0.05	5	10	10	100
benzoanthracene	< 0.02	2	5	5	50
benzofluoranthrene	< 0.02	2	5	5	50
benzoperylene	< 0.02	5	10	10	100
benzopyrene	< 0.02	2	5	5	10
chrysene	< 0.02	2	5	5	50
fluoranthrene	< 0.02	5	10	10	100
indeno(1.2.3)pyrene	< 0.02	2	5	5	50
naphthalene	< 0.02	2	5	5	50
phenanthrene	< 0.05	2	5	5	50
pyrene	< 0.5	5	10	10	100
total PAH	< 0.1	7.5	25	15	150
IV. Petroleum hydrocarbons					
total petroleum hydrocarbons	< 100	200	1000	500	2000

S - sensitive uses; NS - less sensitive uses

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Table 11. Reference values for traces of chemical substances in soils – organochlorine and triazine pesticides.

Traces of pollutants	Concentration (mg/kg in dry substance)				
	Normal value in soil	Prag de alertă/ Tip de folosinţă		Normal value in soil	
		S	NS	S	NS
I. Organochlorine pesticides					
suma DDT	< 0.15	0.5	1.5	1	4
DDT	< 0.05	0.25	0.75	0.5	2
DDE	< 0.05	0.25	0.75	0.5	2
DDD	< 0.05	0.25	0.75	0.5	2
HCH	< 0.005	0.25	0.75	0.5	2
alfa-HCH	< 0.002	0.1	0.3	0.2	0.8
beta-HCH	< 0.001	0.05	0.15	0.1	0.4
gama-HCH	< 0.001	0.02	0.05	0.05	0.2
delta-HCH	< 0.001	0.05	0.15	0.1	0.4
total organochlorine pesticides	< 0.2	1	2	2	5
II. Triazines pesticides					
total triazines	< 0.1	1	2	2	5

S - sensitive uses; NS - less sensitive uses

Conclusions

Starting from the definition of terms such as the environment, environmental quality, pollutant, pollution, the main pollution sources and specific pollutants from air, water and soil were presented in the present teaching module unit. The unit continued with the schematic presentation of the stages of a monitoring program, the institutions responsible for environmental monitoring in Romania and in Iceland, followed by the systems for monitoring environmental components (air, water and soil), with reference to the main European and national regulations in the field.

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