Environmental pollution assessment

Lecturer – Nikitina Maria, PhD

MODULE’S ANNOTATION

Number of ECTS credits allocated:	***3 ECTS***
classroom load	***1 ECTS (3L, 5lab (8 hours)***
independent load	***2 ECTS***
Semester/trimester when the course unit is delivered	***3 semester***
Name of lecturer(s)	***Nikitina Maria*** ***m.nikitina@narfu.ru***
Chair	***Chemistry and chemical ecology***
High School	***High School of Natural Science and Technologies***
Type of course unit (compulsory, optional)	***Compulsory***
Mode of delivery (face-to-face, blended, distance learning)	***face-to-face***

Course content:

1. Regulation of environmental quality.

- Key indicators and standards of air quality. Atmospheric features as an object of environmental monitoring.
- Key indicators and quality standards of the hydrosphere. Features of the natural waters as an object of environmental monitoring.
- Key indicators of soil quality and standards. Soil characteristics as the object of environmental monitoring.

2. Basic methods of environmental analysis

- Sampling and sample preparation. Analysis of air, water, soil, sediment. Regulatory framework.
- Basic methods of analysis of environmental objects (spectrophotometric, electrochemical , chromatographic) .

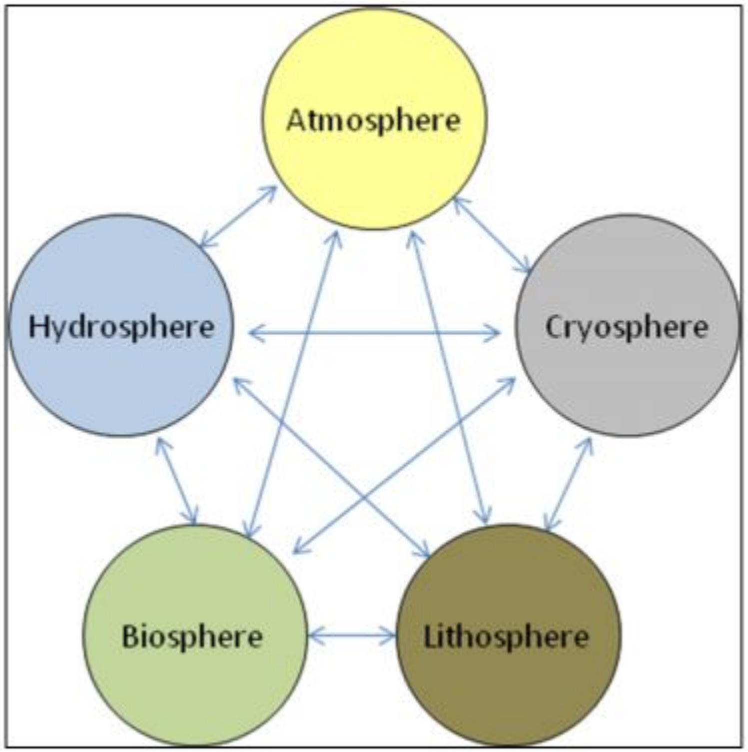
Environmental monitoring

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

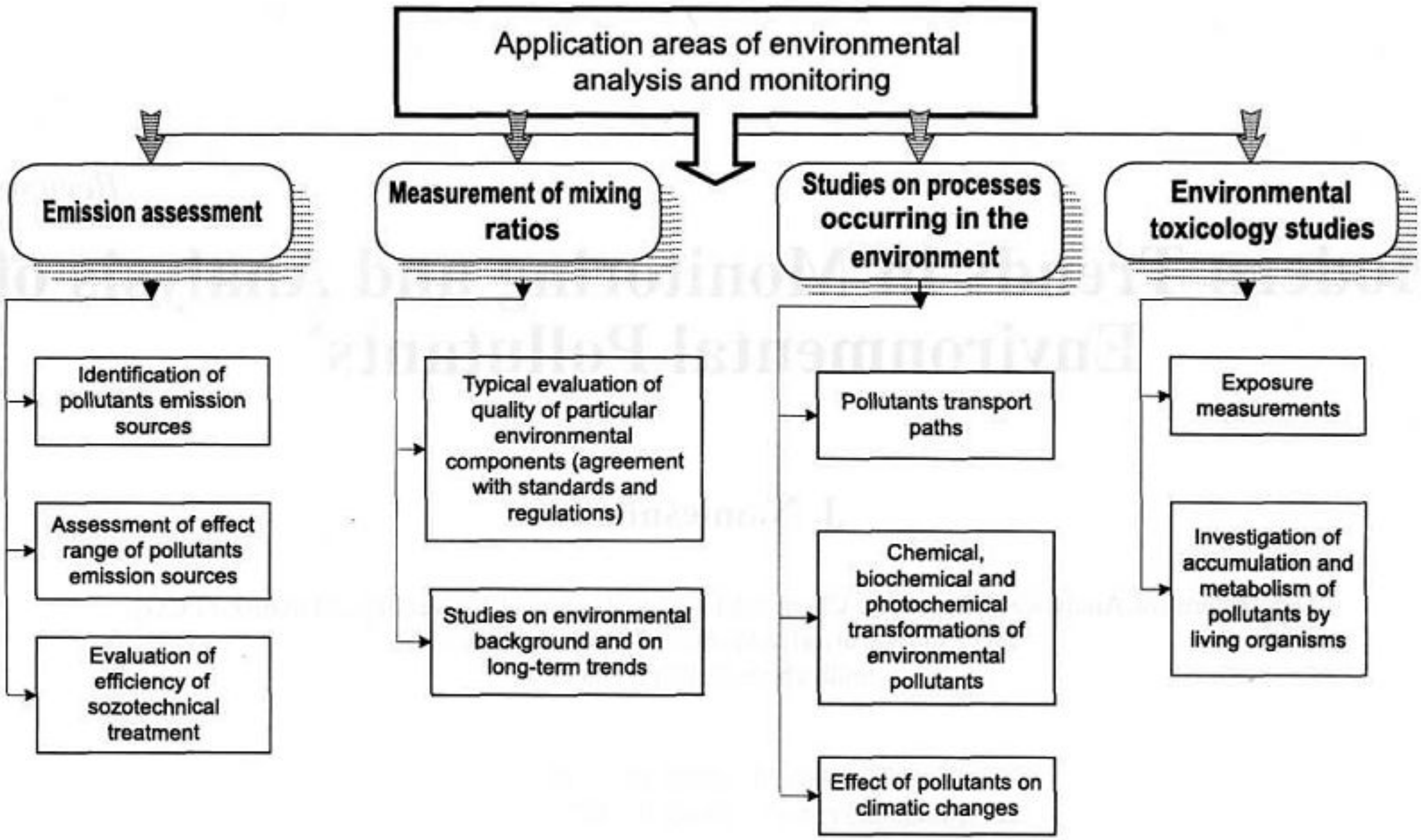
Monitoring can be conducted for a number of purposes, including:

- to establish environmental “baselines, trends, and cumulative effects” (Mitchell, 2002, pg. 318),
- to the 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).

The five spheres of the Earth System



Application areas of environmental analysis and monitoring.



BOX 1.1 *Knowledge-Based Regulation and Benefits of Environmental Monitoring*

Protection of public water supplies: Including surface and groundwater monitoring; sources of water pollution; waste and wastewater treatment and their disposal and discharge into the environment

Hazardous, nonhazardous and radioactive waste management: Including disposal, reuse, and possible impacts to human health and the environment

Urban air quality: Sources of pollution, transportation, and industrial effects on human health

Natural resources protection and management: Land and soil degradation; forests and wood harvesting; water supplies, including lakes, rivers, and oceans; recreation; food supply

Weather forecasting: Anticipating weather, long- and short-term climatic changes, and weather-related catastrophes, including floods, droughts, hurricanes, and tornadoes

Economic development and land planning: Resources allocation; resource exploitation

Population growth: Density patterns, related to economic development and natural resources

Delineation: Mapping of natural resources; soil classification; wetland delineation; critical habitats; water resources; boundary changes

Endangered species and biodiversity: Enumeration of species; extinction, discovery, protection

Global climate changes: Strategies to control pollution emissions and weather- and health-related gaseous emissions

Scales of space.

GLOBAL–Earth(>10,000km)

MESO–Continent, country, state (>100km)

INTERMEDIATE–Watershed, river, lake(>1km)

FIELD–Agric. field, waste site (>1m)

MACRO–Animal, plant, soil clod (>1mm)

MICRO—Soil particle, fungi, bacteria (>1μm)

ULTRA-MICRO—Virus, molecules (>1nm)

ATOMIC–Atoms, subatomic particles (<1nm)

Scales of time.

GEOLOGIC (> 10,000 years)

GENERATION-LIFETIME (20-100 years)

ANNUAL (>1 year)

SEASONAL (>4 months)

DAILY (>24 hours)

HOURLY (>60 minutes)

INSTANTANEOUS (<1second)

Monitoring

1. Methodical requirements:

- high sensitivity of measurements,
- producing analytical information continuously in real time or with only negligible delay,
- high resolution of results characterized by short response time of the instruments,
- long time of autonomous operation.

Monitoring

2. Technical requirements:

- automatic zeroing and instrument calibration,
- protection against abrupt power failure,
- equipping instruments with:
- independent power supply,
- calibration module,
- system for filling and refilling solution and reagents (electronic monitoring of liquid level),
- system protecting flames from extinguishing (monitors based on the use of FID and FPD detectors),
- possibility of automatic regeneration or exchange of filters.

Classification of Trends in Monitoring Environmental Analytics

1. methodological trends in environmental analytics and monitoring:

- dissemination of speciation analysis;
- use of total parameters to assess environmental pollution level;
- tendency to determine lower and lower analyte concentrations in samples of very complex matrix;
- search for methods applicable for determination of many analytes in the same sample during a single analytical process;
- introduction of solventless techniques to analytical practice;
- increase in significance of bioanalysis and biomonitoring;

Classification of Trends in Monitoring Environmental Analytics

2. trends in the area of instrumentation:

- new designs of sensors and detectors;
- introduction of coupled methods to analytical practice;
- computerization, automation and robotization of monitoring and measuring instruments;
- use of expert systems;
- miniaturization of measuring systems (introduction of "electronic nose" and "electronic tongue") to analytical practice;
- design of passive devices and devices for conducting measurements in situ, including direct reading of analyte amount (concentration);
- development of remote control techniques for assessment of environmental pollution;
- use of cine-camera techniques, photographic documentation and geographical information systems in assessment quality.

Present methods and techniques of determination of total parameters can be classified:

1. Area of practical use
- atmospheric air studies,
- water and wastewater studies,
- soil and sediment studies.

2. The parameter determined
- total content of a given element in all pollutants present in a sample,
- content of a given element in a given group of pollutants present in a sample.

3. Way of conducting chemical analysis
- directly in a sample,
- after analytes extraction (extract analysis).

4. Method of extraction of analytes from the sample studied.

5. Mineralization technique before final analysis
- dry techniques based on catalytic oxidation at high temperature,
- wet oxidation at low temperature (with oxidant addition).

EQS

- Environmental quality standards (EQS) mandate the level of permissible pollution in order to protect human health and natural ecosystems. Most standards are derived based on the assumption of **zero risk** for human health and apply to the quality of water, air, soil, and foodstuffs.
- Russia started creating hygiene standards in 1922 (at the beginning of the Soviet period) when the first three criteria pollutants were identified and regulated values for the working area were set.
- In 1925, there were as many as ten standards. In the 1940s, formulation of maximum allowable concentrations (MACs) started for chemical substances in ambient air, then in drinking water, fishing waters, soil, and foodstuffs.
- In addition to MACs, the so-called “tentatively safe exposure levels” (TSEL) are used as temporarily allowable concentrations. Their values are estimated, unlike the MACs that are determined experimentally.

Regulating quality of the environment

- Environmental regulation implies measurement of a permissible environmental load. A load is considered **permissible** if it **does not result** in deviations of the status of the ecosystem, exceeding natural changes, and consequently leading to undesirable effects on living organisms and to worse environment quality.
- Both environmental and sanitary and hygiene regulation are based on knowledge of effects, produced by various influencing factors on living organisms. These factors may be of physical (radiation, electromagnetic radiation, etc.), chemical and biological nature.

Regulating quality of the environment

- Establishment of environment quality and quality of food is based on the impact **threshold concept**.

- *Threshold concentration is a minimum dose of a substance, whose impact may cause changes in an organism beyond physiological and adaptive reactions, or latent (temporally compensated) pathology.*

- Threshold concentration (or threshold impact in general) may result in a response, which cannot be compensated through mechanisms, maintaining internal balance of an organism.

Regulating quality of the environment

Sanitary and hygiene regulation is based on the notion of **maximum permissible concentration**.

- ***Maximum permissible (allowable) concentrations (MPCs)*** *are standards, establishing concentrations of a harmful substance per volume unit (of air, water), mass unit (food, soil) or surface unit (skin of employees), which produce almost no impact on health and have no adverse effect on next generations, when in contact with a human being in the course of a certain period of time.*

Regulating quality of the environment

Therefore sanitary and hygiene regulation covers all environments, various processes, which allow harmful substances in an organism, though these regulations *rarely cover combined impact* (meaning parallel or consecutive effects of several substances through a single entry channel) and covers neither effects of *integrated impact*, (meaning harmful substances entering an organism through different channels, i.e. air, water, food, skin), nor a *combination of effects* of different characters (physical, chemical, biological).

Regulating quality of the environment

- For substances, on which we have not obtained sufficient information, **temporary permissible concentration (TPC)** rates can be calculated and established for the next two or three years.

Regulating quality of the environment

- Development of sanitary and hygiene standards is within the competence of the Federal Service for Consumer Protection and Human Well-Being of the RF Ministry of Health. Lists of maximum permissible concentration rates and other standards are published in special collections of sanitary standards and rules (SanPiN).

Toxic dose

- It should be noted, that some authors introduce other characteristics, interpreting **toxicity** as the ability of certain substances to cause alteration of physiological functions, which, in its turn, leads to diseases (intoxications, poisoning) or, in grave cases, to death. In other words, toxicity is the level of fatality a substance implies.
- The rate of toxicity is usually characterized through the volume **of toxic dose**, i.e. the amount of a substance (projected over a mass unit of an animal or a human being), which produces a certain toxic effect. The lesser the toxic dose is, the higher the toxicity.

Toxic dose

- There are **median lethal doses (LD 50), absolutely lethal doses (LD 100), minimal lethal doses (LD 0-10),** etc. The figures in the index stand for the likelihood (%) of a certain toxic effect, i.e. the likelihood of death in the group of test animals, in this case. It should be noted, that the amount of toxic doses depends on how a substance enters an organism. The LD50 dose (death of the half of test animals) gives a more certain characteristics of toxicity, than LD100 or LD0 doses. Depending on the species, selected for the tests, the ways toxic agents penetrate an organism, toxic doses and the position of substances on the toxicity scale **may vary**.

Comparing the toxicity of chemicals

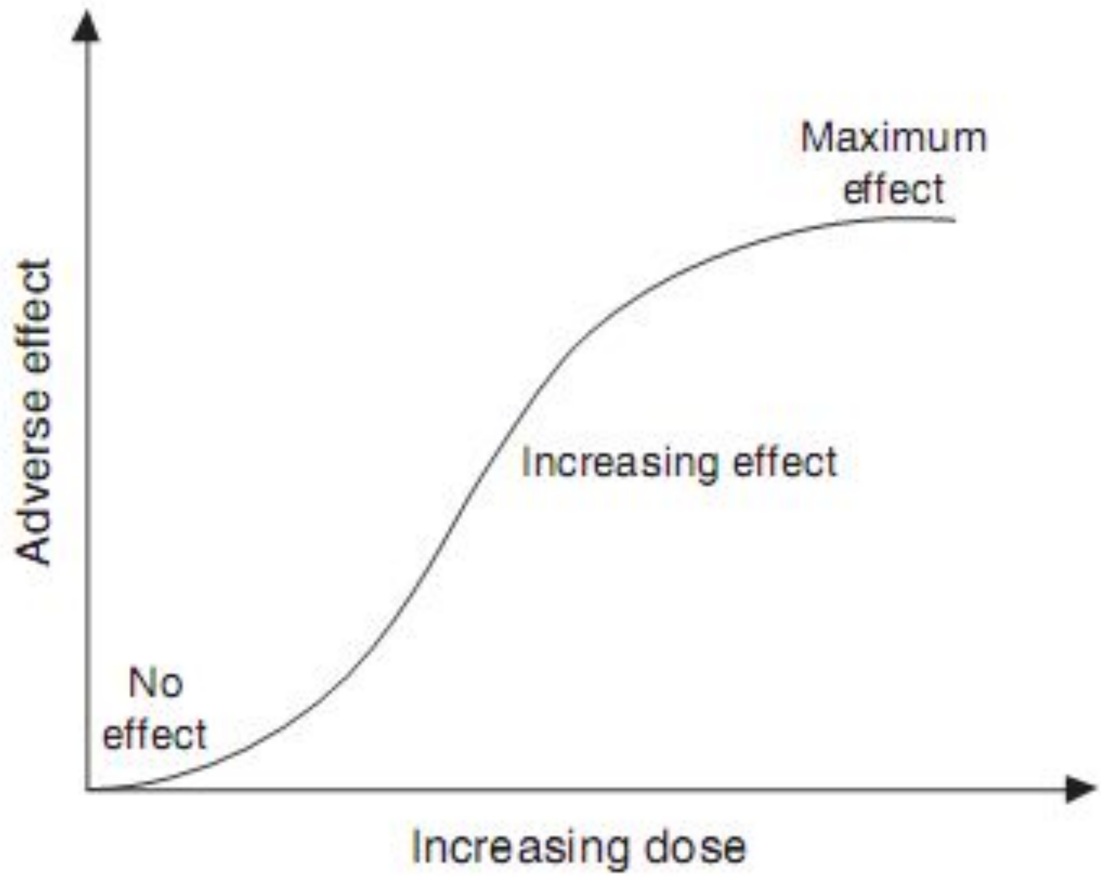
Toxicity	LD_{50}[a]	Examples
Slightly toxic	500–5000	Aspirin, vanillin, salt
Moderately toxic	50–500	Phenobarbital, caffeine, nicotine, warfarin
Highly toxic	1–50	Sodium cyanide, vitamin D, parathion
Supertoxic	Less than 0.01–1	Atropine, nerve poisons 2,3,7,8-TCDD
Biotoxins	Much less than 0.01	*Botulinum* toxin, ricin (in castor oil beans)

[a] LD_{50} is the dose killing 50% of the animals exposed to it. Here LD_{50} is expressed as milligrams per kilogram (mg/kg) body weight. Adapted from Crone, H. D. *Chemicals and Society*, Cambridge: Cambridge University Press, p. 35, 1986.

Definitions

Toxicant	A substance causing adverse effects in a plant, animal, or human. It does so by impairing vital metabolic functions.
Toxin	A toxin is a toxicant produced by a living organism (microbe, plant, insect, spider, snake, or bird). The word is often used loosely.
Poison	A poison is a substance, which, "in small amounts is injurious to health or endangers the life of a living organism." Poison is a synonym for toxicant, but is often used loosely.
Hazardous substance	A hazardous substance may be toxic, corrosive, reactive, flammable, radioactive, or infectious, or more than one of these. It cannot be harmful unless actual exposure to it occurs.
Xenobiotic	A chemical substance that is foreign to (not synthesized in) the body of the animal exposed to it.

Increasing adverse effect with increasing dose



Acute and chronic toxicity

- Acute toxicity is an adverse effect seen soon after a one-time exposure to a chemical. The effect may be vomiting, diarrhea, breathing difficulties, irregular heartbeat, poor coordination, or unconsciousness. Symptoms might arise in a child who ingested a parent's prescription drug, a farm worker who sprayed a pesticide without proper protection, or a teenager who sniffed glue or gasoline vapors.
- Chronic toxicity results from long-term exposure to lower doses of a chemical or an adverse effect that happens long after an exposure has ended. Long term may be several weeks or 30 to 40 years.

The MPC (MAC) concept

- Therefore, the volume of a toxic *dose* ***is not applicable*** within regulation. MPC systems feature the harmfulness class of a substance, including its toxicity class. Speaking of other disadvantages of sanitary and hygiene regulation, one should emphasize, that it fails to specify a type of a certain impact substances are likely to produce on living organisms, if actual concentration in environmental bodies exceeds maximum permissible rate. The MPC concept does **not stipulate**, that certain substances shall be used **under minimum threshold**, below which there exists insufficiency of the substance in the environment, which may significantly impact organisms, inhabiting the environment.

The MPC concept

- Certain environments, being in close *to natural (background) condition*, contain a number of substances, *exceeding MPCs*. This is typical for mining anomalies, oil bearing areas, peat areas, etc. In these cases, MPC-based assessment of the quality of natural waters, which practically do not suffer from man-caused impacts, leads to incorrect conclusions. It is also worth mentioning, that resistance of organisms (including human-beings) against substances varies depending on regions and zones, which is due both to climates as well as to other environmental factors, including such hydrochemical properties of used water, as mineralization, its buffer value, etc. Thus, it seems obvious that metal adaptation at the background level is inherent through generations.

The MPC concept

- Sanitary and hygiene and environmental standards *do not specify the source* of the impact and do not regulate it directly. However, they are used to establish science and technical standards, i.e. requirements on impact sources. Science ant technical standards include rates of discharges and emissions of harmful substances, rates of waste generation and their disposal, as well as technology, construction, town planning standards and rules, specifying environmental requirements. Science and technical regulation is based on the following principle: if standards and rates are observed by all the companies operating in the region, the concentration of any foreign material in water, air and soil shall be in line with sanitary and hygiene regulations.

The MPC concept

- This principle is difficult for implementation, when environmental pollution *is significant itself without a company contributing to the pollution* (e.g.: a water body, used for production processes, contains polluting substances in the initial amount close to or exceeding MPCs).
- This may occur even at the background areas, as noted above.

Exposure to multiple chemicals

- The most common effect is additive. This commonly happens when the chemicals in question exert their effects in a similar manner, as when a person is exposed to several organophosphate pesticides at a time: each inhibits the activity of a specific enzyme. The chemicals do not interact.
- In synergism the combined effect of two chemicals are greater, sometimes much greater than additive, i.e., one plus one equals much more than two
- In antagonism one chemical interferes with the action of another – it acts as an antidote.

Systemic and local effects

Typically systemic effects are being referred to – effects occurring at a point distant from where a chemical enters the body. For example, cyanide, arsenic, and other toxicants exert their poisonous effects after being absorbed into the body.

Local effects too – effects occurring at the point of contact with skin, eyes, lungs, or gastrointestinal (GI) tract. Aweak acid for instance is an irritant at the point of contact; it shows a local effect. A reactive gas such as formaldehyde also shows local effects such as irritating the eyes.

Structure and functions of the key environmental enforcement authorities in Russia