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BIOINDICATION ASSESSMENT OF WATER, AIR AND SOIL QUALITY

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Abstract: Various bioindicative organisms can be used for rapid assessment of environmental quality. For the bioindicative assessment of air quality lichens are most often used; primarily planktonic microorganisms as well as benthic organisms including macrophytes for water quality; microbiological, enzymatic, lichenological, zoological and phytoindicative methods for quality of soil.

Keywords: air, water, soil, bioindicators, quality

Introduction

Bioindicative research detects and determines ecologically significant natural and anthropogenic pollution based on the reactions of living organisms in the environment.

Biological indicators are characterized by properties that are characteristic of a system or process, on the basis of which a quantitative or qualitative assessment of change tendencies, determination or qualification of the state of ecological systems, processes and phenomena is carried out.

There are great possibilities of using living organisms in bioindicative research, especially indicator species, which are able to survive in a narrow interval of action of a certain factor, based on their morphological, anatomical, physiological, biochemical, genetic and other properties. With their presence, they are indicator of the existence of that factor in the environment. With the help of micro- and macro-organisms, enzymatic activity and genetic properties of the mentioned organisms, bioindicative studies of air, water and soil quality (Bioindication) are carried out - Đukić et al., 2013.

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Biological diagnosis of air

As is known, air is a mixture of certain gases, which are present everywhere on Earth in approximately equal parts by volume. Air pollution occurs when there are substances in the mixture in such quantities and for such a long time that they become a danger for humans, animals, plants or material goods (Đukić and Mandić, 2005; Đukić et al., 2022). Air pollution has a harmful effect on all living organisms, especially plants. Plants are best suited for detecting initial changes in air composition. Corresponding indices indicate the toxic effect of substances that pollute the air.

Many researchers have determined the importance of lichens in the bioindication of air quality (lichenindication) - Table 1. They have very specific properties because they react to changes in the composition of the atmosphere. Their biochemistry is different from other organisms, they are widely distributed on different types of substrates, starting with rocks, up to the bark and leaves of trees, and are exposed to direct action (Szwed et al., 2020).

It is possible to obtain completely reliable data on the level of air pollution with the lichens (Samsudin et al., 2012). Lichens are particularly sensitive to: sulphur and nitrogen oxides, hydrogen fluoride and chloride and heavy metals. Many lichens die at low levels of atmospheric pollution with these substances.

Table 1. Air quality scale based on the projected coverage of trees with lichens (Đukić et al., 2013)

<table>
<tr><th>Degree of coverage</th><th>Number of species</th><th>The number of lichens as dominant species</th><th>Degree of pollution</th></tr>
<tr><td rowspan="3">More than 50%</td><td>More than 5</td><td>More than 5</td><td>VI zone
Very clean air</td></tr>
<tr><td>3 – 5</td><td>More than 5</td><td>V zone
Very clean air</td></tr>
<tr><td>2 - 5</td><td>Less than 5</td><td rowspan="2">V zone
Relatively clean air</td></tr>
<tr><td rowspan="2">20 – 50 %</td><td>More than 5</td><td>More than 5</td></tr>
<tr><td>More than 2</td><td>Less than 5</td><td>III zone
Moderate pollution</td></tr>
<tr><td rowspan="2">< 20%</td><td>3 - 5</td><td>Less than 5</td><td>II zone
Heavy pollution</td></tr>
<tr><td>0 – 2</td><td>Less than 5</td><td>I zone
Very heavy pollution</td></tr>
</table>

Assessment of air purity can also be done using plants. For example, gymnosperms are excellent indicators of atmospheric cleanliness. It is also possible to study mutations in the fibers of the anther filaments of tradescantia. It has been observed that with an increase in carbon monoxide and nitrogen oxides in the air, emitted by internal combustion engines, the color of the stamens changes from blue to pink. The consequences of disturbances in the individual development of plants can also be determined based on the frequency of finding morphological deviations (phenodeviants), the size of fluctuating asymmetry indicators (deviation from perfect bilateral and radial symmetry) by the method of analyzing complexly organized complex structures (Mandal, 2006). Significant changes are observed in some biochemical characteristics of plants, such as the content of water, chlorophyll, carotenoids, pH of the extract, content of phenol, ascorbic acid etc. (Uka et al., 2017). The levels of any deviations from the norm are minimal only under optimal conditions and increase under any stressful influences.

Biological diagnostics of water

It should be emphasized that biological research does not study water, but the water basin as a whole as a unique ecosystem. Stroganov (1983) defined water toxicology as the science of environmental toxicity of hydrobionts at all levels of life organization which studies all responses of hydrobionts to any pollution.

In order to assess the level of toxic water pollution with industrial or other wastewater, it is necessary to answer the following questions: is the water that reaches the water basin with wastewater toxic; what is the degree of its toxicity; at what distance from the source of pollution does the toxicity decrease to a minimum value?

All groups of organisms that inhabit water basins can be used for the biological indication of water quality: planktonic and benthic invertebrates, protozoa, algae, macrophytes, bacteria and fish (Đukić and Ristanović 2005; Li et al., 2010). Each of them, being in the role of a biological indicator has some advantages and disadvantages, which determine the limits of their application when solving the tasks of bioindication because all these groups have a leading role in the overall circulation of substances in the water basin. Organisms, which are usually used as bioindicators are responsible for the self-purification of the water basin, participate in the creation of primary production, transform matter and energy in aquatic ecosystems. Any conclusion based on the results of biological research is based on the whole of all the data obtained, and not on the basis of the individual finding of indicator organisms. During the realization of the research, as well as when evaluating the obtained results, it is necessary to take into account the possibility of accidental, local pollution in the test site. For example, decomposing plant remains, frog or fish carcasses can cause local changes in the character of the living world of a water basin.

The best developed assessment of the degree of water pollution based on indicator organisms is the saprobity system (tab. 2).

Table 2. Basic characteristics of compatibility zones (Đukić et al., 2013)

Indicator	**Polysaprobe zones**	**Alpha-mesosaprobic**
Oxygen conditions	Anaerobic	Semi-anaerobic
Nitrogen compounds	Protein matter	Ammonia, amino acids
Hydrogen-sulphide	A lot	Quite a lot
Rotting	Rotten	Rotten
Bacteria in 1 cm^3 of water	10^9	10^6
Dominance of certain species	Very strong	Little
Diversity of species	Very little	Little
Change of colonies	Catastrophic	Often catastrophic
Oxygen requirements of organisms	Negligible	Weak

Indicator	**Beta-mesosaprobic**	**Oligosaprobic**
Oxygen conditions	Aerobic	Aerobic
Nitrogen compounds	Ammonia salts, nitrates, nitrites	Nitrates
Hydrogen-sulphide	Little	None
Rotting	Not rotten	Not rotten
Bacteria in 1 cm^3 of water	10^5	$10 – 10^2$
Dominance of certain species	Significant	Very large
Diversity of species	Significant	Very large
Change of communities	Pretty slow	Slow
Oxygen requirements of organisms	Large	Very large

Among the mentioned groups of indicator organisms higher aquatic plants are the least studied, although they have a number of advantages. They can be seen with the eyes, so they are suitable for research, and also make it possible to visually assess their ecological condition during the hydrobiological examination of water basins. Macrophytes make it possible to determine the trophic properties of water and sometimes the specificity of its chemistry, which is essential for the bioindication of clean waters.

Biological diagnosis of soil

The basis of the principle of soil biological diagnostics is the realization that soil as a living environment forms a unique system with populations of different organisms that inhabit it (Mandić et al., 2019).

Botanical methods of phytoindication and soil diagnostics have been diluted. For example, through the analysis of the composition and structure of plant communities, the distribution of plant indicators or certain indicative properties of certain types of plants, it is possible to determine the type of soil, the degree of its hydromorphism, the development of the process of swamp creation, salt accumulation, etc. Among the plants, indicators of the mechanical and chemical composition of the soil, the degree of enrichment with nutrients, acidity or alkalinity, the depth of thawing of frozen soils or the level of underground water were discovered.

The theoretical assumption of the application of the soil-zoological method for the needs of soil diagnostics is a formulated idea about the "ecological standard" of a species - the need of a species for a certain set of conditions. Each species within its range is found only in those habitats, which ensure the full complex of conditions necessary for the manifestation of life activity (Schloter et al., 2018). The amplitude of variation of certain environmental factors characterizes the ecological harmony of the species. Eurybionts are less suitable for indicator purposes, while stenobionts are good indicators of certain environmental conditions and substrate properties. That setting represents a general theoretical principle in biological diagnostics. However, the use of one species as an indication is not entirely reliable for making correct conclusions (here the "rule of habitat change" and consequently the change of ecological properties of the species has a place). It is better to examine the entire complex of organisms, among which some may be indicators of humidity, others of temperature, others of chemical or mechanical composition. The more common types of land animals are found on the compared plots, the more likely it is to judge the similarity of their regimes, and therefore, the unity of the pedogenetic process. Microscopic forms are less useful - protozoa and microarthropods (ticks, for example). Their representatives are characterized by cosmopolitanism, despite the fact that the soil is not their only habitat: they live in a system of pores, capillaries and cavities, which can be found in any soil. Of the microarthropods, the indicator properties of shell-like (armored) ticks have been best studied. The composition of the complex of their communities depends not only on the soil conditions, but also on the character and floristic composition of the vegetation, therefore it is promising to use them to indicate harmful effects on the soil.

Communities of large invertebrates (earthworms, centipedes, insect larvae) are particularly valuable and suitable for indication interventions (Menta, Remelli, 2020). So, for example, staphylinids of the genus *Bledius* and black-headed beetles of the genus *Belopus* are typical for salt-salt soils, while some centipedes and lungworms (pulmonary molluscs) are indicators of lime content in the soil. Earthworms *Octolasium lacteum* are indicators of high calcium content in groundwater.

Soil-algological diagnostics is also interesting, based on the thesis that the zonation of soil and vegetation corresponds to the zonation of groups of algae. It is manifested by the overall composition of species and the complex of dominant species of algae, the presence of specific species, the nature of the distribution (spread) along the soil profile and the dominance of certain life forms.

Microbiological and biochemical soil characterization are the most complex parts of soil biodiagnostics. Microorganisms are very sensitive indicators that strongly react to various changes in the environment (Tab. 3). Hence the exceptional dynamism of microbiological indicators. The soil is characterized not only by the composition and abundance of different groups of organisms, but also by their overall activity, as well as the activity of biochemical processes, conditioned by the presence of a certain enzyme, separated during the life activity of plants, animals and microorganisms or accumulated in the soil after the decomposition of cells. Quantitative characteristics of abundance and biomass of different groups of soil organisms, their total productivity, some energy indicators, processes related to the cycling of elements, enzymatic activity of soil. Also the amount and speed of accumulation of some products of life activity of organisms can be indicators of soil biological activity.

Table. 3. Effect of diverse concentrations of lead, copper, cadmium and mercury on the total counts of bacteria (10^6 g^{-1} absolutely dry soil), actinomycetes and fungi (10^5 g^{-1} absolutely dry soil) (Mandić et al., 2010)

Treatments	Concentration (mg dm^{-3})	Total bacterial count	Count of actinomycetes	Fungal count
Control		89.2	75.4	18.2
Pb^{2+}	6.250 0.625 0.125	25.6 ** 65.2 ** 87.8 ^{ns}	34.6 ** 35.6 ** 47.6 **	12.0 ** 14.2 * 15.6 ^{ns}
Cu^{2+}	6.000 0.600 0.160	27.2 ** 43.6 ** 71.6 *	17.2 ** 43.4 ** 70.6 ^{ns}	10.2 ** 16.4 ^{ns} 16.6 ^{ns}

Cd^{2+}	2.700 0.270 0.027	24.2 ** 27.6 ** 31.6 **	23.6 ** 31.4 ** 45.6 **	6.4 ** 12.6 * 13.0 *
Hg^{2+}	2.220 0.220 0.022	15.8 ** 25.6 ** 30.6 **	13.6 ** 17.4 ** 34.2 **	1.4 ** 6.6 ** 12.2 *

*; **) significant at 0.05 and 0.01, respectively, after the Dunnett test; ns) non-significant

The most basic methods, which allow to evaluate total biological processes based on initial or final products are: methods of determining soil respiration based on O_2 consumption or SO_2 release; determination of nitrogen fixation activity based on acetylene reduction; microcalorimetric measurements to determine the level of thermostability; applied methods with the use of special materials (cellulose, chromatographic paper, cellophane) to assess the speed and degree of decomposition and accumulation of metabolic products, for example amino acids. A special group consists of methods for determining the potential activity of certain enzymes in soils (actually activities, not quantities).

Conclusion

Various bioindicative organisms can be used for rapid assessment of environmental quality. For the bioindicative assessment of air quality lichens are most often used; water - primarily planktonic microorganisms, as well as benthic organisms, including macrophytes; and soils - microbiological, enzymatic, lichenological, zoological and phytoindicative methods.

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