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PHYTOINDICATION RESEARCH IN THE SYSTEM OF ENVIRONMENTAL MONITORING

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The features of analytical and biological methods of environmental monitoring are analyzed. The resource consumption of using the physical and chemical methods of studying the abiotic environment contamination level and the expediency of using living organisms in environmental monitoring are evaluated. The use of biological methods in the environmental control system provides the possibility of the test material analyzing in both natural and laboratory conditions, which greatly expands the possibilities of practical environmental science. The most common and dangerous pollutants of anthropogenic origin that can be effectively metabolized by plant organisms are listed. The perspective of plant objects use as indicators of ecological state of the environment is considered. Advantages of plant organisms as effective indicators of environmental quality in comparison with other living systems are given. Indicators of plant vitality at different levels of the biosystem organization – from molecular to population and species level – are characterized. A comprehensive biomonitoring approach is proposed, which provides a systematic and comprehensive study of plant life processes, adaptive and destructive changes under the influence of adverse environmental factors. The cumulative features of plants are analyzed, three main groups of phyto objects are distinguished: batteries, eliminators and indicators. Possibilities of introducing indicator species for environmental quality assessment and remediant species for environmental quality improvement are described. The advantages of phytoindication comparing with other methods of environmental monitoring are presented. The most informative plant test parameters have been identified using a comprehensive approach to environmental quality assessment. The green areas of urban ecosystems creation, a competent combination of plants in different environmental conditions according to the level of environmental sustainability will effectively combat its contamination and prevent its anthropogenic transformation in the future.
Key words: phytoindication, environment, test parameters, pollution, environmental monitoring, phytoremediation.

Фітоіндикаційні дослідження в системі екологічного моніторингу. Глібовицька Н.І., Михайлюк Ю.Д.
Проаналізовано особливості аналітичних та біологічних методів екологічного моніторингу стану довкілля. Оцінено ресурсозатратність фізико-хімічних методів дослідження рівня забруднення абіотичного середовища та доцільність використання живих організмів при проведенні екологічного моніторингу. Вживання біологічних методів у системі контролю за станом довкілля передбачає можливість здійснювати аналіз дослідного матеріалу як у природних, так і в лабораторних умовах, що значно розширює можливості практичної екологічної науки. Наведено найбільш поширені та небезпечні забруднювачі антропогенного походження, які можна ефективно метаболізувати рослинними організмами. Розглянуто перспективність використання рослинних об'єктів як індикаторів екологічного стану довкілля, наведено їх переваги порівняно з іншими живими системами. Охарактеризовано показники життєвості рослин на різних рівнях біосистемної організації – від молекулярного до популяційно-видового. Запропоновано комплексні рекомендації біомоніторингу, який передбачає системний підхід у вивченні процесів життєдіяльності рослинних об'єктів та дослідження адаптивних і деструктивних змін під впливом несприятливих чинників довкілля. Розглянуто кумулятивні особливості рослин, на основі чого виділено три основні групи фітооб'єктів: акумулятори, елімінатори та індикатори. Описано можливість впровадження видів-індикаторів для оцінки характеристик довкілля, а також ремедіантів для покращення якості навколишнього середовища. Наведено переваги фітоіндикації поряд з іншими методами екологічного моніторингу. Виділено найбільш інформативні тест-параметри рослин при використанні комплексного підходу до оцінки якості навколишнього середовища. При створенні зелених зон урбанізованих екосистем грамотне поєднання рослин з різними середовищетвірними компонентами відповідно до рівня екологічної несприятливості довкілля дозволить ефективно боротися з його контамінацією та попередити його антропогенну трансформацію у майбутньому.
Ключові слова: фітоіндикація, довкілля, тест-ознаки, забруднення, екологічний моніторинг, фіторемедіація.

Formulation of the problem. Environmental anthropogenic transformation has necessitated the use of a comprehensive approach to the assessment of the ecological status of natural and urban ecosystems. Environmental monitoring involves two main groups f methods – biomonitoring and analytical, or physico-chemical. The first one involves the study of a particular territory ecosystems with the help of living organisms – insects, crustaceans, plants and microorganisms, etc. Analytical methods are alternative and are used in the study of the quality of the abiotic environment – air, soil, water resources.

The quality analysis of inorganic samples is carried out under laboratory conditions using equipment and chemical reagents, which is resource-intensive. The main air pollutants include nitrogen, carbon and sulfur oxides, dust of inorganic origin, as well as hydrocarbons, which account for 90–98 % of the volume of all harmful

substances [1]. The dominant soil toxicants are heavy metals, the availability of which to plants increases with increasing the soil acidity [2]. Water resources are undergoing a major transformation in the nutritional chains, which is manifested in the death of aquatic organisms through pollution by petroleum products [3].

For the purpose of monitoring and forecasting the ecological situation in the environment, so-called species-bioindicators are used, which, by changing their vital parameters, reflect the state of their territory of existence. Biomonitoring studies can be carried out both in the natural environment and in the laboratory. In the first case, biological indication is carried out, in the second one – biological testing.

Relevance of research. Biomonitoring studies can be conducted at all levels of the biosystem organization from molecular to biogeocenotic. Plants are one of the most informative objects of study in the eco-monitoring system. They are easy to use, suitable for growing in natural and artificial conditions, fixed and most economically viable. Phytoindication today has the following priority areas of research – bryoindication, the objects of which are mosses, lichenindication – the objects of which are lichens, and the dendroindication – the objects of which are woody plants. Tree plantations are unique organisms in terms of bioindication as they have several advantages over other biological systems. In particular, the trees perform phytomeliorative function, a large area of photosynthetic organs allows woody plants to effectively absorb toxicants from the environment and to carry out an assimilation role.

Relation of copyright work with important scientific and practical tasks. The challenges facing modern environmental science include both the need to control the environmental changes caused by anthropogenic activity and the search for effective and cost-effective ways to overcome environmental pollution. In this regard, plants are not only the primary recipients of complex anthropogenic exposure, can be used as phytoindicators of the state of the environment, but also through unique metabolic processes detoxify toxicants and turn into bio-safe products. In this case, herbaceous and woody plants have a certain feature in the phytoindication and phytoremediation plan of their use. This is due to the structure of their vegetative sphere, features of reproduction and ontogeny, body size.

Analysis of recent research and publications. Trees and herbs are equally suitable for study at all levels of the biosystem hierarchy, but the population level of research is used mainly in natural biocenoses [4]. Woody plants that have a K-strategy, a long life cycle, accumulate a large above-ground mass, since they are not able to give full offspring in the urban conditions. This ensures the survival of the plants and enables them to act as the most effective air and water filters. That is why urban phytocenoses are created with the participation of trees and shrubs [5]. On the other hand, herbs have a short life cycle and direct their energy resources to the formation of the generative sphere and the increase in the number of offspring. They can be used as indicators and remediants in both natural and artificial growth conditions [6].

Today special attention is paid to the study of the problem of environmental oil pollution and the prospects of plants as decomposers of oil products [7; 8]. There are some remarkable phytoremediation possibilities of some herbs and woody plants that metabolize oil toxicants and turn them into safe substances such as water and carbon dioxide [3; 9; 10].

Selection of previously unresolved parts of the general problem addressed by the article. Finding environmentally friendly, least costly, and most effective methods of combating environmental pollution is a pressing environmental concern. Plant organisms, due to their unique organization and vitality, are able to respond quickly to changes in the environmental state by the appearance of a number of processes aimed at neutralizing the relevant pollutants. Given the indicative or remedial capacity of a particular species, it is proposed to create green spaces according to the degree of contamination of certain territories.

Novelty. Thus, trees can be viewed from two positions – as promising bioindicators and as effective pollutant filters. In addition, it is possible to trace the dynamics of accumulation of pollutants by plants in space and time depending on their place of growth. Studies of plant vitality under the influence of stressors of different origin help to prevent the ecological crisis of a certain territory.

Outline of the main material. According to plants specificity to pollutants absorption, plants are divided into phyto-indicators, phyto-eliminators and phyto-accumulators. Phytoindicators are the most sensitive to environmental conditions changes, and phyto-accumulators are the most resistant. Eliminators occupy an intermediate position and are characterized by the fact that they selectively absorb toxicants from the environment. Some of the studied plant species are used as a remediants for the contaminated environment. These are the types of batteries that accumulate toxicants in large quantities without visible signs of impaired functioning. This is explained by the presence of powerful protective mechanisms of plant organisms against the negative effects of toxicants. In particular, metalothionein chelator proteins capture the metals absorbed by the plant and render them inaccessible to the plant. The ability of plants to absorb and detoxify the toxic components of petroleum is related to the specific metabolism of the remediant species. Such organisms, without sacrificing themselves, convert hydrocarbons to non-toxic compounds – water and carbon dioxide. Among the woody plants *Hippophae rhamnoides* L., *Juglans regia* L., *Salix* L. and *Betula* L. species have the valuable remedial potential [11; 12; 13; 14].

Phytoindication studies cover the processes of plants vitality that have the lowest manifestation

even at molecular level. Metabolic changes are the first invisible reactions of an organism to changing its existence conditions. Plants respond by adaptive or destructive changes depending on the exposure duration degree to the damaging factor. An example of an indication parameter used at the molecular level of the plant's biosystem hierarchy is the rate of biosynthetic processes and photosynthetic activity. Adaptive responses of some species testify to the broad individual potential and genetically driven resistance to adverse conditions and environmental plasticity. Protein synthesis is one of the major metabolic units because the proteins are enzymes that catalyze all biochemical reactions in the body. Suppression of protein synthesis is a classic destructive response of plants to a stress factor. The amino acid chains and protein molecules formation is a very energy-intensive process. In conditions of the organism's resources reduction, the processes of substances synthesis are suppressed and the processes of substances decay are intensified in order to conserve the energy. Under the conditions of environmental pollution, there is a decrease in the photosynthetic function of plants, a reduction of the green pigments concentration and an increase of the carotenoids content. This speeds up the aging of cells and the entire organism. It is also manifested in the gradual loss of plants phytomeliorative function. The processes of cell division are directly connected with protein synthesis. Exposure to environmental toxicants leads to the degradation of chlorophylls, the destruction of protein complexes, and the generation of free radicals. In particular, heavy metals replace metals in the enzymes active center, which blocks the activity of the latter [15; 16].

Enhanced synthesis of lipids and simple monosaccharides is adaptive response of plants to adverse environmental factors. The lipid cuticular layer thickening on the plants organs' surface creates additional protection against drying up and pollutants influx into the body. Increasing the concentration of monosaccharides in plant tissues under stress is an additional source of energy needed for survival. The adaptive reaction of plants to anthropogenic influence is the synthesis of protective substances – proline and abscisic acid. The activity of antioxidant enzymes – catalase, peroxidase, superoxide dismutase is also increased under unfavorable environmental conditions. The intensity of cell membranes' lipid peroxidation is another indicative parameter of the molecular level of organization [17].

The cellular level of plant life study suggests the presence of mitosis disorders and chromosomal mutations as a result of stressful influence. Damage of generative cells due to the action of negative factors is also a characteristic manifestation of destructive changes in the body. The integrity and normal functioning of cell organelles are regarded as indicative parameters for assessing the vitality of individuals in certain conditions of existence. It is known that under stressful conditions the generation of free radicals is more active, which leads to an increase in the number of cellular structures damages and the membrane peroxidation process increase. At the tissue level of the biological systems organization the most promising in the indication plan are the following features – tissue thickness, xeromorphic index, respiration intensity [18].

At the organ level, the bio-indicative characteristics of a plant are quantitative and qualitative parameters of vegetative and generative organs. Most commonly used as test features are the area and linear features of the assimilation organs, the type and degree of necrosis, the asymmetry coefficient, the number and weight of individual vegetative and generative organs. The classic phytoindication feature is a decrease in the number of plant structures, inhibition of growth and development processes in order to reduce the contact area of the plant organism with the polluted environment [19].

Plant morphological responses are visible changes that occur as a result of invisible biochemical metabolic reactions. Leaf necrosis is a specific manifestation of the environmental factors influence on the body. In particular, marginal necrosis of plants leaves indicate the accumulation of heavy metal salts at the edges of the leaf, and interspacial and spotty leaf necrosis are the result of acid rain. Fish skeleton necrosis type occurs due to the entry of toxic compounds through the root system. The organisms level of the biosystem hierarchy involves the study of phenological phases – periods of individual plant development, as well as the presence of diseases and pests [20].

The vitality of each individual is determined by comparing it with the corresponding species representatives living in the background conditions. Based on these observations at the organismal level, the entire populations vitality of a particular plant species can be estimated. At the population level the type of the populations life strategy, its viability, dynamic and static parameters can be determined. As phyto-indicative parameters the age, number, density and species distribution can be investigated.

The main conclusions and perspectives of the research results use. The use of a comprehensive phytoindication approach to environmental quality assessment allows not only to determine the level of ecological hazard of a particular area, but also to identify perspective species in bioindication and bioremediation. Phyto-indicative research is a promising, informative and effective method of environmental monitoring. The study of life processes at different levels of plant organization gives a complete picture of their adaptive capacity to the existence conditions. Thus it is possible to introduce into the landscaping of territories the different plants according to their phytomeliorative characteristics. This will simultaneously fix the smallest changes in the ecological state of the environment with the help of indicator plants and restore the optimal functioning of ecosystems disturbed by anthropogenic activity.

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