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ASSESSMENT METHODOLOGY OF GREEN PLANTATIONS VITALITY IN THE CONDITIONS OF TECHNOGENICALLY TRANSFORMED ECOSYSTEMS

The most informative parameters of woody plants living condition are analyzed, which should be used for the ecological monitoring of urbanized and oil-contaminated areas. The reactions of the plant organism at different levels of the biosystem organization in response to the action of priority pollutants of the technogenic-transformed environment – heavy metals and oil products – are provided. The relevance of the study of oil pollution as one of the current main environmental problems is substantiated. The adaptive-protective reactions characteristic of the resistant plant species and destructive changes in the stress-sensitive phytoobjects are highlighted. It is established that the widest range of plant reactions to the man-made environmental impacts can be found at the molecular, cellular and organ levels of biosystems organization. Based on a set of morphological, physiological, cytological, histological and phenological processes of plants, it is recommended to use indicator species in biomonitoring studies, and remediative species – in the reclamation measures for the anthropogenically altered areas. The authors have highlighted the methodical approaches to assessing the ecological condition of urbanized and oil-contaminated ecosystems, based on the specifics of zoning and choice of background area. The classes of vitality and the categories of plant stability are characterized based on the percentage deviation of the analyzed plant parameters from the background values. The prospects of green plantations as the primary producers of organic matter and recipients of the complex impact of biotic, abiotic and anthropogenic environmental factors are substantiated. The criteria for sampling plant material for bioindication studies to obtain reliable factual data are described. The relationship between the processes that occur at all levels of the biosystem hierarchy of the plant organism – from molecular to ecosystem – is highlighted. Based on establishing the living condition of the green areas of urbanized and oil-contaminated areas, it is possible to timely record the slightest changes in the ecological state of the environment and to prevent further negative trends in it.

Key words: living condition, green plantations, oil pollution, urbanized ecosystem, biosystem organization.

Problem statement. Plants are an integral part of any ecosystem, as they act as the primary producers of organic matter and absorbers of the man-made pollutants. Carrying out the environment-creating function, plants reflect the environmental state, which is manifested in the change of plants vital parameters at different levels of biosystem organization. Therefore, the urgent task of practical environmental science is to study the plants living conditions under the active influence of anthropogenic activities in order to timely identify irreversible processes in the environment. In urban areas, the main sources of environmental pollution are industry and transport, which produce large amounts of toxic substances for biota – heavy metals, hydrocarbons, acid oxides, chlorine derivatives, etc. A special danger to the stable functioning of ecosystems is caused by oil and its products, which are the most common contaminants of the environment today. In this regard, special attention is paid to monitoring the ecological state in oil-producing areas, and perennial green plantations are recommended to be used as biological indicators and remediates.

Literature review. A large number of scientific papers are devoted to the study of plant organisms reactions to the heavy metals effects, which are components of oil and have carcinogenic action, cause necrotic damage to plants, block photosynthesis and metabolic transformations [2-5, 7-9, 13, 15, 19]. Heavy metals are a source of free radicals in cells, which are formed during cellular respiration and cause oxidative stress. Oil hydrocarbons inhibit the growth and development of plants and are especially dangerous for the generative sphere of phytoobjects [11, 16]. Nitrogen and sulfur compounds, as the components of oil, interact with atmospheric moisture and precipitate in the acid rain form. This leads to the chemical burning of plant tissues and their premature death [10, 17]. Oil pollution is a complex environmental problem that includes the current pressing problems – environmental pollution by heavy metals and acid rain. Therefore, the study of the functional state of plants in terms of oil pollution and its derivatives will identify the sustainable species and species-indicators that can be implemented in the landscaping of man-made areas for various purposes.

The effect of petroleum products and other pollutants of anthropogenic origin on grass plants has been sufficiently studied [11, 12, 18, 20, 21]. However, the reactions of perennial tree plantations to the effects of oil pollution are especially relevant in terms of their prospects as phytoindication markers in ecomonitoring studies. There arises the question of identifying the most informative morphological, phenological, physiological, cytological, and anatomical features of woody plants, which can quickly determine the quality of habitat. Based on the parameters of green plantations vitality, it is possible to identify the species that effectively perform the remediation function and the species that are unstable to the effects of adverse environmental factors. Thus, it is possible to solve two key aspects of biomonitoring – to identify bioindicators to control the slightest changes in the ecological state of the environment, and remediative species to restore the environment degraded by anthropogenic activities.

Setting objectives. The purpose of our work is to identify the biologically indicative reactions of tree species to the complex influence of pollutants in the conditions of technogenic-transformed territories and to investigate the suitability of green plantations as phytomeliorants and phytoindicators.

Results and discussion. The living condition of a plant is a complex of growth and development parameters that reflect the resistance of an individual to a set of environmental factors. As in the conditions of oil-producing territories, the priority contaminants of urban ecosystems are oil and oil products. Vehicles and industry emissions are sources of aliphatic, aromatic hydrocarbons, acid oxides and heavy metals.

To assess the living condition of the plant in specific environment, it is necessary to study the processes of plants' life at all levels of the biosystem hierarchy – from molecular to biocoenotic (table 1).

Table 1

Assessment of woody plants living state at different levels of the biosystem hierarchy in the conditions of oil pollution

No.	Level of biosystem organization	Parameters of plant organism vitality
1	molecular	content of photosynthetic pigments and their ratio, organic and mineral substances content, antioxidant enzymes activity
2	cellular	chromosomal abnormalities during mitotic cell division, number of germinated and viable pollen grains of plants, cell size, intracellular buffering capacity
3	tissue	density and size of stomata, tissue thickness
4	organ	mass and number of vegetative and generative organs of plants, area and linear parameters of leaf plates, types of leaf necrotization, asymmetry of plant organs
5	organismic	intensity of defoliation, dechromation of the crown and its length, age and height of the plant, presence of diseases and pathogens
6	population-species	duration and timing of phenological phases of ontogenesis
7	biocoenotic	cycle of chemical elements in the "plant-environment" system

The molecular level of biosystems organization involves the study of plants photosynthetic processes activity, the suppression of which is a sign of adverse environmental conditions. The concentration of chlorophyll in the plants assimilation organs decreases in direct proportion to the degree of man-made pressure on the environment. The increase of carotenoids content relative to chlorophyll in the leaf blades indicates the ecological plasticity of the species and its high vitality [6, 14].

Among all pollutants, heavy metals, which block enzymatic reactions in cells by inactivating enzymes, have the most detrimental effect on plant assimilation. The action of heavy metals is to replace the element in the active center of the enzyme, which makes it impossible for it to function.

Studying the concentration of glucose, starch, amino acids, proteins, fatty acids and lipids in the plant gives a complete picture of its metabolic processes, indicates the predominance of catabolic or anabolic reactions in the plant body. The increased decomposition of organic matter in the plant body indicates the presence of stress and is an indicator of plant sensitivity to contaminants. The adaptive reactions of plants at the molecular level of biosystem organization are the synthesis of protective proteins – metallothioneins and phytochelatins, heat shock proteins – and the formation of a strong lipid layer on the surface of plant organs. The lipid layer on the cuticle of plant organs prevents the excessive transpiration and damage to plant tissues due to adverse biotic, abiotic or anthropogenic environmental factors. The accumulation of ash is an indicator of the high accumulative capacity of the plant and, as a rule, indicates a strong remediation capacity. Enzymes are substances of protein nature that are extremely sensitive to the chemical and physical influences of the environment, so all components of the man-made environmental pollutants block the activity of enzyme systems. This prevents the physiological course of biochemical reactions and reduces plant viability. However, under stress, the activity of antioxidant enzymes increases and provides protection against the activated forms of oxygen, which are formed in large quantities during cellular respiration under the influence of contaminants. The activity of catalase, peroxidase, glutathione reductase and superoxide dismutase is a reliable parameter of plant life in certain growing conditions.

The classic adaptive response of plants at the cellular level of organization is to reduce cell size in order to minimize the energy costs of metabolic adjustment [21]. The consequence of oil components influence on plants is a violation of cell division and the formation of non-viable pollen grains. Using the iodine starch test is a convenient way to detect starch in the pollen grains of woody plants and diagnose their living condition. The buffering of the intracellular environment of plants indicates the adaptive potential of plants to the effects of stress factors. The research results of the plant cells protoplast reaction in response to a weak solution of hydrochloric acid allow us to classify a particular species as a sensitive or resistant plant.

The plants resistant to stressful growth conditions have a thickening of the integumentary tissues of the vegetative organs and a decrease in the density of the stomata on the inner surface of the leaf blades. The respiratory cells of plants provide gas exchange and transpiration – the key processes of plant life, so reducing the number of stomata is considered as an adaptive-protective reaction aimed at optimizing the water and gas exchange of plants.

The organic level of studying the green plantings vitality provides the analysis of a number of plants morphological parameters – weight and quantity of vegetative and generative organs, sizes of leaves and degree of their necrotic lesions. The intensification of man-made effects causes the inhibition of plant growth processes and the appearance of necrosis of various types on the leaves. Necrotic lesions are specific indications of plants that occur due to the ingress of heavy metals and acid oxides into the plant. When assessing the favorable habitat of organisms the asymmetry coefficient of individual plant organs is used, which indicates the degree of urban pressure on the environment. Particularly promising in this regard is the leaf as a functionally important organ of plants, which ensures the implementation of key physiological processes [1]. Oil is a source of both metals and non-metals in the environment, which leads to the irreversible morpho-physiological processes in the plant body.

At the organismal level, it is advisable to study such morpho-physiological parameters of tree vitality as the degree of dechromation of deciduous crown, length of the crown, height and age of the tree. The adverse environmental factors cause a reduction in the timing of phenological phases of plants, premature aging and leaf fall. All visible phenomena of plant organisms reflect the processes occurring at the previous lower levels of the biosystem organization. Under the conditions of man-made pollution, weakened plants are vulnerable to phytopathogens, which provoke plant diseases.

In any ecosystem, plants play the role of primary producers of organic matter and oxygen, and are the first link in the cycle of matter and energy. Thus, studying the cycle of chemical elements in the "plant-environment" system is an urgent task in monitoring the anthropogenically altered areas.

The following recommendations should be followed when selecting the material of plant objects for research:

- to select the material of age-old plants, which are represented in the number of at least 8-10 individuals within each ecotope of the selected study area;
- to select plant material at the same height from the branches of the same order along the perimeter of the crown of the species during completion of the growing season;
- the selected plant material should be stored in an airy-dry state or used immediately in the experiment.

When studying the ecological condition of green areas of the urban environment, it is advisable to be guided by the functional zoning of the territory or zoning according to the parts of the world. It is recommended to study an oil-contaminated ecosystem based on determining a certain distance from the source of oil emissions, in particular a pit or oil deposit. The living condition of plants growing near the oil deposit will reveal both the distribution of pollutants in the environment and the degree of their toxicity.

The research results of the plants vitality parameters in the man-made environment should be compared with similar parameters of the plants in the so-called background area (table 2).

7The background territory may be a legislatively protected area or an area with homogeneous natural and climatic conditions, where there is no excess of the maximum allowable concentrations of priority pollutants.

With an average parameter deviation from the background value of 1-10%, the plant vitality is considered high; of 11-20% − above average; of 21-30% − average; of 31-50% below average, and with a deviation of 51% or more − low.

Table 2

Assessment of the living condition of woody plants at different levels of the biosystem hierarchy in urban and oil-contaminated ecosystems

Parameter deviation from the background value	Plant vitality class	Category of plant resistance
1−10 %	I	high
11−20 %	II	above average
21−30 %	III	average
31−50 %	IV	below average
>50 %	V	low

Thus, based on the research results, it is possible to draw appropriate conclusions about increase in the degree of man-made pressure in a particular functional area.

Conclusions. When conducting ecological monitoring of urban and oil-contaminated areas, it is necessary to take into account zoning of the selected ecosystem and to follow certain recommendations when selecting plant research sites. Using the parameters of plants vitality at different levels of biosystems organization, it is possible to characterize the ecological state of the environment of anthropogenically-transformed areas. According to the green plantations complex of features, there are species-indicators that reflect the real ecosituation in a certain area, and species-remediates that are resistant to man-made pollutants and have high stress resistance. The adaptive capabilities of remediates allow them to be used as effective phytomeliorants in the oil-contaminated environment.

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МЕТОДОЛОГІЯ ОЦІНКИ ЖИТТЄВОГО СТАНУ ЗЕЛЕНИХ НАСАДЖЕНЬ В УМОВАХ ТЕХНОГЕННО-ТРАНСФОРМОВАНИХ ЕКОСИСТЕМ

Проаналізовано найінформативніші параметри життєвого стану деревних рослин, які доцільно використовувати при проведенні екологічного моніторингу урбанізованих і нафтозабруднених територій. Наведено реакції рослинного організму на різних рівнях біосистемної організації у відповідь на дію пріоритетних забруднювачів техногенно-трансформованого довкілля – важких металів та нафтопродуктів. Обґрунтовано актуальність вивчення нафтового забруднення навколишнього середовища як однієї з головних екологічних проблем сьогодення. Виділено пристосувально-захисні реакції, характерні для стійких видів рослин, та деструктивні зміни у чутливих до стресових умов існування фітооб’єктів. Встановлено, що найширший спектр рослинних реакцій на техногенні впливи довкілля можна виявити на молекулярному, клітинному та органному рівні організації біосистем. На основі комплексу морфологічних, фізіологічних, цитологічних, гістологічних і фенологічних процесів рослин рекомендовано використовувати види-індикатори у біомоніторингових дослідженнях, а види-ремедіанти – у рекультиваційних заходах антропогенно-змінених територій. Висвітлено методичні підходи до оцінки екологічного стану урбанізованих і нафтозабруднених екосистем, що ґрунтуються на специфіці зонування та виборі фонової території. Охарактеризовано класи життєвості та категорії стійкості рослин на основі відсотка відхилення аналізованих параметрів рослин від фонових значень. Обґрунтовано перспективність зелених насаджень як первинних продуцентів органіки та реципієнтів комплексного впливу біотичних, абіотичних і антропогенних чинників навколишнього середовища. Описано критерії відбору проб рослинного матеріалу для проведення біоіндикаційних досліджень з метою одержання достовірних фактичних даних. Висвітлено взаємозв'язок між процесами, що відбуваються на усіх рівнях біосистемної ієрархії рослинного організму – від молекулярного до екосистемного. На основі встановлення життєвого стану зелених насаджень урбанізованих і нафтозабруднених територій можна своєчасно фіксувати найменші зміни в екологічному стані довкілля та попередити подальші негативні тенденції у ньому.

Ключові слова: життєвий стан, зелені насадження, нафтове забруднення, урбанізована екосистема, біосистемна організація.

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