UDC 574 : 504.75 : 504.064.2 : 581.4 : 581.9 : (477.60)

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PHYTOECOLOGICAL CHARACTERISTICS OF INDUSTRIAL URBAN ENVIRONMENT

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Safonov A. I., Safonova Y. S. **Phytoecological characteristics of industrial urban environment. –** The ecological analysis of the territory of an industrial town has been conducted on the example of the Donetsk city with the use of bioindicational indices. The basic strategies of city development have been taken into account. A working scheme of bioindicational estimation of urban environment has been suggested.

Key words: urban environment, bioindicational estimation.

The relatively young science of ecology attempts to forge a holistic understanding of the natural processes that take place within a defined system. The central idea is that a patch of the planet, a natural community, contains discrete living (biotic) and nonliving (abiotic) elements that interact in synergistic ways. These elements include the living organisms, the landscape patches, the parent geologic materials underlying the soils, and the local hydrologic and weather patterns. These patterns of interactions can be categorized and compared between and among various ecosystems. Energy flow (metabolism), food webs, predator-prey interactions and co-evolution are typical categories of investigation common to all ecosystems [1, 2].

Ecologists have been comfortable for over a century with the notion of natural ecosystems such as deserts, tundra, grasslands, old growth forests and estuarine salt marshes. Even animal societies such as honeybee colonies, termite mounds and wolf packs are routinely considered as ecological units. However, the concept of the natural city, a human city functioning as an ecosystem on the scale of an estuary or a rain forest, is in its academic infancy [3, 4].

Traditionally, the study of ecology has been applied to natural systems in such a way that the variable of human impact has been excluded from the biological equation. Our understanding of ecology, and its younger sibling science biodiversity, has been developed by sending researchers into pristine ecosystems in order to gather data on the intricate co-evolved relationships among organisms. Ecologists have focused on the interactions within the natural community. The new biodiversity scientists have tried to identify as many species as possible, and with those data, forge an understanding of species distribution and abundance. The studies have provided lucent images of nature and provide the infrastructure for the disciplines of biogeography (the mapping of species), behavioral ecology (the behavior of individuals and groups) and most recently, conservation biology (protecting those species from extinction). However, with the exception of those researchers interfacing with public health, the studies were conducted in remote areas where the human footprint was as small as possible. Those public health scientists who did work in cities were conducting research on the negative impacts of urban living and essentially trying to stamp out any remaining plant or animal populations that were deemed troublesome. Cities were not viewed as natural entities, but as foreign impositions upon the native landscape.

The development of ecological thinking about cities will have a broad and profound impact on all the issues of social importance to urban stakeholders. Public health, resource allocation, water quality, energy conservation, historical and natural preservation will all benefit from a revisionist approach that includes the biology of the system as the foundation for its understanding and management. The concept of the natural city will have its roots in a series of scientific models that will be testable in a variety of urban environments.

Geopolitical situation of Donetsk is characterized by the fact that the city is a large industrial and economic as well as intellectual and cultural centre of Ukraine. It is situated in the steppe zone in the South-East of Ukraine in the middle of the densest network of railway lines, automobile roads and air transport. It is known that strategic planning in the market conditions originates from the idea that it is possible to influence the future of a certain territory by planned actions aimed at achieving a new state of a territory, which would satisfy the population's needs. In this respect the

General aim of working out the Strategy of Donetsk is achieving European standards in the framework of level and quality of life of the population.

The General aim was determined coming from the basic city problems and competitive advantages of Donetsk. Hence, the strategic objectives – the instruments of the strategy realization and the awaited effects – have been formulated.

The ecological situation in Donetsk is very complicated, it is worse than in a number of other large cities in Ukraine. The omission of harmful substances in the atmosphere in 2006 attained 130 thousands of tons a year. A serious problem are slag heaps of mining and coal preparation situated on the whole city territory. Solving this problem is envisaged in the framework of Alborg obligations accepted by the city in 2004. They are based on the principles of sustainable development: a balanced functioning of economic, ecological and social spheres of human activity in the city in long-term perspective.

The strategy of the Donetsk city development presupposes a number of directions: use of alternative sources of energy; industrial use of shaft methane; purification of ground sediments and improvement of banks of main city's reservoirs; creation of the city's sewerage system; separate collection of domestic wastes; liquidation of spontaneous scrap-heaps of domestic, builder's and industrial rubbish; recultivation of slag heaps and open-cast mines.

The envisaged directions will enable to reduce the level of pollution of the atmospheric air by 40%, water resources – by 20%, the level of waste pollution by more than 3 times.

At present the scientists of the Donetsk National University and the Donetsk Botanical Gardens have conducted reconnoitering work on zoning of the Donetsk city territory with the use of bioindication indices. One of such indices, which has already been approved for northern industrial centres of the Donetsk region, is the index of an extent and specifics of structural alterations of the plants-indicators [5-8].

The interest in urban ecology can be understood from four perspectives. First, human activity is concentrated in urban clusters. Even for those humans living outside of metropolitan centers in what are classified as rural landscapes, the productive activities of these people are often linked to resource requirements in nearby or distant cities. Second, humans as a species dominate each of the earth's ecosystems, whether they are heavily populated or not. Although this idea remains troubling to scientists, anthropogenic impact is an unavoidable variable in the study of ecology. Third, any modern model of ecology must include considerations of human impact in order to be of use as a predictive tool. Finally, developing an understanding of the ecological processes that occur within urban landscapes can be of great utility to those professionals charged with solving the social problems inherent in city life. We can examine these four elements in more detail [9-12].

Human demography has shown a steady increase in the percentage of people living in cities. Beginning with the advent of agriculture 5,000-10,000 years ago, humans have been developing bigger and more densely populated urban centers. The United Nations recognizes over 300 cities with population over 1 million people, with sixteen of these metropolises categorized as megacities (10 million or more inhabitants). This pattern of urbanization is evident in both developed and developing nations [3, 11-14].

As human population has increased, so has our species' impact on global ecosystems. The fossil record points to five major periods of rapid extinction during the past 500 million years on the planet, all of which occurred prior to the evolution of our human lineage. These catastrophic events were triggered by rapid, un-buffered environmental change. The most recent complete cycle, triggered by an asteroid impact on the planet, occurred approximately 65 million years ago during the Cretaceous period and caused the extinction of at least 50% of all of the animal families on earth, including the last of the dinosaurs. Conservation biologists have detected the start of a sixth major period of rapid extinction, beginning in the past 200 years [12-14]. This bout of biodiversity loss is directly linked to environmental degradation caused by human activity and over-exploitation of natural resources. The tremendous impact of humans on the biosphere is concentrated in urban areas where deforestation, soil erosion, pollution and exhaustion of natural resources is the most intense. Finally, bringing an ecological perspective to the challenge of urban management provides a new set of tools for addressing the problems of our cities. Social injustice, poverty, public health and pollution are all societal problems with deep ecological and environmental roots. One of the tremendous advantages of science as a lens for viewing the world is that it brings with it a sense of dispassionate neutrality that can provide a fresh perspective on these problems. The teaming of science with social concern has spawned the relatively new field of environmental justice, which has proven to be a robust approach to such problems as toxic waste management and brownfields reclamation. The development of a new perspective on the ecology of urban systems requires considerable effort on the part of the scientific community, but the potential payoff on the investment is enormous. If one accepts that science should be in the service of humanity, than the needs of urban dwellers worldwide provide a compelling challenge to natural and social scientists. Many conservation biologists agree that densely populated urban centers represent the most likely scenario for a sustainable planet. Understanding the ecology of cities is the first step towards improving the quality of life for all of its living inhabitants. Livable natural cities increase the probability that sprawl can be minimized, and the remaining open spaces outside the city limits can be preserved. The promise of science done well is that its findings provide the basis for rational solutions to human problems. The application of ecological thinking to the vexing problems of the world's cities provides tantalizing opportunities for science to do more good work.

The work "Phytoindication of metallic pressure of anthropogenically transformed environment" is a result of 10 years' activity, including regional reconnaissance and analytical period [15]. The region that was chosen (the Donetsk oblast) is undoubtedly prominent in terms of man-caused pressure on the environment on a global scale. The territory of the immediate monitoring corresponded to the Artemovsk and Konstantinovka administrative districts of the Donetsk oblast, which are determined as adequate to the aims set for phytoindicational experiment. As the location of separate units (sources of both natural and man-caused involving of heavy metals in biogeochemical cycles) allowed us to conventionally differentiate the specificity of metallic pressure on the environment, the areas of north-eastern industrial centres of the Donetsk oblast proved to be perspective for laying a homogeneous monitoring net of a big enough territory to obtain the informative conclusions. Such a circumstance (as a result of numerous superimposition of "specific areoles of pollution") to a great extent explains why, for example, the investigation planned on the territory of the Donetsk, Gorlovka and Enakievo, Mariupol and other industrial centres is pretty much complicated. Those mega-industrialized zones though are always of interest in terms of botanical and ecological investigation. The territory we chose conforms to detailed phytoindicational analysis due to relative homogeneity of edaphic and climatic characteristics, and as a result in geobotanical as well as in orographic relation. It's important that the levels of heavy metal contamination (as the most dangerous and active components of toxicological situation of the analysed zone) were sufficient to conduct not only natural experiment but also to model further artificial situations in laboratory environment and visualize the results on plane.

A working hypothesis was an assumption that the extent of "structural variability" (mostly anatomic) of plants with wide ecological amplitude grows with the increase of geochemical contrast of the environment and (or) the level of man-caused pressure (equivalent to increased concentrations of toxic elements) on natural environments. Experimental results of the research were directed to discovering a pattern of allocation, availability or frequency of separate characteristics or indices with phytoindicational amount in structural aspect. Meanings of these indices were checked in terms of correlation to specifics of heavy metal contamination of the environment. The choice of the centres of immediate localisation of monitoring net as well as species of plants (principally herbaceous and wild-growing, equally often found in all without exception ecotopes of the investigated zone) was based purely experimentally. It was successful to have discovered such areas and phyto-objects.

The data obtained on the state of plant organisms in places with different ecotoxicological characteristics corresponded to the basic principle of dynamism and adequacy – "here and now". Thus, there is a possibility of wide extrapolation of the findings, but first of all the matter concerns regional standards (levels, diapasons, criteria) corresponding with the time domain of materials collection. Originally phytoindication is considered as an applied aspect of botanical and ecological research. The results of the work done contribute to solution of a number of fundamental scientific issues, such as sustainability of biological systems (on the example of sexual organs and fruits of plants), plasticity of biological systems (on the example of anatomic and morphological and physiological plasticity of plants) and heterogeneity of biological systems (on the example of anatomic variability of plants).

The general scheme of the tasks succession is: selection of the research territory → choice of prospective phytoindicators → analysis of migration flows and localization of heavy metals → defining local standards of discrete characteristics of plants or their separate indices range → building indicators' ecological plasticity scales → elaboration and application of the method of cartographic and schematic visualization of the findings on plane → search for correlation connections in the system "factor-index" → correlation groups of joint and attendant characteristics ascertainment → possible forecast of further state of botanical and ecological indices of the territory… approbation, using and improving the methods of structural phytoindication.

Certain reactions of plants to increased concentration of heavy metals compounds in soil were chosen as the research object. The subject of the research is the discrete self-descriptive characteristics of test species structure in contrast metal-toxic conditions.

In view of the aim set and the pointed objects and subjects of the research we used methods of experimental and theoretical complex. Among the most demanded are the methods of ecological and toxicological monitoring, ascertainment of outecological specifics of test species on special metal-bearing substrates, the method of constructing ten-point scales according to the specifics of variation range and the diapasons of metal content values and structural polymorphism of plants, the method of cartographic single-plane visualization of data and realization of their possible many-sided analysis. The survey of information sources reflects some principally important aspects of plants studies in industrial region. First of all, there is a generalization of the notion of phytoindication of ecological factors as well as the directions of using plants for evaluation or monitoring of the environment: be it anthropogenical pressure, natural geochemical anomalies or phenomena connected with it to different extent. A number of generalizations allowed us to assert that the target direction of the scientific activity of separate research institutes or laboratories depends on a complex of regional natural and climatic factors, which determines the state and correlation of the components of natural systems, as well as existing traditions of scientific schools based on authoritative grounds of the corresponding direction by leading scientists. A set of methods and scientific traditions directly depends on material and technical equipment of the laboratories. Being guided by the survey of literary data we determined that "phytoindication" can have various forms of interpretation which directly depends on target destination of the set of experimental series. There are a lot of criteria of phytoindication, a lot of categories of phytoindicational concernment which mustn't be neglected. It's also incorrect to perceive phytoindicational research unambiguously and in a single direction, for instance, without taking into account cause-and-effect relations which form regularity.

The present work includes some generalizations of information sources on different aspects of theoretical and applied direction of phytoindicational research in industrialized region. The data on the specificity of heavy metals contamination of anthropogenically transformed environment have been grouped, primary attention being paid to the system "soil – plant –… " . Multi-factorial character of interaction in this block as well as the nature of accumulation and behaviour of toxic elements in a plant organism have been underlined. Many questions are concentrated in the framework of structural and functional reactions of plants to dynamic alterations or relatively chronic state of the environment (express-diagnostics, histochemical manifestations, morphological alterations and others).

We considered the thesis that the criterion of anthropotolerance of plants can be their ecological plasticity reflecting itself in differentiation of a number of structural elements which allows to realize adaptation of potential phyto-testors to wide conditions of their existence. In this aspect many approaches (geobotanical, biochemical as part of physiological, anatomic and morphological, populational, geological and mineralogical, landscape and descriptive, reconnaissance and others) come to one principal statement on possibility of qualitative and quantitative evaluation of the environment using plants. In the literature survey the attention is accented on peculiarities of the reaction of a leaf apparatus as an informative vegetative part of test-indicators as well as carpological and embryological sphere as sexual component of exactly "test-objects" or "test-characteristics", such terms being more appropriate (than "test-species"), taking into account the specificity of the present experimental work. There have been pointed out the basic procedures of realization of phytoindication process that can be presented as a following algorithm: factor choice, way and scale of measurements choice, search for indicator, elaboration of an evaluation scale, data visualization (in this case plane cartographic), determination of the correlation level between factor and indicator alteration and way of expressing this connection. The data available demonstrate that working out a system of methods of phytoindicational research of metallic pressure on the basis of plants' structural polymorphism is an important and necessary scientific and practical trend of bioindicational monitoring of anthropogenically transformed environment, which is topical for geochemically contrast Donetsk region.

Selection of test-objects for phytoindicational experiment was based on ecological and botanical characteristics, indices of structural plasticity and on the results of the laboratory testing. In the general block of metallic pressure phytoindication we used the following species: *Cichorium intybus* L., *Tripleurospermum inodorum* (L.) Sch. Bip., *Plantago major* L., *Tanacetum vulgare* L., *Reseda lutea* L., *Berteroa incana* (L.) DC., *Echium vulgare* L., *Tragopogon major* Jacq.

The strategy of immediate phytoindicational research consists of the following: 1) defining for the model objects (test-species) characteristics that are characterized by the highest indicational variability; 2) studying the structural elements of plants in the dynamics, as well as ascertainment of their connection with other structures and indices of metallic pressure.

It is stated that inclusion of heavy metals in biogeochemical processes is related to two often interconnected factors: natural biogeochemical processes and human activity. The latter factor for technogenically transformed region of the Donetsk oblast has the determining meaning for forming metallic pressure zones – metalogenic provinces (areoles). With the coefficients of correlation for big extracts we grouped two blocks of metalogeny: 1) Ni-Cu, attending Zn and Pb; 2) Cd-Hg. Reactions of test-plants with individual and combined action of heavy metals at the initial stages of plants germination have been studied in the laboratory. The work studies some peculiarities of absorption and accumulation of heavy metals by *Cichorium intybus* when growing together with other plants.

Thus, there can be several approaches, trends and criteria of phytoindicational evaluation of anthropogenically transformed environment. The most appropriate and so the most prospective with extrapolation of methods and ways of phytoindication are *Cichorium intybus* L., *Tripleurospermum inodorum* (L.) Sch. Bip., *Plantago major* L. and *Tanacetum vulgare* L. These species are indicative due to informative morphological plasticity which is manifested in conditions of metallic pressure mostly of anthropogenic origin, rather than due to availability and frequency in natural and transformed ecotopes. The largest accumulation diapason in the rhyzosphere of soil belongs to Zn и Pb (up to 900-1000 mg/kg), the smallest – to Cd (up to 10 mg/kg) and Hg (up to 3 mg/kg), which accords with general tendencies of biogeochemical cycle of heavy metals in technogenic soils of industrialized region. By translocation coefficients of heavy metals in plants we made it possible to conduct monitoring research and define the levels of technogenic environment contamination.

It is proved statistically that with an increase of soil heavy metals contamination level the extent of structural polymorphism of test-objects grows. Such discrete characteristics of *Cichorium intybus* L. as the polar bulge reduction index, the degree of pollen defectness, the variability of fruits' surface structure, the frequency of teratologic schyzocotily and others are informative and indicative according to specific character of manifestation.

The work presents and applies the criteria of self-descriptiveness of structural phytoindication method: coefficients of correlation and determination values; availability of groups and block coincidence of characteristics of plants' structural alterations correlation with components of elementary metalogeny in the system of their inner connections; data of cartographic and schematic visualization; synchronous correspondence blocks of plants' structural characteristics to the gradient of toxic pressure on soils in anthropogenically transformed environment. Certainly, these criteria will be further changed according to the specificity of the experiment.

On the basis of the suggested system of structural phytoindicational evaluation of soil contamination with heavy metals there were three general structural and transformational blocks singled out: Ni; Cu–Zn–Pb и Cd–Hg. While conducting further detailed ecological and toxicological analysis the number of defined blocks and groups can be largely increased, but the presented principles and exposures will be preserved. Manifestation of indicative polymorphism is specific for various species, which is ascertained by the structure of *Cichorium intybus* L. and *Plantago major* L. blades, the degree of pollen defectness of *Cichorium intybus*, *Tripleurospermum inodorum* (L.) Sch. Bip., *Tanacetum vulgare* L., *Berteroa incana* (L.) DC. and *Echium vulgare* L., indices of structural plasticity of fruits of *Cichorium intybus*, *Tripleurospermum inodorum*, *Tanacetum vulgare* and others. Usually different structures of different plants are altered (elements of pollen structure of *Cichorium intybus*, *Reseda lutea* L., *Plantago major*). Such a condition points to regional specificity of the environment contamination with toxicants as well as of test-objects composition on a certain territory.

In future the programme of continuous phytoindicational monitoring of an industrial region can be enlarged, supplemented with alternative and informative data, which to a certain extent will enrich man's knowledge on the environment and will correct anthropogenic pressure on natural systems.

The main idea of this publication is the approach to the expert estimation of the urban environment with the help of ecological indices of indicator plants being part of the urban flora of Donetsk. The working block-scheme of this project realization consists in the analysis of the plants according to the types of survival in an industrial city while realizing vital strategies.

We suggest the following phyto-indices which range as follows for Donetsk according to a preliminary estimation:

- correlation of violents, patients and explerents (in the model variant 2 : 6 : 1),
- reproductive capacity of explerents (23-45 c.u.),
- reproductive capacity of patients (58-90 c.u.),
- reproductive effort of indicator plants (19-26),
- reproductive success of indicator plants among patients (20-27),
- demographic full value of patients (availability of all vital forms),
- structural plasticity of species of plants on the level of organ morphology (approaching to normal distribution),
- structural plasticity of species of plants according to histological distinctions (tissue deformations, mostly conformational functionally active tissues),
- percentage of species with wide ecological amplitude (no less than 45),
- percentage of species having formed strategies of adaptation to air pollution (no less than 35),
- percentage of species having formed adaptation to soil and water and soil solution pollution (no less than 60).

Such a botanical and ecological approach together with current activities on technical monitoring of the state of industrial environment in the Donetsk city will enable to estimate the ecological misbalance and the extent of ecotopes disturbance more correctly. So far, it's the biota that has that very informative index of living organisms' reaction to additional anthropogenic pressure.

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Сафонов А. И., Сафонова Ю. С. **Фитоэкологические характеристики промышленной урбанизированной среды. –** На примере г. Донецка с использованием биоиндикационных показателей проведен экологический анализ территории промышленного города. Учтены основные стратегии развития города. Предложена рабочая схема биоиндикационной оценки урбанизированной среды.

Ключевые слова: урбанизированная среда, биоиндикационная оценка.

Сафонов А. І., Сафонова Ю. С. **Фітоекологічні характеристики промислового урбанізованого середовища.** – На прикладі м. Донецька за умов використання біоіндикаційних показників проведено екологічний аналіз території промислового міста. Враховано загальні стратегії розвитку міста. Запропоновано робочу схему біоіндикаційної оцінки урбанізованого середовища.

Ключові слова: урбанізоване середовище, біоіндикаційна оцінка.