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INDICATIVE ROLE OF PLANTS IN THE SYSTEM OF CITY MANAGEMENT IN AN INDUSTRIAL REGION

Based on the experiment of 2004-2013 the possibility of using plants in the information and the managerial apparatus of the city have been analyzed (on the example of Donetsk). Aspects of the urban environment where the plants in their indicative properties can optimize analytical measures in addressing environmental programs have been highlighted: functional zoning of the urban environment, the efficiency of public services, the level of contamination of soil and air pollution, predictive planning of new urban areas. Signs of plants for the implementation of the monitoring study have been shown.

Keywords: bioindication, monitoring, urban environment, the environmental situation.

Introduction. Plant organisms are integral part of the urban landscape. Flowering plants have an attached lifestyle, their structure and functions are entirely dependent on environmental conditions and environmental factors. This dependence allows us to consider any sign of plant structure as a response to environmental factors: stability or dynamics parameters of the environment, toxicity and suitability for life. People consciously or unconsciously always use indicative botany. In the conditions of unstable, aggressive and often transformed urban environment in the industrial region of Donbass the use of indicator plants can be part of the managerial decision-making for more efficient operation of urban systems.

The relevance of biomonitoring studies are highlighted in numerous publications [1–4]. In previous papers we described different results of phytoindicational experiment [5–13].We have studied various aspects of the use of plants in the industrial region for monitoring experiment: diagnostic criteria of complex phytoindication for approbation in Donbass [6], phyto-qualimetry of toxic pressure and the degree of ecotopes transformation in Donetsk region [7], initial screening of seed bank of phytoindicators of technogenic pressure on edaphotopes in Donbass [8], phytoecological characteristics of industrial urban environment [9], approbation of ecosystem standardization criteria according to phytoindication component [10].

The environment condition at urban territories is of the highest importance for all people living there, furthermore, it is the pressing issue for almost half of countries population. State authorities are responsible for chemical and physical components of environmental monitoring giving information about composition of urban air, waters and soils in relation to the presence of pollutants and their concentrations as compared to the existing standards [3, 14]. The obtained results give discrete or deducted reflection of environment condition. It is not able to produce integrated understanding or clear picture of the current situation, thus leaving the urban ecosystem health out of comprehension.

But urban ecosystems are able to reflect their condition itself and the main task is to detect and interpret these signs. All environment components are deeply fragmented at urban areas and they are very often isolated from each other so, that they cannot give reliable information about their natural neighbors. But there is all-in-one element of urban ecosystem which is directly connected with all others, actively reactive and clearly visible to human observers – biological objects and green plantations on the whole [15, 16]. They are small natural or artificial ecosystems – united organisms, which face all those negative factors of cities as humans do or even more [17–23]. Increasing gaseous and dust pollution of air, special temperature and water conditions of air and soil, presence of stone, concrete and metallic surfaces, asphalt coverage of streets and areas, presence of underground communications and buildings in the area of root, additional illumination of plants in night-time, intensive mode of plantations usage cause specificity of urban environment and its dramatic difference from natural situation, where plants develop under the influence of biological and ecological factors [24–31]. So, by detecting differences and changes of biota parameters it is possible to study the resulted state of the environment, assess potential risks and make further prognosis or develop some recommendations and take certain measures.

Research methodologies. In previous publications, we describe the nature of phytoindicational experiment [5, 6, 10–13]. All methodological approaches can be divided into geobotanical, structural and botanical, and chemical and analytical methods for assessing the quality of the environment [7, 10, 16–18, 23, 27]. The investigation was aimed at analysis of available bioindication methods in order to choose the most appropriate for urban conditions. Based on methods chosen, the multicomponent assessment scale is to be developed to provide the integral assessment of urban environment condition. These scale must include various indicators to provide as much information as possible about diverse biotic components state and, what is also of high importance, to verify the obtained results by each parameter against the rest.

The assessment of environment quality and anthropogenic changes within ecosystems of different levels can be carried out based on various biotic parameters (bioindicator monitoring). Advantages of biotic parameters usage include reliability and objectivity. The being of biota is determined by the condition of environment in its unity and expressly reacts to negative influences of any origin, regardless of our knowledge about them. Finally, the reaction of ecosystem substantially depends not only on composition of factors, but also on their interaction. But adequately reflecting the degree of negative influence on the whole, the bioindicators do not explain, which factor has created the response.

Biological indicators are species used to monitor the health of environment or ecosystem. They are any biological species or group of species whose function, population, or status can be used to determine ecosystem or environmental integrity. A good biomonitor will indicate the presence of the pollutant and give rough evaluation of the amount and intensity of the exposure. Bioindicators can tell about the cumulative effects of different pollutants in the eco-system and about how long a problem may have been present, which physical and chemical testing cannot tell. These organisms (or communities of organisms) deliver information on alterations in the environment or the quantity of environmental pollutants by changing in one of the following ways: physiologically, chemically or behaviourally. The information can be deduced through the study of the content of certain elements or compounds, their morphological or cellular structure, metabolic-biochemical processes, behaviour, or population structure(s). Biomonitoring can be passive or active. Passive methods observe plants growing naturally within the area of interest. Active methods detect the presence of pollutants by placing test plants of known response and genotype into the study area. Depending on the organism selected and their use, there are several types of bioindicators: plant, animal, microbial and macroinvertebrate indicators.

Urban territories are not rich in fauna, therefore this type of bioindicators cannot be well applied in this case. An increase or decrease in birds population may indicate damage to the ecosystem caused by pollution. For example, if pollution causes the depletion of important food sources, some species dependent upon these food sources will also be reduced in number. Overpopulation, can be the result of opportunistic species growth. In addition, size and rate of deformities or diseases, which arise in bird populations, may be of great use. But more sophisti-cated methods, which involve study of other animal species, as well as macroinvertebrates or microbial indicators, lead to overcomplicated preparation and research techniques to be applied in order to receive clear results. Therefore, the most appropriate group of indicators, which should be used at urban areas, is plants. The presence or absence of certain plant or other vegetative life in an ecosystem can provide important clues to the environment health assessment.

We have studied the local monitoring points of spontaneous transformation of the surface layer of soil. This occurs as a result of industrial and domestic activities, laying or repair of underground utilities, road construction and agronomic activities in cities.

Results and discussion. To summarize our experimental data, we have compiled lists of species (or signs of species) of plants, which may be involved in a successful environmental management of the city (Donetsk).

To determine the zones (areas) of the city, suitable for residential development, we recommend the following plants: *Atriplex patula* L., *Berteroa incana* (L.) DC., *Brassica campestris* L., *Bromopsis inermis* (Leyss.) Holub, *Bromus arvensis* L., *Dactylis glomerata* L., *Daucus carota* L., *Deschampsia caespitosa* (L.) Beauv., *Gnaphalium uliginosum* L., *Lactuca tatarica* (L.) C. A. Mey., *Melilotus albus* Medik., *Melilotus officinalis* (L.) Pall.

For the formation of industrial zones or zones of municipal landfills the following indications of plants will be useful: *Achillea collina* J. Becker ex Rchb., *Achillea nobilis* L., *Ailanthus altissima* (Mill.) Swingle, *Ambrosia artemisiifolia* L., *Anthoxanthum odoratum* L., *Arrhenaterum elatius* (L.) J. et C. Presl., *Artemisia absinthium* L., *Artemisia vulgaris* L., *Atriplex hortensis* L., *Atriplex micrantha* C.A. Mey., *Atriplex patens* (Litv.) Iljin, *Calamagrostis epigeios* (L.) Roth, *Cirsium arvense* (L.) Scop., *Coniza Canadensis* (L.) Crong, *Convolvulus arvensis* L., *Cyclachaena xanthiifolia* (Nutt.) Fresen., *Cynoglossum officinale* L., *Digitalis purpurea* L., *Echium vulgare* L., *Elytrigia repens* (L.) Nevski), *Grindelia squarrosa* (Purch) Dunal, *Hyoscyamus niger* L., *Kochia laniflora* (S. G. Gmel.) Borb., *Oberna behen* (L.) Ikonn., *Otites media* (Litv.) Klokov, *Plantago major* L., *Polygonum aviculare* L., *Reseda lutea* L., *Rumex crispus* L., *Salsola australis* R. Br., *Senecio vulgaris* L., *Sinapis alba* L., *Sinapis arvensis* L., *Sisymbrium polymorphum* (Murray) Roth, *Sonchus arvensis* L., *Stenactis annua* Nees, *Swida alba* Opiz, *Thlaspi arvense* L., *Xanthium albinum* (Widd.) H. Scholz.

To create recreational areas presence of the following plants should be identified: *Agrostis stolonifera* L., *Amaranthus albus* L., *Amaranthus retroflexus* L., *Capsella bursa-pastoris* (L.) Medik., *Capsella orientalis* Klokov, *Centaurea diffusa* Lam., *Chelidonium majus* L., *Chenopodium album* L., *Cichorium intybus* L., *Digitaria sanguinalis* (L.) Scop., *Diplotaxis muralis* (L.) DC., *Diplotaxis tenuifolia* (L.) DC., *Erucastrum armoracioides* (Czern. ex Turcz.), *Eupatorium cannabinum* L., *Euphorbia seguieriana* Neck., *Fallopia convolvulus* (L.) A. Löve, *Galinsoga parviflora* Cav., *Galium mollugo* L., *Papaver rhoeas* L., *Persicaria maculata* (Rafin.) A. & D. Löve, *Plantago lanceolata* L., *Polygonum patulum* M. Bieb., *Tragopogon major* Jacq., *Tripleurospermum inodorum* (L.) Sch. Bip.

We have found that for toxicological monitoring it is informative to use indicational indices of plants (*Berteroa incana*, *Echium vulgare, Reseda lutea, Brassica campestris*, *Capsella orientalis, Diplotaxis muralis*, *D. tenuifolia*, *Tripleurospermum inodorum* (appearance of the structure of plants, the life form), *Capsella bursa-pastoris, R. lutea, E. vulgare, Calamagrostis epigeios*, *Daucus carota*, *Elytrigia repens* (transformation in the root tip terminals), *B. incana, C. bursa-pastoris*, *R. lutea, E. vulgare, Atriplex patula*, *Cichorium intybus*, *Melilotus albus*, *M. officinalis*, *Tragopogon major, T. inodorum* (variability in shoot formation, inflorescence formation), *E. vulgare, Convolvulus arvensis*, *Oberna behen*, *R. lutea*, *Agrostis stolonifera, C. intybus*, *Cirsium arvense, Grindelia squarrosa*, *T. major* (teratological manifestations in the flower), *Ambrosia artemisiifolia*, *Achillea nobilis*, *Ailanthus altissima*, *Amaranthus albus*, *A. retroflexus* (genetic heterogeneity of seeds), *B. incana*, *Kochia laniflora., C. bursa-pastoris, Cyclachaena xanthiifolia, E. vulgare, Deschampsia caespitosa, Galium mollugo, R. lutea, Digitaria sanguinalis* (general generative transformation subpopulations) to determine the mechanical transformation - presence of plant species: *Bromopsis in ermis*, *Calamagrostis epigeios* (1), *Achillea collina*, *Artemisia vulgaris*, *Dactylis glomerata*, *Eupatorium cannabinum, Otites media*, *Rumex crispus* (3-4), *Anthoxanthum odoratum, Arrhenaterum elatius, Convolvulus arvensis*, *Deschampsia caespitosa, Diplotaxis tenuifolia*, *Elytrigia repens*, *Euphorbia seguieriana*, *Fallopia convolvulus*, *Galium mollugo, Kochia laniflora, Lactuca tatarica*, *Melilotus officinalis*, *Polygonum patulum*, *Reseda lutea*, *Senecio vulgaris*, *Sinapis arvensis*, *Stenactis annua*, *Thlaspi arvense*, *Tragopogon major* (8), *Amaranthus albus*, *Atriplex micrantha*, *Brassica campestris*, *Capsella bursa-pastoris, Capsella orientalis, Cichorium intybus*, *Cyclachaena xanthiifolia*, *Diplotaxis muralis*, *Echium vulgare, Elytrigia repens*, *Melilotus albus*, *Oberna behen*, *Plantago major*, *Sinapis alba*, *Sisymbrium polymorphum*, *Sonchus arvensis* (9), *Atriplex patens*, *Atriplex patula*, *Berteroa incana*, *Capsella bursa-pastoris, Diplotaxis muralis*, *Echium vulgare, Tragopogon major* (10), and for integrated pollution – indices of universal phytoindicators (*Atriplex patula, Berteroa incana, Capsella bursa-pastoris, Cichorium intybus, Dactylis glomerata, Diplotaxis muralis, Echium vulgare, Plantago major, Reseda lutea, Tragopogon major, Tripleurospermum inodorum*) for industrial ecotopes of Donbass.

Areas of constant transformation, mixing of surface soil horizons in Donetsk are accompanied by the following plants: *Atriplex hortensis*, *Coniza canadensis*, *Gnaphalium uliginosum*, *Grindelia squarrosa*, *Thlaspi arvense*, *Tragopogon major, Tripleurospermum inodorum, Atriplex patens*, *Atriplex patula*, *Berteroa incana*, *Capsella bursa-pastoris, Diplotaxis muralis*, *Echium vulgare, Tragopogon major, Amaranthus retroflexus*, *Ambrosia artemisiifolia*, *Centaurea diffusa*, *Polygonum aviculare*, *Reseda lutea.*

Availability of some plants (*Ailanthus altissima* (Mill.) Swingle, *Calamagrostis epigeios* (L.) Roth, *Melilotus albus* Medik., *Stenactis annua* Nees, *Swida alba* Opiz,),above lines of groundwater communications may indicate chronic disturbances in the system of water supply, in such places repairs are needed.

Cd contamination of soil causes the following symptoms in plants: *B. incana*, *E. vulgare, R. lutea, B. campestris*, *C. orientalis, D. muralis*, *D. tenuifolia*, *T. inodorum* (appearance of the structure of plants, the life form – correlation coefficient – 0.94); *B. incana, C. bursa-pastoris*, *R. lutea, E. vulgare, A. patula*, *C. intybus*, *M. albus*, *M. officinalis*, *T. major, T. inodorum* (variability in shoot formation, inflorescence formation – correlation coefficient – 0.74); *A. artemisiifolia*, *A. nobilis*, *A. altissima*, *A. albus*, *A. retroflexus* (genetic heterogeneity of seeds – correlation coefficient – 0.55); *B. incana*, *K. laniflora, C. bursa-pastoris, C. xanthiifolia, E. vulgare, D. caespitosa, G. mollugo, R. lutea, D. sanguinalis* (general generative transformation subpopulations – correlation coefficient – 0.88).

Pb contamination of soil causes the following symptoms in plants: *B. incana*, *E. seguieriana*, *R. lutea*, *E. cannabinum, C. album, K. laniflora, A. artemisiifolia*, *A. hortensis*, *A. micrantha*, *A. patens*, *H. niger*, *P. lanceolata*, *P. major*, *S. polymorphum*, *S. annua* (conformational variability of the internal tissues of the leaf – correlation coefficient – 0.69); *B. incana*, *E. vulgare, R. lutea, B. campestris*, *C. orientalis, D. muralis*, *D. tenuifolia*, *T. inodorum* (appearance of the structure of plants, the life form – correlation coefficient – 0.78); *B. incana*, *C. bursa-pastoris*, *A. retroflexus*, *A. absinthium*, *A. odoratum , C. officinale*, *D. tenuifolia*, *A. vulgaris*, *A. collina*, *A. elatius, G. parviflora*, *G. uliginosum*, *L. tatarica*, *P. rhoeas*, *R. crispus, S. alba*, *S. arvensis*, *T. arvense*, *T. major, T. inodorum*, *X. albinum* (morphological heterogeneity of fruit – correlation coefficient – 0.90).

Cr contamination of soil causes the following symptoms in plants: *B. incana*, *E. vulgare, R. lutea, B. campestris*, *C. orientalis, D. muralis*, *D. tenuifolia*, *T. inodorum* (appearance of the structure of plants, the life form – correlation coefficient – 0.90); *B. incana*, *E. seguieriana*, *R. lutea*, *E. cannabinum, C. album, K. laniflora, A. artemisiifolia*, *A. hortensis*, *A. micrantha*, *A. patens*, *H. niger*, *P. lanceolata*, *P. major*, *S. polymorphum*, *S. annua* (conformational variability of the internal tissues of the leaf – correlation coefficient – 0.68); *A. artemisiifolia*, *A. nobilis*, *A. altissima*, *A. albus*, *A. retroflexus* (genetic heterogeneity of seeds – correlation coefficient – 0.84).

Zn contamination of soil causes the following symptoms in plants: *C. bursa-pastoris, R. lutea, E. vulgare, C. epigeios*, *D. carota*, *E. repens* (transformation in the root tip terminals – correlation coefficient – 0.91); *D. glomerata*, *B. incana*, *D. purpurea, P. aviculare, B. inermis*, *B. arvensis*, *C. diffusa*, *P. maculata*, *S. australis*, *S. vulgaris*, *T. inodorum* (variability in the male generative sphere – defective pollen – correlation coefficient – 0.90); *B. incana*, *K. laniflora., C. bursa-pastoris, C. xanthiifolia, E. vulgare, D. caespitosa, G. mollugo, R. lutea, D. sanguinalis* (general generative transformation subpopulations – correlation coefficient – 0.87).

Hg contamination of soil causes the following symptoms in plants: *E. vulgare, C. arvensis*, *O. behen*, *R. lutea*, *A. stolonifera, C. intybus*, *C. arvense, G. squarrosa*, *T. major* (teratological manifestations in the flower – correlation coefficient – 0.93); *B. incana, C. bursa-pastoris*, *R. lutea, E. vulgare, A. patula*, *C. intybus*, *M. albus*, *M. officinalis*, *T. major, T. inodorum* (variability in shoot formation, inflorescence formation – correlation coefficient – 0.94); *C. bursa-pastoris, R. lutea, E. vulgare, C. epigeios*, *D. carota*, *E. repens* (transformation in the root tip terminals – correlation coefficient – 0.90).

Ni contamination of soil causes the following symptoms in plants: *B. incana, C. bursa-pastoris*, *R. lutea, E. vulgare, A. patula*, *C. intybus*, *M. albus*, *M. officinalis*, *T. major, T. inodorum* (variability in shoot formation, inflorescence formation – correlation coefficient – 0.88); *D. glomerata*, *B. incana*, *D. purpurea, P. aviculare, B. inermis*, *B. arvensis*, *C. diffusa*, *P. maculata*, *S. australis*, *S. vulgaris*, *T. inodorum* (variability in the male generative sphere – defective pollen – correlation coefficient – 0.97).

Co contamination of soil causes the following symptoms in plants: *B. incana*, *E. seguieriana*, *R. lutea*, *E. cannabinum, C. album, K. laniflora, A. artemisiifolia*, *A. hortensis*, *A. micrantha*, *A. patens*, *H. niger*, *P. lanceolata*, *P. major*, *S. polymorphum*, *S. annua* (conformational variability of the internal tissues of the leaf – correlation coefficient – 0.90).

Cu contamination of soil causes the following symptoms in plants: *B. incana*, *E. seguieriana*, *R. lutea*, *E. cannabinum, C. album, K. laniflora, A. artemisiifolia*, *A. hortensis*, *A. micrantha*, *A. patens*, *H. niger*, *P. lanceolata*, *P. major*, *S. polymorphum*, *S. annua* (conformational variability of the internal tissues of the leaf – correlation coefficient – 0.84); *B. incana*, *C. bursa-pastoris*, *A. retroflexus*, *A. absinthium*., *A. odoratum, C. officinale*, *D. tenuifolia*, *A. vulgaris*, *A. collina*, *A. elatius, G. parviflora*, *G. uliginosum*, *L. tatarica*, *P. rhoeas*, *R. crispus, S. alba*, *S. arvensis*, *T. arvense*, *T. major, T. inodorum*, *X. albinum* (morphological heterogeneity of fruit – correlation coefficient – 0.84); *B. incana*, *K. laniflora., C. bursa-pastoris, C. xanthiifolia, E. vulgare, D. caespitosa, G. mollugo, R. lutea, D. sanguinalis* (general generative transformation subpopulations – correlation coefficient – 0.71).

Mn contamination of soil causes the following symptoms in plants: *E. vulgare, C. arvensis*, *O. behen*, *R. lutea*, *A. stolonifera, C. intybus*, *C. arvense, G. squarrosa*, *T. major* (teratological manifestations in the flower – correlation coefficient – 0.95); *B. incana*, *C. bursa-pastoris*, *A. retroflexus*, *A. absinthium*., *A. odoratum, C. officinale*, *D. tenuifolia*, *A. vulgaris*, *A. collina*, *A. elatius, G. parviflora*, *G. uliginosum*, *L. tatarica*, *P. rhoeas*, *R. crispus, S. alba*, *S. arvensis*, *T. arvense*, *T. major, T. inodorum*, *X. albinum* (morphological heterogeneity of fruit – correlation coefficient – 0.94).

If plants are to be used as bioindicators, some measure of what are 'normal' concentrations of material within plant tissue is required. This can be acquired by comparison with supposed pristine conditions, but care must be taken to ensure that confounding factors are accounted for. If using plants in situ, some estimate has to be made for intrinsic genetic variation in uptake and accumulation; if using active biomonitoring with standardised plants it may be necessary to account for changed growth rates in different situations, as well as changed uptake rates as a direct result of pollutant exposure. Any answer to the 'normal' question assumes that temporal variability is understood, and also the spatial variation within the plant, for example whether to use standardised leaf ages, or standardised positions on a plant when sampling. Different scenarios can be constructed that illustrate how material may accumulate as a plant grows, and not all of these are amenable to the use of the particular plant/pollutant combination for biomonitoring.

Inferences from field sampling can be profoundly wrong if the spatial heterogeneity of the area under study is not well characterised. Often, biomonitoring is used to target a suspected pollutant source, to gain a better understanding of the spatial extent of any effects. However, because the response of plants is often interpreted only in terms of spatial correlations, with no knowledge of causal relationships, the influence of other spatial factors (soil type, exposure, water relations etc.) has to be excluded, or at least investigated. Although an obvious issue for in situ studies, active biomonitoring with standardised plants can also be prone to such spatial correlations. Moreover, the 'normal' variation in plant material may swamp any response, so the lack of spatial correlation with the presumed source should not necessarily be used to infer the lack of any effect.

Plant bioindicators at urban territories and their investigation. There are several types of plant bioindicators, including mosses, lichens, tree bark, bark pockets, treerings, leaves, and fungi. By the increase of plants tolerance to the impacts of pollutants, they can be ranged as follows: lichens – coniferous – grassy – deciduous. The choice of bioindicators depends on the following organism properties or qualities: living indicators must not be too sensible and too tolerant to contamination; living indicators must have a prolonged life cycle; living indicators must be wide-spread, thus every species must be linked to certain locality. Lichens and mosses meet all this requirements. They respond to the pollution of atmosphere with the oxides of sulfur and nitrogen. They react on contamination differently, if compared with higher plants.

Long-term influence of low concentrations of pollutants causes such damages to lichens and mosses, which do not disappear up to their death. This happens due to very slow process of dead cell substitution in lichens and mosses. The fact is that lichens react on pollutants in two ways: gradually disappear under the influence of acid oxides and, at the same time, accumulate heavy metals in thallus, which also leads to their gradual disappearance.

This process can be divided into 4 stages: specific variety of lichens, mosses goes down, quantity of lichens, mosses goes down, size of lichen thallome and mosses bodies diminishes and losses color, concentration of heavy metals in the body grows constantly.

The methods of licheno- and bryophytaindication can be divided into three groups: the methods based on identification of changes, which take place in the structure and vital functions of lichens under the influence of lichens; the methods based on description of lichen species dwelling in districts with different level of atmosphere pollution; the third group includes the methods of study of whole lichens associations in polluted areas and making special maps.

In relation to air pollution, the types of lichens and mosses can be divided into three categories: 1) most sensible, vanishing at the first signs of pollution; 2) medium sensitive, which substitute the most sensible vanished species, which they could not compete with, while the air was clean; 3) resistible, tolerant to pollution.

Based on individual features of lichens special scales of pollution, which allow defining the level of pollution based on presence or absence of certain species of lichens, are developed. In general, fruticose lichens are the most sensible to air pollution, crustose lichen are the most resistible, and foliose lichens are moderately sensitive. Arboreal plants due to their spread, long life term, accessibility and variety are still the most efficient bioindicators.

The condition of trees is determined visually by the sum of basic biomorphological signs: crown density, foliation or level of defoliation, size and color of leaves (needles), presence or absence of deviations and deformations in the structure of trunk, crown and sprout, presence and share of dry sprouts in the crown or dry top, integrity and state of bark and oak. All these signs are produced by negative natural and anthropogenic environmental factors. The integration of all those mentioned above parameters can be used for integral trees condition and environment quality assessment.

Evaluation of trees condition is conducted by two methods, supplementing each other. First, trees are divided into three quality groups in city planting regulations: 1 – good, 2 – satisfactory and 3 – unsatisfactory conditions. Secondly, on the basis of the operating "Sanitary rules in the forests of Ukraine" there are 6 categories of trees viability: 1 – trees without the signs of weakening, 2 – weak, 3 – extremely weak, 4 m drying, 5 m dead trees of current year (dried in the current year), 6 – dead trees of past years. This type of assessment can be conducted for big territories and accompanied with sampling for further investigations.

As it was said, coniferous trees are more sensitive to environment pollution. The characteristic signs of environment deterioration and especially air pollution are the appearance of different sorts of chlorosis and necrosises, diminishing of organs sizes (length of pine-needle, sprouts of current and past years, their thickness, size of cones, reduction of size and number of final buds). The last is pre-condition of branching diminishing. Due to slowed growth of sprouts and needles at polluted areas the distance between needles is reduced (there are more needles per 10 cm of a sprout at polluted areas comparing to those of clean areas). Duration of needles life also diminishes (1–3 year at polluted area and 6–7 years at clean). Influence of pollutants also causes sterility of seed (reduction of their germination). All these signs are not specific; however, their sum gives the objective picture. The biggest advantage of coniferous is that they could be used as bioindicators during the whole year. They are also very often found in the composition of protecting green belts and therefore may be used to assess environmental impacts of industrial enterprises or highways.

Deciduous trees have their own advantage: they change their leaves every year, so deviations from normal environment state detected with their help will be related to very specific period of time. Leaves are also good object for further investigation in lab, namely the investigation of their condition based on the phenomena of asymmetry. In this case, any species, for which bilateral symmetry is typical, can be chosen as a test-object. Differences in width of left and right halves of leaf, length of vein of the second order, distance be-tween the bases of the first and second veins of the second order, distance between the ends of the same veins and angle between the main vein and the second order vein of the leaf. These values could be converted into numbers and thus quantitive assessment of bioindicators will be performed and the results will look more reliable and could be easily compared. Further it is possible to evaluate the level of technogenic pressure at the area of investigations by studying signs of leaves damage.

The thing is that tissues of arboreal plants leaves, damaged as a result of anthropogenic pollution of air, do not take part in photosynthesis and stop to execute the basic functions: synthesis of organic substances, oxygen and phytoncydes production. The dust retaining role of urban plant is also weakened, as dust settles down on slightly moist surface of living leaves. The photosynthesis function highly depends on the area of leaf surface (leaf index). So, the area of leaves is an important bioindicating parameter, which can be easily compared with that of background trees.

The visual methods of leaves area estimation and percent of damages of leaf tissues are not very exact, although on the whole they reflect the general picture of damages and green plantations condition. Application of simple reagents (acids) gives possibility to distinguish really dead tissues from others and thus increases accuracy of the results. Also it is possible to apply lab techniques for the investigation of tree leaves resistance to high and low temperatures, dusting and salinization, which gradually deteriorate under the influence of anthropogenic pressure at urban territories.

Finally, number of species and condition of grasses is also important for the assessment of environment quality of cities. The most important parameter would be diversity of grasses, their average height and average length of leaves. These should be also compared with the corresponding parameters of grasses, grown in natural conditions. All the results obtained in the course of biomonitoring at certain territory will be subjected to certain riticism due to mostly qualitative character and absence of strong theoretical grounds for their interpretation.

However, if the investigation is based on a range of methods applied and indicators studied, then the result will have higher credibility. The fragment of the complex biomonitoring scheme for urban territory and interpretation of the obtained results is presented below.

The results obtained in the course of the offered sequence of urban biomonitoring must be evaluated based on comparative scale, which could be supplemented with point scores. The scale ranges the values of studied parameters to reflect the level of environmental disbalance in the following order – minor, low, medium, high, catastrophic. The corresponding score is made of points obtained for each parameter, if minor level is equal to 0 or 1, low – 2, medium – 3, high – 5, catastrophic – 7. Depending on the number of parameters evaluated, the environmental situation at the study area will be interpreted. The proposed biomonitoring scheme includes 20 parameters, consequently, the most favorable environmental conditions will be at urban areas with the score below 20, 21–40 stand for normal conditions, 41–60 corresponds acceptable situation, 61–80 marks the disturbed condition, 80–100 means that the environment condition imposed high risks for population and if the score is over 100, then the eco-system is ruined and dangerous for population. Thus, based on combination of various parameters of living bioindicators it is possible to define the level of environmental disbalance and develop a range of recommendations for further degradation prevention.

The protection and management of ecological resources generally focus on responses measured at higher levels of organization. Thus, the success of biomarkers in supporting ecological risk assessment depends importantly on the identification of valid biomarkers and the establishment of process-level linkages between biomarkers and higher-level responses, for example, bioindicators. A basic premise underlying the use of biomarkers and bioindicators in ecological risk assessment is that responses to chemical stress manifest initially as disruptions of normal molecular, biochemical, or physiological structure and function. If the accumulation of a toxic chemical is sufficient in magnitude and(or) duration to overwhelm the normal homeostatic capacity or repair mechanisms of these biological systems, deleterious effects might be observed for individual organisms. If a sufficient number of organisms are impacted, the response to stress might be subsequently measured as changes in population size or alterations in community structure. In the vernacular of hierarchy theory, the expression of stress has its explanation in levels of biological organization below its observation, and significance in levels above. Therefore, studies that characterize ecological responses to chemical stressors across several levels of biological and ecological organization are particularly valuable in that such studies might identify mechanistic linkages between lower-level responses (biomarkers) and relevant individual-, population-, or community-level assessment endpoints.

Uses of biomarkers in support of ecological risk assessment identified: characterize mechanisms of toxicity involved in biological responses at higher levels of organization; help establish causal relationships between stressors and response; indicate presence of specific groups of contaminants; establish absence of significant effects at population, community, or ecosystem level; predict higher-level responses; signal the exceedance of critical physiological thresholds or tolerance limits; provide biological responses for use in weight-of-evidence approach to ecological risk assessment; monitor changes in environmental health in relation to mitigation or risk management.

A second set of recommendations focused on the use of biomarkers and bioindicators in risk management and assessment: biomarkers and bioindicators should be incorporated into risk assessment frameworks using a weight-of-evidence approach based on sensitive short-term responses and longer-term ecologically relevant endpoints; biomarkers need to be related to responses of concern and then used to evaluate the safety of pesticides and other chemicals; suites of biomarkers and bioindicators that address exposure and effects should be used to characterize risks posed by multiple stressors; field studies should be designed to rigorously link cause (i.e., stressors) and effects measured for endpoints chosen *a priori* to represent different levels of organization; novel measures that identify thresholds for environmental tolerances should be developed and incorporated into regulatory and experimental toxicology; biomarkers and bioindicators should be used in assessing risks posed by agrochemicals in the context of sustainable agriculture. To the extent that the preceding recommendations can be implemented, biomarkers and bioindicators will likely increase in their usefulness for assessing ecological risk. In addition to fulfilling the preceding recommendations, risk assessors must become increasingly knowledgeable concerning the selection and application of biomarkers and bioindicators. Assessors with formal training and professional experience in more traditional ecotoxicology (e.g., acute and chronic toxicity benchmarks, effects on populations, community structure) require additional training to become more familiar with the concepts, methods, and interpretation of indicators of exposure and effects measured at suborganism levels of organization: *classical ecotoxicologists need to become better biochemists*. The suggested previously could facilitate this extension of environmental toxicology to further embrace biochemistry that is relevant to risk assessment.

Conclusions. Intensive development of urban infrastructure and residential construction leads to the growth of competition for available land resources as well as access to the residuals of natural ecosystems within the city. This way green islands of cities become both needed element for normal life and physical obstacle for urban expansion. But the essence of green plantations role for urban settlements and residence is far beyond provision of visual attraction and free space. These green objects form appearance of the city, have sanitary-hygienic, recreational, landscape-architectural, cultural and scientific value. The latter means, that they can provide valuable information about the environment quality and level of anthropogenic pressure at urban area. The proposed combination of bioindication methods is an efficient instrument simple to use and reliable to interpret, which gives possibility to obtain information about environmental situation, define sources of negative impacts and develop activities for relevant consequences mitigation.

Thus, the presented lists of plant species and their life signs can form the basis for long-term monitoring of environmental quality in the industrial city. In such cases, the Executive Board should have a profile specialization and hold botanical and environmental qualifications to implement the program of "clean city".

REFERENCES

1. Bartell S. M. Biomarkers, bioindicators, and ecological risk assessment – a brief review and evaluation / S. M. Bartell // Environmental Bioindicators. – 2006. – Vol. 1. – P. 60–73.
2. Franzle O. Complex bioindication and environmental stress assessment / O. Franzle // Ecological Indicators. – 2006. – Vol. 6. – P. 114–136.
3. Radomska M. Complex assessment of urban landscapes condition based on bioindication methods / M. Radomska // Science-Based Technologies. – 2013. – Vol. 2, No 18. – P. 236–241.
4. Kiurski J. S. Multivariate Statistical interpretation of fountain solutions as indicator of environmental pollution / J. S. Kiurski // Journal of Environmental Indicators. – 2012. – Vol. 7. – P. 11–19.
5. Глухов О. З. Фітоіндикація металопресингу в антропогенно трансформованому середовищі / О. З. Глухов, А. І. Сафонов, Н. А. Хижняк. – Донецьк: Вид-во Норд-Прес, 2006. – 360 с.
6. Safonov A. I. New diagnostic criteria of complex phytoindication for approbation in Donbass / A. I. Safonov // Problems of ecology and nature protection of technogenic region. – 2008. – Vol. 8, No 1. – P. 91–96.
7. Safonov A. I. Phyto-qualimetry of toxic pressure and the degree of ecotopes transformation in Donetsk region / A. I. Safonov // Problems of ecology and nature protection of technogenic region. – 2013. – Vol. 13, No 1. – P. 52–59.
8. Safonov A. I. Initial screening of seed bank of phytoindicators of technogenic pressure on edaphotopes in Donbass / A. I. Safonov // Problems of ecology and nature protection of technogenic region. – 2010. – Vol. 10, No 1. – P. 92–96.
9. Safonov A. I. Phytoecological characteristics of industrial urban environment / A. I. Safonov, Y. S. Safonova // Problems of ecology and nature protection of technogenic region. – 2007. – Vol. 7, No 1. – P. 70–76.
10. Safonov A. I. Approbation of ecosystem standardization criteria according to phytoindication component / A. I. Safonov // Problems of ecology and nature protection of technogenic region. – 2012. – Vol. 12, No 1. – P. 108–114.
11. Сафонов А. І. Фітоіндикаційна експертиза техногенних екотопів Донбасу / А. І. Сафонов // Вісн. Донец. ун-ту. Сер. А. Природн. науки. – 2007. – № 1. – С. 272–276.
12. Сафонов А. І. Інтегральний показник структурної фітоіндикації рівня токсичного навантаження на природні та техногенні екотопи / А. І. Сафонов // Вісн. Донец. ун-ту. Сер. А. Природн. науки. – 2007. – № 2. – С. 281–285.
13. Сафонов А. И. Фитоиндикационная информативность *Ehium vulgare* L. в промышленном регионе / А. И. Сафонов // Вісн. Донец. ун-ту. Сер. А. Природн. науки. – 2009. – № 1. – С. 340–345.
14. Burger J. Bioindicators: a review of their use in the environmental literature 1970–2005 / J. Burger // Environmental Bioindicators. – 2006. – Vol. 1. – P. 136–144.
15. Giesy J. P. Monitoring of exposure to and potential effects of contaminants in the environment / J. P. Giesy // Environmental Bioindicators. – 2007. – Vol. 2. – P. 129–130.
16. Hof L. Biomonitoring of air quality with plants, animals and humans / Belgium Book of abstracts. – Antwerp: 2012. – 97 p.
17. Ambo-Rappe R. Translational fluctuating asymmetry and leaf dimension in seagrass, *Zostera capricorni* aschers in a gradient of heavy metals / R. Ambo-Rappe // Environmental Bioindicators. – 2007. – Vol. 2. – P. 99–116.
18. Cox R. D. Composition of soil seed banks in southern California coastal sage scrub and adjacent exotic grassland / R. D. Cox, E. B. Allen // Plant Ecology. – 2008. – Vol. 198. – P. 37–46.
19. Gibson D. J. Grasses and Grassland Ecology / D. J. Gibson. – Oxford, New York: Oxford University Press, 2009. – 306 p.
20. Klimkowska A. Species trait shifts in vegetation and soil seed bank during fen degradation / A. Klimkowska, R. Bekker // Plant Ecology. – 2010. – Vol. 206. – P. 59–82.
21. Krueger T. The role of expert opinion in environmental modeling / T. Krueger // Environmental Modelling & Software. – 2012. – Vol. 36. – P. 4–18.
22. Honda Y. Ecological correlations between the persistence of the soil seed bank and several plant traits, including seed dormancy / Y. Honda // Plant Ecology. – 2008. – Vol. 196. – P. 301–309.

23. Butler C. D. Reference module in earth systems and environmental sciences, from climate vulnerability / C. D. Butler, L. Hanna // Ecosystems, Biodiversity, Climate, and Health. – 2013. – Vol. 1. – P. 69–78.
24. Characteristics of the soil seed bank in Mediterranean temporary ponds and its role in ecosystem dynamics / C. Aponte, G. Kazakis, D. Ghosn, V. Papanastasis // Wetlands Ecol. Manage. – 2010. – Vol. 18. – P. 243–253.
25. Brophya C. A modelling framework for analysing the reproductive output of individual plants grown in monoculture / C. Brophya // Ecol. Model. – 2007. – Vol. 207. – P. 99–108.
26. Burger J. Bioindicators: types, development, and use in ecological assessment and research / J. Burger // Environmental Bioindicators. – 2007. – Vol. 1. – P. 22–39.
27. Kumar S. Assessment of the status of municipal solid waste management in metro cities, state capitals, class I cities, and class II towns in India: an insight / S. Kumar // Waste Management. – 2009. – Vol. 29. – P. 883–895.
28. A comparison of seed banks across a sand dune successional gradient at Lake Michigan dunes (Indiana, USA) / S. A. Leicht-Young, N. B. Pavlovic, R. Grundel, K. J. Frohnapple // Plant Ecology. – 2009. – Vol. 202. – P. 299–308.
29. Rein1' R. Spatial patterns in seed bank and vegetation of semi-natural mountain meadows / R. Rein1', C. Chocarro, F. Fillat // Plant Ecology. – 2006. – Vol. 186. – P. 151–160.
30. Schamineel H. J. Vegetation-plot data and databases in Europe: an overview / H. J. Schamineel // Preslia. – 2009. – Vol. 81. – P. 173–185.
31. Zurlini G. Indicating retrospective resilience of multi-scale patterns of real habitats in a landscape / G. Zurlini // Ecological Indicators. – 2006. – Vol. 6. – P. 184–204.

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РЕЗЮМЕ

На основании эксперимента 2004–2013 гг. проведен анализ возможности использования растений в информационном и управленческом аппарате функционирования города (на примере г. Донецка). Выделены аспекты деятельности в урбанистической среде, в которых растения по своим индикационным признакам могут оптимизировать систему аналитических мероприятий в решении экологических программ: функциональное зонирование городской среды, эффективность работы коммунальных служб, уровень загрязнения почвенной и воздушных сред, прогнозное планирование новых территорий городской застройки. Указаны признаки растений для реализации мониторингового исследования.

Ключевые слова: биоиндикация, мониторинг, городская среда, экологическая обстановка.

РЕЗЮМЕ

На підставі експерименту 2004–2013 рр. проведений аналіз можливості використання рослин у інформаційному та управлінському апараті функціонування міста (на прикладі м. Донецька). Виділено аспекти діяльності в урбаністичному середовищі, в яких рослини за своїми індикаційними показниками можуть оптимізувати систему аналітичних заходів у вирішенні екологічних програм: функціональне зонування міського середовища, ефективність роботи комунальних служб, рівень забруднення ґрунтового та повітряного середовища, прогнозне планування нових територій міської забудівлі. Наведено ознаки рослин для реалізації моніторингового дослідження.

Ключові слова: біоіндикація, моніторинг, міське середовище, екологічний стан.