UDC 581.5 : 574.21 : 581.15 (477.60)

© A. I. Safonov

PHYTO-QUALIMETRY OF TOXIC PRESSURE AND THE DEGREE OF ECOTOPES TRANSFORMATION IN DONETSK REGION

Donetsk National University
Schorsa Str., 46, Donetsk, 83050, Ukraine; e-mail: andrey_safonov@i.ua

Safonov A. I. **Phyto-qualimetry of toxic pressure and the degree of ecotopes transformation in Donetsk region. –** The work deals with informativeness of phytoindication under different environment transformations. Implementation of the principles of phytomonitoring must be differentiated depending on the specific impacts on ecotopes: chemical pollution (toxic effects), mechanical disturbance of the surface layer of soil (edaphotope degradation) and co-transformation (complete exposure). The following phytoindicational criteria are proposed: informative species to determine types of environmental regimes, features of plants to establish local technogenic pressure and universal phytoindicators to be used for industrial ecotopes of Donbass. Phyto-qualimetry is based on the use of index scales and indices, obtained as a result of geobotanic or structural (anatomic) analyses of plant facilities.

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.

We have found that for toxicological monitoring it is informative to use indicational indices of plants (*Berteroa incana, Echium vulgare, Reseda lutea* (appearance of the structure of plants, the life form)*, Capsella bursa-pastoris, R. lutea* (transformation in the root tip terminals)*, R. lutea, Agrostis stolonifera* (teratological manifestations in the flower)*, B. incana, C. bursa-pastoris* (general generative transformation subpopulations) to determine the mechanical transformation – presence of plant species (*Atriplex patens, Atriplex patula, B. incana, C. bursa-pastoris, Diplotaxis muralis, E. vulgare, Tragopogon major*), and for integrated pollution – indices of universal phytoindicators (*A. patula, B. incana, C. bursa-pastoris, Cichorium intybus, Dactylis glomerata, D. muralis, E. vulgare, Plantago major, R. lutea, T. major, Tripleurospermum inodorum*) for industrial ecotopes of Donbass.

Key words: phyto-qualimetry**,** phytomonitoring, phytoindicational criteria, Donbass.

Introduction

Today one of applied tasks of the environment monitoring is a necessity to use special indices for the quality of the environment assessment [4, 7, 20, 29]. Such an assessment becomes possible only with the use of complex data that must be adequately presented in both parametric and nonparametric expressions [2, 5, 8, 14, 17, 22, 23, 28].

If we define the norm of environmental quality, the views of scholars and practitioners often differ [3, 7, 9, 15, 20, 26, 27].Theoretical ecology is often limited to models that are not connected with any real objects. And practical results need further forecast that can be realizes by modeling stable processes. In such circumstances, the environmental task is to always be able to determine whether the state of the ecosystem complies with the standard (ecotope, biogeocenosis, landscape-territorial complex, geosystems). In dealing with such problems the standard is defined as a state, which would allow the system to preserve natural historic and productive communication, as well as flows of matter, energy and information [1, 6, 10, 11, 29]. Due to these characteristics, the system under the influence of external factors maintains its properties or the resistant ability to heal itself (self-support, self-development, self-cleaning). In such circumstances, scientists face a very serious problem. This problem is either not popularized or is not mentioned at all. This problem is generated due to multidirectional anthropogenic impacts on ecosystems. Natural systems are experiencing a tremendous amount of impacts of human activities, which we conventionally divide into two groups: mechanical transformation of the landscape and change of biogeochemical functional parameters of the studied ecosystem.

Thus, part of research is either dedicated to only toxic pressure [2, 4, 6, 7, 12, 13, 16, 18, 19, 21, 28] or mechanical disturbances (transformation of environmental modes) [1, 2, 10, 11] in the structure of the system. Correlation between these two vectors of pressure is not shown.

The purpose of our work is to study long-term data on the dynamics of geochemical indicators and the degree of transformation of natural landscapes and to establish the dependence of these vectors of pressure using the approach and principles of phytoindication in environmental monitoring for industrial ecotopes of Donetsk region.

Materials and methods

All the studied ecotopes of Donetsk region we divided into three categories: chemically polluted, mechanically transformed and complex – experiencing both types of effects on the ecosystem. For each category of the impact of anthropogenic factors we installed on a 10-point scale. Plant response to the impact of such factors we also assessed on a 10-point scale. In case of using plants both indicational indices and indicator plants were considered. In the first case we mean the signs of the structure of plants, in the second – presence of these plants on the studied ecotopes. All observations were designed so as to take account of plant reproductive strategies in industrial ecotopes.

To conduct the botanical part of the research we used the following species of plants: *Achillea collina* J. Becker ex Rchb., *Achillea nobilis* L., *Agrostis stolonifera* L., *Ailanthus altissima* (Mill.) Swingle, *Amaranthus albus* L., *Amaranthus retroflexus* L., *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, *Atriplex patula* L., *Berteroa incana* (L.) DC., *Brassica campestris* L., *Bromopsis inermis* (Leyss.) Holub, *Bromus arvensis* L., *Calamagrostis epigeios* (L.) Roth, *Capsella bursa-pastoris* (L.) Medik., *Capsella orientalis* Klokov, *Centaurea diffusa* Lam., *Chelidonium majus* L., *Chenopodium album* L., *Cichorium intybus* L., *Cirsium arvense* (L.) Scop., *Coniza Canadensis* (L.) Crong, *Convolvulus arvensis* L., *Cyclachaena xanthiifolia* (Nutt.) Fresen., *Cynoglossum officinale* L., *Dactylis glomerata* L., *Daucus carota* L., *Deschampsia caespitosa* (L.) Beauv., *Digitalis purpurea* L., *Digitaria sanguinalis* (L.) Scop., *Diplotaxis muralis* (L.) DC., *Diplotaxis tenuifolia* (L.) DC., *Echium vulgare* L., *Elytrigia repens* (L.) Nevski), *Erucastrum armoracioides* (Czern. ex Turcz.), *Eupatorium cannabinum* L., *Euphorbia seguieriana* Neck., *Fallopia convolvulus* (L.) A. Löve, *Galinsoga parviflora* Cav., *Galium mollugo* L., *Gnaphalium uliginosum* L., *Grindelia squarrosa* (Purch) Dunal, *Hyoscyamus niger* L., *Kochia laniflora* (S. G. Gmel.) Borb., *Lactuca tatarica* (L.) C. A. Mey., *Melilotus albus* Medik., *Melilotus officinalis* (L.) Pall., *Oberna behen* (L.) Ikonn., *Otites media* (Litv.) Klokov, *Papaver rhoeas* L., *Persicaria maculata* (Rafin.) A. & D. Löve, *Plantago lanceolata* L., *Plantago major* L., *Polygonum aviculare* L., *Polygonum patulum* M. Bieb., *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., *Tragopogon major* Jacq., *Tripleurospermum inodorum* (L.) Sch. Bip., *Xanthium albinum* (Widd.) H. Scholz.

To conduct the technical part of the research we investigated content of heavy metals in soils, the degree of transformation of the soil horizon, violation of surface soil under direct contact with the root system of plants.

The definition of stability of natural ecosystems is closely connected with phytoindication indices. We considered indices of weed plants structure as informative criteria of ecosystems resistance towards anthropogenic pressure. The research was conducted in the Donetsk region (Ukraine). The materials were being collected from 2000 till 2013. The test sites were laid in node localization of the monitoring network. To obtain stationary data we chose points where the level of industrial pollution is the highest in the region, oints that were the most affected by human influence (landscape transformation, agricultural use) and control points – the sites corresponding to the background environmental monitoring – areas of natural reserve fund of Ukraine.

Basic monitoring points corresponded to the following industrial facilities: OJSC «Ilyich Iron and Steel Works of Mariupol, OJSC «Iron and Steel Works of Mariupol Azovstal'», Starobeshevo TEPS OJSC «Donbassenergo», Kurakhovo TEPS OJSC «Skhidenergo», Vuglegirsk TEPS OJSC «The State energy generating company «Centrenergo», OJSC «The Zasiadko coal mine», Zooevka

TEPS-2 «Skhidenergo», Slovyansk TEPS OJSC «Donbassenergo», OJSC «Iron and Steel Works of Makiyivka», OJSC «Iron and Steel Works of Yenakiyevo», OJSC «Coke and Chemical Works of Avdiyivka, OJSC «Makrokhim», OJSC Coalmine «Pivdennodonbasska № 1», OJSC «Donetskstal», OJSC Iron and Steel Works of Donetsk», OJSC «Coke and Chemical Works of Yasynuvata, OJSC «Coke and Chemical Works of Yenakiyevo, OJSC «Coke and Chemical Works of Makiyivka, CJSC «Makyivkoks», OJSC «Donetskkoks».

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.

Methodological approaches to the structural analysis of plants are described in our previous publications [24, 25].

Results and discussion

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 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. 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 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. 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.

The results of creating the base of plots in the Donetsk region are presented in Table 1.

Table 1

The base of plots in the Donetsk region: trial plots for the experiment (1-2 km zone from the company)

Company name	Number of monitoring points	Chemical pollution	Mechanical transformation	Integrated pressure
		level, 10-point scale		
OJSC «Ilyich Iron and Steel Works of Mariupol	3 (2000-2012) + 2 (2008, 2013)	9.5	6.4	15.9
OJSC «Iron and Steel Works of Mariupol Azovstal'»	2 (2000-2012) + 1 (2008, 2009)	9.3	5.2	14.5
Starobeshevo TEPS OJSC «Donbassenergo»	3 (2000-2012) + 1 (2008)	5.2	5.4	10.6
Kurakhovo TEPS OJSC «Skhidenergo»	3 (2000-2012) + 1 (2008, 2013)	6.8	4.1	10.9
Vuglegirsk TEPS OJSC «The State energy generating company «Centrenergo»	3 (2000-2012) + 1 (2008, 2009)	7.1	6.3	13.4
OJSC «The Zasiadko coal mine»	2 (2000-2012) + 1 (2008, 2013)	6.7	3.5	10.2
Zooevka TEPS-2 «Skhidenergo»	2 (2000-2012) + 1 (2008, 2013)	4.1	6.4	10.5
Slovyansk TEPS OJSC «Donbassenergo»	1 (2000-2012) + 1 (2008, 2009)	5.2	2.0	7.2
OJSC «Iron and Steel Works of Makiyivka»	2 (2000-2011) + 1 (2008, 2013)	8.7	4.6	13.3
OJSC «Iron and Steel Works of Yenakiyevo»	3 (2000-2012) + 2 (2008)	9.0	6.8	15.8
OJSC «Coke and Chemical Works of Avdiyivka	3 (2000-2012) + 1 (2008)	8.0	7.5	15.5
OJSC «Makrokhim»	3 (2000-2012) + 1 (2008)	7.6	3.1	10.7
OJSC Coalmine «Pivdennodonbasska № 1»	3 (2000-2012) + 2 (2008)	5.9	3.2	9.1
OJSC «Donetskstal»	2 (2000-2012) + 1 (2008, 2009)	6.3	6.7	13.0
OJSC Iron and Steel Works of Donetsk»	3 (2000-2012) + 2 (2008, 2013)	7.0	5.0	12.0
OJSC «Coke and Chemical Works of Yasynuvata	3 (2000-2012) + 1 (2008, 2010)	6.4	7.1	13.5
OJSC «Coke and Chemical Works of Yenakiyevo	3 (2000-2012) + 2 (2008, 2013)	9.5	9.6	19.1
OJSC «Coke and Chemical Works of Makiyivka	2 (2000-2012) + 1 (2013)	9.2	4.9	14.1
CJSC «Makyivkoks»	3 (2000-2012) + 1 (2008, 2013)	8.5	7.7	16.2
OJSC «Donetskkoks»	2 (2000-2012) + 1 (2008, 2013)	8.4	3.0	11.4

On the results of collection of 2000–2013 we established correlation between presence of toxic active elements in the environment and plant responses to pollution (Table 2) and the degree of transformation of soil horizons (Table 3).

Table 2

Informativeness of indicator species of plants to determine the concentrations of heavy metals

Block of phytoindicational experiment	Species of plants	Metal (soil content in active form)	Correlation coefficient
appearance of the structure of plants, the life form	*Berteroa incana, Echium vulgare, Reseda lutea, Brassica campestris, Capsella orientalis, Diplotaxis muralis, D. tenuifolia, Tripleurospermum inodorum*	Pb	0.78
		Cd	0.94
		Cr	0.90
transformation in the root tip terminals	*Capsella bursa-pastoris, R. lutea, E. vulgare, Calamagrostis epigeios, Daucus carota, Elytrigia repens*	Zn	0.91
		Hg	0.90
variability in shoot formation, inflorescence formation	*B. incana, C. bursa-pastoris, R. lutea, E. vulgare, Atriplex patula, Cichorium intybus, Melilotus albus, M. officinalis, Tragopogon major, T. inodorum*	Hg	0.94
		Cd	0.74
		Ni	0.88
conformational variability of the internal tissues of the leaf	*B. incana, Euphorbia seguieriana, R. lutea, Eupatorium cannabinum, Chenopodium album, Kochia laniflora, A. artemisiifolia, Atriplex hortensis, A. micrantha, A. patens, Hyoscyamus niger, Plantago lanceolata, P. major, Sisymbrium polymorphum, Stenactis annua*	Co	0.90
		Cu	0.84
		Pb	0.69
		Cr	0.68
teratological manifestations in the flower	*E. vulgare, Convolvulus arvensis, Oberna behen, R. lutea, Agrostis stolonifera, C. intybus, Cirsium arvense, Grindelia squarrosa, T. major*	Mn	0.95
		Hg	0.93
variability in the male generative sphere – defective pollen	*Dactylis glomerata, B. incana, Digitalis purpurea, Polygonum aviculare, Bromopsis inermis, Bromus arvensis, Centaurea diffusa, Persicaria maculata, Salsola australis, Senecio vulgaris, T. inodorum*	Ni	0.97
		Zn	0.90
genetic heterogeneity of seeds	*Ambrosia artemisiifolia, Achillea nobilis, Ailanthus altissima, Amaranthus albus, A. retroflexus*	Cr	0.84
		Cd	0.55
morphological heterogeneity of fruit	*B. incana, C. bursa-pastoris, Amaranthus retroflexus, Artemisia absinthium., Anthoxanthum odoratum , Cynoglossum officinale, Diplotaxis tenuifolia, Artemisia vulgaris, Achillea collina, Arrhenaterum elatius, Galinsoga parviflora, Gnaphalium uliginosum, Lactuca tatarica, Papaver rhoeas, Rumex crispus, Sinapis alba, Sonchus arvensis, Thlaspi arvense, T. major, T. inodorum, Xanthium albinum*	Mn	0.94
		Pb	0.90
		Cu	0.84
general generative transformation subpopulations	*B. incana, Kochia laniflora, C. bursa-pastoris, Cyclachaena xanthiifolia, E. vulgare, Deschampsia caespitosa, Galium mollugo, R. lutea, Digitaria sanguinalis*	Cd	0.88
		Zn	0.87
		Cu	0.71

Table 3

Informativeness of indicator species of plants to determine the extent of transformation of ecotopes

The degree of transformation (for root-zone soil layer)	Species of plants	Correlation coefficient
1–2	*Bromopsis in ermis, Calamagrostis epigeios*	0.95
	Bromus arvensis, Chelidonium majus	0.80
3–4	*Achillea collina, Artemisia vulgaris, Dactylis glomerata, Eupatorium cannabinum, Otites media, Rumex crispus*	0.95
5–6	*Artemisia absinthium, Hyoscyamus niger, Persicaria maculata, Swida alba*	0.90
	Achillea nobilis, Cirsium arvense	0.80
7	*Agrostis stolonifera, Chenopodium album, Cynoglossum officinale, Daucus carota, Elytrigia repens, Erucastrum armoracioides, Papaver rhoeas, Salsola australis, Tripleurospermum inodorum*	0.80
8	*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*	0.85
	Cyclachaena xanthiifolia, Digitalis purpurea, Galinsoga parviflora, Plantago lanceolata, Polygonum aviculare, Tripleurospermum inodorum, Xanthium albinum	0.75
9	*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*	0.95
	Ailanthus altissima, Berteroa incana, Digitaria sanguinalis, Polygonum aviculare, Reseda lutea	0.80
	Atriplex hortensis, Coniza canadensis, Gnaphalium uliginosum, Grindelia squarrosa, Thlaspi arvense, Tragopogon major, Tripleurospermum inodorum	0.70
10	*Atriplex patens, Atriplex patula, Berteroa incana, Capsella bursa-pastoris, Diplotaxis muralis, Echium vulgare, Tragopogon major*	0.90
	Amaranthus retroflexus, Ambrosia artemisiifolia, Centaurea diffusa, Polygonum aviculare, Reseda lutea	0.75

Thus, 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.

References

1. Al-Wabel, M.A., Heil, D.M., Westfall, D.G., & Barbarick, K.A. (2002). Solution chemistry influence on metal mobility in biosolids-amended soils. Journal Environmental Quality, 31, 1157-1165.
2. Amini, M., Afyuni, M., Fathianpour, N., Khademi, H., & Fluhler, H. (2004). Continuous soil pollution mapping using fuzzy logic and spatial interpolation. Geoderma, 124 (3-4), 223-233.
3. Blaha, L., & Hnilička, F. (2004). Influence of abiotic stresses on the basic traits of the root system. Biologia (Bratislava), 59, 145-162.
4. Bross, M.J., Aarts, L., van Tooren, C.F., & Stein, A. (1999). Quantification of the effects of spatially varying environmental contaminants into a cost model for soil remediation. Journal of Environmental Management, 56 (2), 133-145.
5. Butler, C.D., & Hanna, L. (2013). Reference Module in Earth Systems and Environmental Sciences, from Climate Vulnerability. Ecosystems, Biodiversity, Climate, and Health, 1, 69-78.
6. Chaignon, V., & Hinsinger, P. (2003). Heavy Metals in the Environment: A Biotest for Evaluating Copper Bioavailability to Plants in a Contaminated Soil. Journal Environmental Quality, 32, 824-833.
7. Czarnowska, A., & Milewska, A. (2000). The content of heavy metals in an indicator plant (*Taraxacum officinale*) in Warsaw. Polish Journal of Environmental Studies, 9, 125-140.
8. Franzle, O. (2006). Complex bioindication and environmental stress assessment. Ecological Indicators, 6, 114-136.
9. Frerot, H., Lefebvre, C., Gruber, W., Collin, C., Santos, A., & Escarre, J. (2006). Specific interactions between local metallicolous plants improve the phytostabilization of mine soils. Plant Soil, 282, 53-65.
10. Jessel, B. (2006). Elements, characteristics and character – Information functions of landscapes in terms of indicators. Ecological Indicators, 6, 153-167.
11. Hengl, T., Heuvelink, G.B.M., & Stein, A. (2004). A generic framework for spatial prediction of soil variables based on regression-kriging. Geoderma, 122(1-2), 75-93.
12. Kabata-Pendias, A. (2004). Soil-plant transfer of trace elements – an environmental issue. Geoderma, 122, 143-158.
13. Kozanecka, T., Chojnicki, J., & Kwasowski, W. (2002). Content of heavy metals in plant from pollution-free regions. Polish Journal of Environmental Studies, 11, 371-395.
14. Krueger, T. (2012). The role of expert opinion in environmental modeling. Environmental Modelling & Software, 36, 4-18.
15. Macaskie, L.E., Mikheenko, I.P., Yong, P., Deplanche, K., Murray, A.J., Paterson-Beedle, M., Coker, V.S., Pearce, C.I., Cutting, R., Pattrick, R.A.D., Vaughan, D., Laan, G., & Lloyd, J.R. (2013). Reference Module in Earth Systems and Environmental Sciences, from Comprehensive Biotechnology (Second Edition). Today's Wastes, Tomorrow's Materials for Environmental Protection, 6, 719-725.
16. Manouchehri, N., Besancon, S., & Bermond, A. (2006). Major and trace metal extraction from soil by EDTA: Equilibrium and kinetic studies. Analytica Chimica Acta, 559, 105-112.

17. Markert, B. (1993). Plant as a biomonitors: Indicators for heavy metals in the terrestrial environment, VCH Weinheim. New York: Basel, Cambridge, 427 p.

18. Minkina, T.M., Motuzova, G.V., Mandzhieva, S.S., & Nazarenko, O.G. (2012). Ecological resistance of the soil – plant system to contamination by heavy metals. Journal of Geochemical Exploration, 123, 33-40.

19. Nicholson, F.A., Smith, Sr., Alloway, B.J., Carlton-Smith, C., & Chambers, B.J. (2003). An inventory of heavy metals inputs to agricultural soils in England and Wales. Science of the total environment, 311 (1-3), 205-219.

20. Peijnenburg, W.J.G.M, & Jager, T. (2003). Monitoring approaches to assess bioaccessibility and bioavailability of metals: Matrix issues. Ecotoxicology and Environmental Safety, 56, 63-77.

21. Pis, V., & Novakova, K. (2002). Influence of soil properties on the heavy metals mobility. Phytopedon (Bratislava), 1, 180-201.

22. Reichman, S.M. (2002). The responses of Plants to Metal Toxicity: A review on Copper, Manganese and Zinc. Australian Minerals & Energy Environment Foundation. Retrieved from www.ameef.com.au

23. Romic, M., Hengel, T., Romic, D., & Husnjak, S. (2007). Representing soil pollution by heavy metals using continuous limitation scores. Computers & Geosciences, 33(10), 1316-1326.

24. Safonov, A.I. (2008). New diagnostic criteria of complex phytoindication for approbation in Donbass. Problems of ecology and nature protection of technogenic region, 8, 91-96.

25. Safonov, A.I. (2012). Approbation of ecosystem standardization criteria according to phytoindication component. Problems of ecology and nature protection of technogenic region, 1(12), 108-114.

26. Tilman, D. (1988). Plant strategies and the dynamics and structure of plant communities. Princeton: Princeton Univ. Press, 360 p.

27. Yoccoz, N.G., Nichols, J.D., & Boulinier, T.U. (2001). Monitoring of biological diversity in space and time. Trends Ecology Evolution, 16(8), 446-453.

28. Zhang, C., & Selinus, O. (1998). Statistics and GIS in environmental geochemistry, some problems and solutions. Journal of Geochemical Exploration, 64, 339-354.

29. Zurlini, G. (2006). Indicating retrospective resilience of multi-scale patterns of real habitats in a landscape. Ecological Indicators, 6, 184-204.

Received: 7.10.2013 Accepted: 24.10.2013

Сафонов А. И. **Фитоквалиметрия токсической нагрузки и степени трансформации экотопов в Донецкой области.** – В работе рассмотрены вопросы информативности метода фитоиндикации в условиях различной трансформации среды. Осуществление принципов фитомониторинга должно быть дифференцированным в зависимости от специфики воздействий на экотопы: химическое загрязнение (токсические эффекты), механическое нарушение поверхностного слоя почв (деградация эдафотопа) и совместная трансформация (комплектное воздействие). Предложены фитоиндикационные критерии: информативные виды для определения экологических режимов, признаки растений для установления локальных техногенных нагрузок и универсальные фитоиндикаторы для использования в промышленных экотопах Донбасса. Фитоквалиметрия основана на использовании индикационных шкал и индексов, полученных в результате геоботанического или структурного (анатомического) анализов растительных объектов.

Ключевые слова: фитоквалиметрия, фитомониторинг, фитоиндикационный критерий, Донбасс.

Сафонов А. І. **Фітокваліметрія токсичного навантаження та ступеню трансформації екотопів у Донецькій області.** – У роботі розглянуто питання інформативності методу фітоіндикації в умовах різної трансформації середовища. Здійснення принципів фітомоніторингу повинно бути диференційованим залежно від специфіки впливів на екотопи: хімічне забруднення (токсичні ефекти), механічне порушення поверхневого шару ґрунтів (деградація едафотопу) і сумісна трансформація (комплексний вплив). Запропоновано фітоіндикаційні критерії: інформативні види для визначення екологічних режимів, ознаки рослин для встановлення локальних техногенних навантажень та універсальні фітоіндикатори для використання у промислових екотопах Донбасу. Фітокваліметрія базується на використанні індикаційних шкал та індексів, які отримано в результаті геоботанічного або структурного (анатомічного) аналізів рослинних об’єктів.

Ключові слова: фітокваліметрія, фітомоніторинг, фітоіндикаційний критерій, Донбас.

Надійшла до редакції 7.10.2013 Прийнята до друку 24.10.2013