Ecosystem approach to the assessment of land reclamation on the example of Zaporizhzhskiyy manganese ore quarry

I. M. Loza, O. Y. Pakhomov

Oles Honchar Dnipro National University, Dnipro, Ukraine

Article info
Received 18.02.2019
Received in revised form 25.02.2019
Accepted 04.03.2019

Introduction

Protection of environment, lands and natural resources rational use and environmental safety arrangements are important conditions for sustainable economic and social development of Ukraine (Pecharova et al., 2006, 2011). In this regard, the problem of anthropogenically disturbed areas is especially important. Mining industry is considered to be one of the powerful factors that leads to the degradation of various natural ecosystems. As a result of mining activity some agricultural lands withdraw for non-agricultural purposes. Man-made landscapes and ecosystems developed instead agricultural lands tend to surface subsiding, raising of subsoil waters, mineralization of its aqueous extracts, which together leads to extremely low suitability of such substrates for the existence of biota. That is why the mine rock is covered with a reclamation layer that consists of a non-toxic material (unsalted loam, clay) parent rocks with safety shields from loam, clay, sand or their mixture 1–1.5 m in thickness, and subsequent covering with fertile topsoil of 0.6–0.8 m in thickness. At the initial remediation stage landscape planning and covering by humic topsoil are carried out. The main agrochemical characteristics that determine the reclaimed land productivity and degree of their suitability for the existence of biota are value of actual acidity (pH) and salinity level (Eisenhauer, 2010).

The American Society of Soil Scientists defines the term «soil quality» as the ability of soil to function within an ecosystem with maintaining biological productivity, maintaining environmental quality, and enabling conditions for animal and plant living (Karaca, 2011). Researchers note that the mine rock often has high density values, low structural coefficient, and high mineralization of its aqueous extracts, which together leads to extremely low suitability of such substrates for the existence of biota. That is why the mine rock is covered with a reclamation layer that consists of a non-toxic material (unsalted loam, clay) parent rocks with safety shields from loam, clay, sand or their mixture 1–1.5 m in thickness, and subsequent covering with fertile topsoil of 0.6–0.8 m in thickness. At the initial remediation stage landscape planning and covering by humic topsoil are carried out. The main agrochemical characteristics that determine the reclaimed land productivity and degree of their suitability for the existence of biota are value of actual acidity (pH) and salinity level (Eisenhauer, 2010).

The American Society of Soil Scientists defines the term «soil quality» as the ability of soil to function within an ecosystem with maintaining biological productivity, maintaining environmental quality, and enabling conditions for animal and plant living (Karaca, 2011). Researchers note that the mine rock often has high density values, low structural coefficient, and high mineralization of its aqueous extracts, which together leads to extremely low suitability of such substrates for the existence of biota. That is why the mine rock is covered with a reclamation layer that consists of a non-toxic material (unsalted loam, clay) parent rocks with safety shields from loam, clay, sand or their mixture 1–1.5 m in thickness, and subsequent covering with fertile topsoil of 0.6–0.8 m in thickness. At the initial remediation stage landscape planning and covering by humic topsoil are carried out. The main agrochemical characteristics that determine the reclaimed land productivity and degree of their suitability for the existence of biota are value of actual acidity (pH) and salinity level (Eisenhauer, 2010).

Mining industry is the one of the powerful factors leading to the degradation of native ecosystems. Disturbed ecosystems developed instead the native may be remediated using certain reclamation techniques. The purpose of this work was assessment of the remediation quality within Ordzhonikidze Ore Mining and Processing Integrated Plant on the possibility of their economic use and suitability for the existence of soil biota, as well as providing recommendations for further rational economic use. Technical remediation of the surveyed area included such stages as removal of topsoil with gross method, followed by its storage in piles; reformation and levelling of overburden above-ore dump disposed in the exhaust space of career by gross way; keeping of levelled rocks up to 3 years with the purpose of their subsidence; surface repair after subsidence; application of humic layer; ploughing of reclaimed lands. Assessment of soil quality was carried out by comparing a quality score of reclaimed soils with a quality score of zonal soil. Data collection and processing were carried out on values of humus layer thickness; humus content in filling top layer; content of physical clay in topsoil and subsoil; granulometric composition of one-meter thick fill layer; topsoil and subsoil salinity; composition and properties of underlying rocks. As a result of mining operations, topsoil of remediated soil is depleted in chemical elements necessary for plant growth; as a result, the soil becomes more calcareous, and contains humus 1.5–2 times less than that in topsoil of undisturbed soil. Topsoil thickness is on average 58 cm. Humus content in the filled layer on average is 2.2%. Mechanical composition of the arable layer is middle loamy. The soil is compacted below the plow pan. Mechanical composition of the underlying rock is fine-textured. Salinization with water-soluble salts above the toxicity threshold in the arable layer of the studied soils was not found. Before agricultural use of reclaimed lands, it is essential to repair it with the techniques of biological reclamation. This is achieved through cultivation of salt-resistant perennial grasses for 3–5 years.

Keywords: land reclamation; soil bonitation; mining industry; sustainable land use; content of humus.
(Bekarevich et al., 1992). The next stage of remediation is application of humic layer onto mine spoil. On the territory of steppe Ukraine humic mass of ordinary chernozem or humusless filling substrates usually applied for this purpose.

Biological stage is the final stage of disturbed soil remediation. Options of this stage are various phytoremediation techniques with herbaceous, woody and shrub plant species (Lovinska, 2016), aimed at development of ecologically stable landscapes. At this stage of remediation, soil mesofauna plays an important role in development of mechanisms of ecosystem stability, in particular, representatives of soil saprotrophic complex such as earthworms, millipedes, centipedes etc. In the result of tropho-metabolic activities, these invertebrates make a significant environmental contribution to transformation of soil ecological properties. They are called «ecosystem engineers», namely living organisms capable of using their vital activity to influence the habitat and groups of biota in soil, as well as capable of causing ecosystem succession (Eisenhauer, 2010). It is proved an increase in efficiency of remediated soils recovery by enrichment of them with earthworm coprolites when improving the quality of bulk soils (Kulbachko et al., 2011, 2015, 2016). Under modern conditions, there is a tendency to evaluate the remediation effectiveness on the principle to maximize effect and to minimize costs taking into account interrelations between all elements within the ecosystem.

The purpose of this work was to assess the quality of reclaimed land within Ordzhonikidze Ore Mining and Processing Integrated Plant (OJSC, Nikopol Raion of Dnipropetrovsk Oblast), on the possibility of their economic use and suitability for the existence of soil biota, as well as providing recommendations for further rational economic use. The subject of the presented research is to assess the reclaimed soil quality in order to identify the conditions for the existence of representatives of the zooenotic unit. The object of this study was the ecological properties of reclaimed soils of the Zaporizhzhsky open quarry, OJSC (thickness of humic layer, humus content, content of physical clay in the humic layer and parent rock, salinity of humic layer and underlying rock (level)).

Material and methods

The surveyed area of Zaporizhzhsky quarry was approximately 8.9 hectares. Mining plans of scale 1:5 000 was used as cartographic basis for the field survey. Each site was divided into squares where pits and wells were staked angularly. The number of laid pits and wells was 2, the number of samples was 30 (10 in triplicate) (Medvedev, Plisco, 2006). Agrochemical analyses of soil and rock samples were performed in the laboratory of SE «Dnipropetrovsk Scientific Research and Design Institute of Land Management».

Brief description of the mining and technical stage of reclamation. Mining-technical recultivation of the surveyed plots included the following stages: removal of fertile soil layer (topsoil) with gross method, followed by its storage in piles; reformation and leveling of overburden above-ore dump disposed in the exhaust space of career by gross way; keeping of leveled rocks up to 3 years with the purpose of their subsidence; surface repair after subsidence; application of humic layer; ploughing of reclaimed lands.

Climatic and moisture conditions. District of Nikopol manganese ore basin refers to dry as water availability. Hydrothermal coefficient of the territory is 0.8–0.9. The average annual rainfall amounted 401 mm. Ten-day mean rainfall is 7–20 mm, while the maximum is observed in June–July (17–20 mm). Average annual temperature is + 8.8°C. Duration of effective temperatures above +5°C is 214 days; accumulated temperatures are 3487°. Duration of temperatures higher +10°C is 178 days; accumulated temperatures are 3216°. The temperature regimen is characterized by significant differences, which leads to intensive weathering of reclaimed lands with the release of mineral elements. Unfavorable climatic conditions are long rainless periods with relative humidity up to 30% and strong dry winds. Moistening of reclaimed soils occurs only due to atmospheric precipitation.

The surveyed area of the Zaporizhzhsky quarry reclamation is located on the territory of the Pokrovskaya Rural Soviet, and is intended for use in arable purposes. The territory belongs to Apostolovskiy natural and agricultural district, province of the desert steppe on right bank of the Dnipro River. The surface slope of the surveyed area is up to 1°. Microdepressions and other forms of surface deformations due to subsidence have not been found. The surveyed area of reclamation is presented by one whole plot.

Characteristics of evaluation units. Soil bonitet is a comparative evaluation of soil fertility, which determines the rate of soil suitability for crop growing. Soil suitability group is used in assessment of undisturbed lands. Regarding reclaimed soils, it is not possible to allocate such evaluation groups and to compile a uniform list, since the parameters of actual remediation do not always correspond to the design parameters. According to the design data, the reclaimed lands should be cover with 50-cm humic layer underlaid with loess-like loams to a depth of 150 cm.

Data collection on properties of reclaimed lands is carried out per plots of completed reclamation. The data were obtained from the materials of soil-geochemical analyze. Soil properties correlating with yield are expressed in points. As object of the researches was physico-chemical properties of reclaimed soil (thickness of humic filling layer, humus content in the humic layer, content of physical clay in layer of parent rock and in humic layer, average density of layer 1 meter in thickness, salinity of topsoil and of underlying rocks (rate), composition and the properties of the underlying rocks).

With the purpose of bonitation, a numerical scale of 100 points is applied, and soil quality by bonitet is assessed in points from 81–100 (very fertile) up to 100 and less (the lowest fertile). To account for soil processes, which significantly affect the yield, but are not sufficient with the use of quantitative indicators, apply correction factors specific to specific areas.

While calculation the bonitet scores of reclaimed lands in the early stages of usage, the first three fertility indicators are used as correction factors. The soil map of reclaimed lands consists of four cartograms (salinity of the soil mixture, capacity of the bulk humus layer, underlying rocks and mechanical composition of the soil mixture) and is characterized by considerable diversity. The bonitet scores calculated are compared with that of reference zonal soil and concluded the value of a given soil with the position of agricultural use, and also in economic calculations of land monetary evaluation.

Results and discussion

Characteristics of underlying rocks. Kinds of rocks that underlie the fertile soil layer within the study area are Pleistocene loess deposits (up to 3 tiers), red-brown Pleiocen clay and man-made mixture of the above rocks. On average, in a layer of 0–100 cm, the content of physical clay (particles smaller than 3.01 mm) was 52.9%. The content of easily soluble salts was from 0.178% to 0.338% (dry residue). Underlying loesses were slightly and medium saline. Salinity types were sulphate and chloride-sulphate, respectively.

Data on soil cover and soil properties used to assessment the recultivated land. Studies have established that the productivity of reclaimed soil in the process of its usage does not reach the level of native soil productivity. Bonitation of reclaimed lands on the agri-environmental basis is implemented with the use of soil-ecological indexes. This approach provides ability to account practically the entire complex of abiotic and biotic factors in the system of man-made edaphotop. Productivity of remediated soils depends on several factors as the content of humus and nutrients, thickness of humic layer, the physical properties of underlying rock in 1 m layer, content of water-soluble salts and carbonates, etc. (Bekarevich et al., 1992).

Fundam. Appl. Soil Sci., 19(1)
According to the soil survey, on the site of reclamation areas of Zaporizhzhsky open quarry moderately clayey southern chernozem and fine-textured low-humic ordinary chernozem had previously been formed in place of the Zaporizhzhsky open quarry. As a reference for bonitation of re-cultivated land used for arable farmland, ordinary chernozem, fine-textured, low-humic, shallow was used in this region. This soil is characterized by the following main values: thickness of humic layer (H+Hp) 54 cm; humus content in the topsoil 3.5%; content of physical clay in the topsoil 54.8%. A score of bonitett was 84; in taking into account the environmental factor it amounted 41. The above data are used for the assessment quality of the remediated land. The soil studied was well-enriched with nitrogen and phosphorus, and contain high level of potassium; the soil has a neutral reaction of soil solution. Carbonate accumulation was observed at a depth of 35–45 cm; salinity is absent. Subsoil material are represented with loess and loesslike loams. Thus, fine-textured low-humic ordinary chernozem are the most valuable lands of universal use within the surveyed region.

Evaluation of the remediation effectiveness is an integral part of soil and agrochemical survey, and it includes bonitation of recultivated soils.

While selective removal of humic layer on the native soil that further used for reclamation, the layer will be mixed (diluted) with humusless loam, resulting to depletion of fertile part of soil and agrochemical survey, and it includes bonitation that further used for reclamation, the layer will be mixed with loess and loesslike loams. Thus, fine-textured low-humic ordinary chernozem are the most valuable lands of universal use within the surveyed region.

Table 1

| Index of horizons | Sample collection depth, cm | Hygroscopic water, % | Humus content, % | Mechanical composition, % of particle with diameter, mm |
|------------------|-----------------------------|----------------------|------------------|------------------------------------------------------|
|                  |                             |                      |                  | more than 0.25                                       |
|                  |                             |                      |                  | 0.25–0.05                                            |
|                  |                             |                      |                  | 0.05–0.01                                            |
|                  |                             |                      |                  | 0.01–0.005                                           |
|                  |                             |                      |                  | 0.005–0.000                                          |
|                  |                             |                      |                  | less than 0.001                                      |
|                  |                             |                      |                  | less than 0.001                                      |
| H+Hp+Ph          | 0–10                        | 3.8                   | 2.1              | 0.1                                                 |
|                  |                             |                      |                  | 5.2                                                 | 22.3 |
|                  |                             |                      |                  | 8.3                                                 | 12.0 |
|                  |                             |                      |                  | 30.0                                                | 22.1 |
| H+Hp+Ph          | 20–30                       | 4.2                   | 2.0              | 0.1                                                 |
|                  |                             |                      |                  | 2.2                                                 | 23.5 |
|                  |                             |                      |                  | 7.2                                                 | 10.5 |
|                  |                             |                      |                  | 30.5                                                | 26.0 |
| H+Hp+Ph          | 40–50                       | 3.9                   | 2.0              | 0.1                                                 |
|                  |                             |                      |                  | 2.8                                                 | 30.2 |
|                  |                             |                      |                  | 6.9                                                 | 8.8  |
|                  |                             |                      |                  | 33.9                                                | 17.3 |
| H+Hp+Ph          | 58–67                       | 3.5                   | 0.9              | 0.2                                                 |
|                  |                             |                      |                  | 2.6                                                 | 32.3 |
|                  |                             |                      |                  | 7.6                                                 | 10.3 |
|                  |                             |                      |                  | 28.9                                                | 18.1 |
| Pk               | 90–100                      | 3.6                   | 0.2              | 3.9                                                 | 39.9 |
|                  |                             |                      |                  | 7.7                                                 | 13.0 |
|                  |                             |                      |                  | 25.3                                                | 7.0  |
|                  |                             |                      |                  |                                                     |      |
| H+Hp+Ph          | 0–10                        | 4.3                   | 2.2              | 0.2                                                 |
|                  |                             |                      |                  | 3.8                                                 | 28.5 |
|                  |                             |                      |                  | 7.3                                                 | 10.4 |
|                  |                             |                      |                  | 32.8                                                | 17.0 |
| H+Hp+Ph          | 20–30                       | 4.4                   | 2.3              | 0.2                                                 |
|                  |                             |                      |                  | 3.2                                                 | 26.2 |
|                  |                             |                      |                  | 7.2                                                 | 11.2 |
|                  |                             |                      |                  | 32.0                                                | 20.0 |
| H+Hp+Ph          | 40–50                       | 4.2                   | 1.5              | 0.3                                                 |
|                  |                             |                      |                  | 2.5                                                 | 27.3 |
|                  |                             |                      |                  | 5.2                                                 | 12.4 |
|                  |                             |                      |                  | 32.4                                                | 19.9 |
| H+Hp+Ph          | 48–56                       | 4.1                   | 1.2              | 0.2                                                 |
|                  |                             |                      |                  | 1.5                                                 | 30.5 |
|                  |                             |                      |                  | 10.3                                                | 11.2 |
|                  |                             |                      |                  | 36.4                                                | 9.9  |
| Pk               | 90–100                      | 4.3                   | 1.5              | 0.2                                                 |
|                  |                             |                      |                  | 0.8                                                 | 30.5 |
|                  |                             |                      |                  | 11.2                                                | 9.3  |
|                  |                             |                      |                  | 35.8                                                | 12.2 |

Analysis of water extracts of reclaimed soils of Zaporizhzhsky open quarry did not find the presence of water-soluble salts above the toxicity threshold in the bulk Chernozem layer throughout the site (Table 2).

Table 2

| Horizon index | Sample collection depth, cm | Dry residue, % | Water extract, mg-eq per 100 g of soil |
|---------------|-----------------------------|---------------|--------------------------------------|
|               |                             |               | CO₃²⁻       | HCO₃⁻       | CI⁻         | SO₄²⁻       | Ca²⁺         | Mg²⁺        | Na⁺         | PH of water extract |
| H+Hp+Ph       | 0–10                        | 0.106         | –           | 0.076       | 0.03        | 0.06        | 0.73        | 0.44        | 0.73        | 5.5                  |
| H+Hp+Ph       | 20–30                       | 0.078         | –           | 0.110       | 0.02        | 0.03        | 0.17        | 0.17        | 0.62        | 0.83                  |
| H+Hp+Ph       | 40–50                       | 0.106         | –           | 0.338       | 0.03        | 0.58        | 0.58        | 4.16        | 2.91        | 5.6                  |
| H+Hp+Ph       | 58–67                       | 0.404         | –           | 0.196       | 0.16        | 0.58        | 0.62        | 1.64        | 0.4         | 5.8                  |
| Pk            | 90–100                      | 0.387         | –           | 0.300       | 0.20        | 0.58        | 0.60        | 3.23        | 1.98        | 6.3                  |

According to the mechanical composition analysis of the reclaimed soils in the Zaporizhzhsky open quarry, OJSC, dilution of humusless loam, resulting to depletion of fertile part of soil and agrochemical survey, and it includes bonitation of recultivated soils.
Assessment of reclaimed soils. To determine the score of reclaimed soils, the following indicators of their properties were used (average per the site, Table 3 and 4).

### Table 3
Characteristics of remediated soil

| Parameter                                      | Value of parameter |
|-----------------------------------------------|--------------------|
| Thickness of filled humus layer, cm           | 58.0               |
| Humus content in the layer 0–10 cm, %         | 2.2                |
| Content of physical clay in 0–100 cm, %      | 52.9               |
| Correction factors for:                       |                    |
| underlying rocks                              | 0.97               |
| salinization                                  | 1.00               |

### Table 4
The results of calculation of bonus points on the properties of reclaimed soils of Zaporizhzhskiy quarry PJSC «OGOK» (natural and agricultural area-SZG-9)

| Soil properties and their assessment in points | Correction factors for: | Final score |
|----------------------------------------------|--------------------------|-------------|
| Name of soil                                 | underlying  | salinity  | Without environmental coefficient | With environmental coefficient of 0.49 |
| Ordinary chernozem, fine-textured, low-humic, shallow | 54            | –         | 84                        | 41                              |
| Reclaimed soils (average per site)           | 58          | 107       | 89                        | 2.2                             |
|                                              | 63          | 47        | 52.9                      | 100                            |
|                                              | 90          | 90        | 0.97                      | 1.00                           |
|                                              | 87          | 43        |                            |                                |

Conclusion

The conducted researches have shown that reclamation works in the territory of mining developments of JSC OGOK (on the example of Zaporizhzhskiy quarry) are carried out at the proper level.

As a result of mining operations, topsoil of recultivated soil is depleted in chemical elements necessary for plant growth; as a result, the soil becomes more calcareous, and contains humus 1.5–2 times less than that in topsoil of undisturbed soil. Topsoil thickness is on average 58 cm. Humus content in the filled layer on average is 2.2%. Mechanical composition of the arable layer is middle loamy. The soil is compacted below the plow pan. Mechanical composition of the underlying rock is fine-textured. Salinization with water-soluble salts above the toxicity threshold in the arable layer of the studied soils was not found. Analysis of water extracts of underlying rocks revealed the presence of water-soluble compounds above the water solubility limit. The reclaimed soils are nonsalted. Calcium carbonates were observed throughout the soil profile. Thus, in result of technical stage of reclamation artificial reclaimed soil was made with features similar to that of native zonal soil located in this area prior to mining operations, and, although it has slightly lower fertility and greater salinity of the lower horizons, it can be used successfully in agricultural purposes.

Recommendations for improvement of remediated soil.

Before agricultural use of reclaimed lands it is essential to repair it with the techniques of biological reclamation (required). At the biological stage, agrophysical properties (structure, duty cycle, air regime, water permeability), agrochemical (enrichment with humus and nutrients), chemical (removal of easily soluble salts from the soil) are improved. This is achieved through cultivation of salt-resistant perennial grasses for 3–5 years. For this, grass mixtures are recommended with following seeding rate, in kg per 1 ha:

1. Yellow alfalfa 6–8 + awnless bromegrass 10–12 + wheatgrass 8–10.
2. Awnless bromegrass 25 + alfalfa blue-hybrid 18.

Technologies of work on the biological reclamation should be developed in a separate work project.

References

Bekarevich, N. E., Masyuk, N. T., Chaban, I. P. (1992). Sostoyanie i perspektivy ravritiya nauchno-issledovatelskikh i prkladnykh rabot po agromelioratsii v stepnuy zone Ukrainy. [State and prospects of development of research and applied works on the agricultural of reclamation in the steppe zone of Ukraine]. Ecological problems of agricultural production. Dnepropetrovsk (in Russian).

Eisenhauer, N. (2010). The action of an animal ecosystem engineer: Identification of the main mechanisms of earthworm
impacts on soil microarthropods. Pedobiologia, 53, 343–352. DOI: 10.1016/j.pedobi.2010.04.003.
GOST 17.5.1.02-86. Ohrana prirody. Zemli. Klassifikatsiya vskryshnyih i vmeschayushchih porod diya biologicheskoy rekultivatsii zemel. [Nature protection. Lands. Classification of overburden and enclosing rocks for biological recultivation of lands] (in Russian).
Karaca, A. (2011). Biology of Earthworms, Soil Biology 24, Springer-Verlag Berlin Heidelberg. DOI: 10.1007/978-3-642-14636-7_16.
Kul’bachko, Y. L., Didur, O. O., Loza, I. M., Pakhomov, O. E., Bezrodnova, O. V. (2015). Environmental aspects of the effect of earthworm (Lumbricidae, Oligochaeta) tropho-metabolic activity on the pH buffering capacity of remediated soil (Steppe zone, Ukraine). Biology Bulletin (Izvestiya Rossiiskoi Akademii Nauk – Seriya Biologicheskaya), 42(10), 899–904. DOI: 10.1134/S1062359015100088.
Kulbachko, Y. L., Didur, O. A., Loza, I. M., Kryuchkova, A. I. (2016). Effects of saprophages (Earthworms, Lumbricidae, and Millipedes, Diplopoda) on ecosystem services implementation: optimization of some ecological functions in remediated soil. Issues of the ecosystem services provided by animals under anthropogenic pressure within Ukrainian steppe: monogr. Ed. by O. Y. Pakhomov. Vienna: "East West" Association for Advanced Studies and Higher Education GmbH, 2016. Ch. 4. P. 62–87.
Kul’bachko, Y. L., Didur, O. O., Loza, I. M., Pakhomov, O. E., Bezrodnova, O. V. (2015). Environmental aspects of the effect of earthworm (Lumbricidae, Oligochaeta) tropho-metabolic activity on the pH buffering capacity of remediated soil (Steppe zone, Ukraine). Biology Bulletin, 42(10), 899–904. DOI: 10.1134/S1062359015100088.
Kul’bachko, Y., Loza, I., Pakhomov, O., Didur, O. (2011). The zoological remediation of technogen faulted soil in the industrial region of the Ukraine Steppe zone. M. Behnassi et al. (eds.), Sustainable Agricultural Development, Springer Science+Business Media: Springer Dordrecht Heidelberg London New York, 2011. – P. 115–123.
Lovinska, V., Sytnyk, S., Kharytonov, M., Loza, I. (2016). Features of pine stands function in Dnieper North Steppe, Ukraine. Agriculture and Forestry, 62(1), 155–163. DOI: 10.17707/AgricultForest.62.1.18.
Medvedev, V. V., Plisko, I. V. (2006). Bonitirovka i kachestvennaya otsenka pahotnyih zemel Ukrainy. [Bonitation and qualitative assessment of arable land in Ukraine]. UAAN, National Scientific Center “Institute for Soil Science and Agrochemistry Research named after O.N. Sokolovsky” - Kharkiv: 13 Printing House, 2006. – 386 p.: Rice. - Bibliography: p. 360–370 (in Russian).
Pecharová, E., Martis, M., Kašparová, I., Zdražil, V. (2011). Environmental approach to methods of regeneration of disturbed landscapes. Journal of Landscape Studies, 4, 71–80.
Pecharova, E., Hrabankova, M. (2006). A concept for reconstructing the post-mining region under the Lisbon strategy. Ekológia (Bratislava), 25(3), 194–205.