Rehabilitation of the Biological Activity of the Soil Microbiota and the Structure of the Living Cover of the Soil under Technogenic Burden of the Extractive Industry

N Nevedrov¹, E Protsenko², A Poluyanov³

¹Candidate of Biology Sciences, Researcher of Scientific Research Laboratory of Environmental Monitoring, Kursk State University, Radischeva st. 33, Kursk 305000, Russian Federation
²Doctor of agricultural Sciences, Senior Researcher of Scientific Research Laboratory of Environmental Monitoring, Kursk State University, Radischeva st. 33, Kursk 305000, Russian Federation
³Doctor of Biology Sciences, Professor of Department of Biology and Ecology, Kursk State University, Radischeva st. 33, Kursk 305000, Russian Federation

E-mail: 9202635354@mail.ru

Abstract. The article focuses on the features of the morphological, physical and chemical properties of the humus-accumulative embryo soils of nonfunctional stock heap of Mikhailovsky Mining and Concentrating Company (Mikhailovsky MCC). The biological activity of various groups of soil microorganisms: actinomycetes, microfungus and ammonifying saprophytes was studied. The types of plant communities of technogenic territory of overburden stock heap are identified, the main parameters describing the structure and dynamics of phytocenosis are described. It is established that the soils of key catena have high numbers of fungic microflora up to 145 thousand CFU / g in the gray-humus horizon, actinomycetes and ammonifiers have a low level of development. However, relating to the previously obtained data, a general temporal tendency has been revealed, characterized by the increase in the biological activity and biomass of the groups under consideration, which is clearly observed in areas with soils rich in organic matter and mineral elements.

1. Introduction
Conservation and restoration of biological diversity in the conditions of technogenic development of territories is the most important practical task of modern ecology. Biota, as a component of the environment, carries out processes of biogeochemical transformations and cycles of substances and ensures the stability of ecosystems and the biosphere as a whole [1, 2, 3].

Technogenic burden leads to the deprimation of the vital activity of living organisms, their productivity decrease and to the disappearance of species. Economic development of the territories is often destructive for natural landscapes. The resulting technogenic landscapes are characterized by a high level of toxicity of their components - soils and subsoils, surface and ground waters, and outside air. Under such conditions, the species diversity of biocenoses is significantly reduced [4, 5].

Mineral extraction is one of the types of economic activity, characterized by a powerful impact on natural landscapes in the mining site [2, 6]. The open-cut mining leads to the complete destruction of...
the biological components of the landscape; new man-made complexes with extreme living conditions are created. To restore technogenic landscapes, restoration activities are carried out, the basic purpose of which is to restore the productivity and economic value of the land, as well as to improve environmental conditions [2, 6, 7]. The disturbed lands after restoration can be used for agricultural lands, hayfields, forest plantations, and also can be used in recreation purposes or urban infrastructure (sports and playgrounds, parks, campgrounds).

The purpose of the work is to study the properties of the soil, the biomass of the main groups of soil microbiota and the biological diversity of the vegetation cover of the nonfunctional heap of the Mikhailovsky MCC for developing recommendations on the further use of the recultivated territory.

2. Objects and methods of research

Mikhailovsky MCC is located in Kursk region. In terms of iron ore production, the company is the second largest in Russia. While quarrying, overburden heaps were formed on the area of more than 11,000 ha, in which more than 1 billion tons of various subsurface rocks were piled [1]. The 5th conveyor type stock heap (451 ha) is under analysis, it is nonfunctional. Stockpile filling ended about 40 years ago. The stock heap is a positive technogenically transformed landscape. Due to the lack of operational registration of lithological variety of rocks in the process of stockpile filling, its body is a complex structurally inhomogeneous overburden mixture. The soil is represented by loess loam, clay and sands of the Cenomanian Albian horizon. Separate areas of the stock heap are restored, there are 40 years old tree and shrubbery plantings [2]. Site No. 5 is characterized by extremely diverse plant communities, formed as a result of natural regrowth of overburden.

The soil cover was studied using the profile and catenary methods. Performing the reconnaissance description of the technogenic landscape stock heap No. 5 of Mikhailovsky MCC, a key catena was selected (the slope of the northern exposure) located in the northeastern part of the heap. Soil profile cuts were made in the eluvial, transit, and accumulative geomorphological elements of the key catena.

Soil sampling was carried out from each genetic horizon in triplicate. Laboratory and analytical studies were conducted on fresh soil samples using conventional methods [8, 9]. Ammonifiers that use organic nitrogen were put on meat-and-peptone agar, actinomycetes that use mineral nitrogen - starch-and-ammonia agar. The number of fungi was taken into account on Czapek's medium. Analysis of the physical and chemical properties of soils was carried out according to standard methods [10, 11].

The study of vegetation was carried out by geobotanical descriptions. The descriptions were carried out according to standard methods. Within the plant communities sample plots were organized. The size of the sample plots, as a rule, was 100 m² for grass communities and 400 m² for tree and shrubbery vegetation. Part of the communities was described in the contours of their growth. For each plot all types of plants within the tree, shrub, grass-shrub and moss-lichen layers were specified and total estimate for each species was determined. In addition, the degree of sheltering for the tree and shrub layers, and the total projective cover degree for the grass-shrub and moss-and-lichen layers were estimated. To assess the total estimate of species, the Braun-Blanquet scale was used [12]. In the research 15 geobotanical descriptions of tree-shrub and grass vegetation were made. Based on the results of geobotanical descriptions, tabulated summaries of descriptions of plant communities of technogenic landscapes were made, revealing the main types of tree-shrub and grass vegetation of the stock heap No. 5 [13]. Statistical data processing was carried out using Microsoft OfficeExcel.

3. Soil research

The soil cover of the key catena is represented by humus-accumulative medium loamy embryo soils close in morphology to light gray forest soils (Albic Luvisols). The thickness of the humus-accumulative horizon varies from 10 to 15 cm and depends on the topographic form. The maximum thickness is noted in relatively flat tracts of land - the eluvial and accumulative zones of the key catena. On the slope, the thickness of the light-humus horizon is 23.1-33.3% less, due to the steepness of the slope (9.5°) and erosion processes. Humus-accumulative horizons of key catena have a nutty and granular structure. The texture of the soils of the profiles under analysis varies from heavy loamy
The increase of all soil profiles is very low, even at high values of the exchangeable mobile form of potassium and mobile forms of phosphorus and nitrogen. The activity of the exchange processes between the soil solution and the exchangeable mobile fraction of nitrogen fixing processes in young soils, as well as low availability of organic matter. High acidity slows down the exchange processes between the soil and the decay products of plant material. However, in the humus-accumulative horizons of the embryo soils under analysis, the average level of biogenic nitrogen accumulation was 1.7–2.0 ppm, which is explained by the relative increase in the activity of biota (Table 1).

4. Microbiological study of the soils of key catena
Soil biological indicators are variable and highly dependent on the state of the environment. The most important forms of microbiota activity in technogenic landscapes are the destruction of minerals, the involvement in the biological circulation of elements of technogenic materials, nitrogen fixation, the synthesis and mineralization of organic matter [14]. The age of the stock heap and the physicochemical properties of overburden materials determine the specifics of the development and functioning of microbiocenoses and phytocenoses, as well as their succession [15, 16, 17]. In the research of A.I. Stifeeva a significant temporal dynamics of communities of soil microorganisms in the stock heap of overburden of the Mikhailovsky MCC is noted [2, 18]. From the moment of settling on the overburden, the structure of microbiocenoses undergoes significant transformations, which are
accompanied by changes in activity within individual groups in connection with general population trend (according to the r-strategy model) [1, 19]. This is due to the instability of environmental conditions.

The carried-out research shows that the soils of the key catena have high number of fungic microflora. Maximum values were observed in the accumulative zone of the catena and exceeded the values of the eluvial and transit zones by 15–42 thousand CFU/g, along the horizon AJ. The high number of micromycetes can be explained by the fact that the embryo soils under study have low soil fertility rates, which is due to the acidic reaction of the soil environment, low cation exchange capacity, soil nutritive regime, and high soil moistening and low soil porosity, which contributes to the development of fungic microflora in the soil (Table 2).

**Table 2.** Data on the biological potency of communities of soil microorganisms.

| Genetic soil horizon | Actinomycetes on starch-and-ammonia agar (mn.CFU/g) | Number of fungi on Czapek's medium (thousands CFU/g) | Ammonifiers on meat- and-peptone agar (mn.CFU/g) |
|----------------------|---------------------------------------------------|--------------------------------------------------|-----------------------------------------------|
| Soil Profile 1        |                                                   |                                                  |                                               |
| AJ                   | 1.4±0.1                                           | 103±3.2                                          | 7.4±0.7                                       |
| Bt                   | 1.6±0.1                                           | 95±2.7                                           | 4.2±0.4                                       |
| C                    | 0.7±0.1                                           | 62±3.0                                           | 0.6±0.1                                       |
| Soil Profile 2        |                                                   |                                                  |                                               |
| AJ                   | 1.8±0.2                                           | 130±4.1                                          | 7.0±0.6                                       |
| Bt                   | 0.9±0.1                                           | 96±3.9                                           | 5.4±0.5                                       |
| C                    | 0.3±0.1                                           | 54±1.2                                           | 0.7±0.2                                       |
| Soil Profile 3        |                                                   |                                                  |                                               |
| AJ                   | 2.8±0.3                                           | 145±5.4                                          | 8.3±0.4                                       |
| Bt                   | 1.4±0.1                                           | 90±5.0                                           | 6.1±0.5                                       |
| C                    | 0.8±0.1                                           | 75±4.3                                           | 0.5±0.1                                       |

Actinomycetes and ammonifiers have low abundance in these soil conditions. This is due to the high acidity and low buffering capacity of the soil. The low activity of these groups of microorganisms is determined by the nutrient for them, an insufficient amount of easily decomposed vegetable remains, *Betula pubescens*, *Pinus sylvestris*, *Sorbus aucuparia*, *Populus alba*, *Equisetum arvense*, mosses prevail in the vegetation cover. In the accumulative zone of the key catena, the activity of soil microorganisms increases due to a higher level of humus and mineral nutrients, as well as lower level of soil acidity.

The temporal dynamics in the period of 35-40 years for the studied groups of soil microorganisms is characterized by an increase in the activity of actinomycetes on starch-and-ammonia agar, fungi on Czapek's medium, ammonifiers on meat-and-peptone agar with reference to the data received by A.I. Stifeev with co-authors analysing the soils of the 35-year-old heap No. 5 of the Mikhailovsky MCC.

**5. Vegetative cover study of the stock heap №5 Mikhailovsky MCC**

The main types of plant communities of the stock heap No. 5 are tree-shrub communities represented by parvifoliolate forest (birch forests rich in herbs, birch-aspen-willow trees, reed birch forests) and grassy communities (reed-grassy and reed communities). Vegetative cover of the stock heap is characterized by uniformness and is represented by serial communities of various stages of succession. The main direction of vegetative cover on the stock heap No. 5 is tree-shrub vegetation. There are areas completely devoid of vegetation or occupied by moss-lichen communities, representing the initial stage of substrate regrowth. Grass communities occupy areas with immature soil cover: either the most xerophytic (reed grass communities) or hydromorphic (reed communities).
Poverty of the substrate and constant anthropogenic distortion (recreational load, forest fires) lead to the constant rejection of these phytocenoses at the initial stages of succession and their long-term existence in such a stage. Only reed communities are stable. Tree-shrub communities (parvifoliolate forest) refer to sites with the most developed soil layer. Such phytocenoses can also be characterized as a long-existing stage of the succession, but the factors that prevent further progress of the succession (introduction of broad-leaved species into the community and the formation of zonal broad-leaved forests) are soil and hydrological conditions.

In addition to the main ones, there are also numerous transitional communities creating a mosaic vegetation cover. There are some small areas with *Pinus sylvestris* and *Pinus banksiana*.

Parvifoliolate forests are spread over the territory of the heap No. 5. The dominant tree species are *Betula pendula*, *Salix caprea*, *Populus tremula*. *Pinus sylvestris* is sometimes present. The height of the tree layer is on average 17-18 m, the crowns density - up to 60-70%. The shrub layer of these communities is formed by such species as *Sorbus aucuparia*, *Frangula alnus*, *Acer platanoides*. In the grass layer, light-demanding meadow and marginal meadow species prevail – *Calamagrostis epigeios*, *Medicago falcata*, *Achilea millefolium*, *Taraxacum officinale*. The composition of the tree stratum depends on the soil quality and soil moisture. The most common are birch, aspen and willow. The role of aspen is increasing in places with the mature, humous and moist soil cover. On such sites, representatives of the conifer forest flora can be seen — *Pyrola rotundifolia*, *Orthilia secunda*, *Chimaphila umbellata*. The birch forests rich in herbs occupy the habitats with plentiful sunshine - edges, glades. Small areas of reed birch forests are located in water-logged soils - along the edges of lakes, in depressions and swale features. The moss stage is often developed there, rare and protected species of the flora of the Kursk region can be found: *Dactylorhiza maculata*, *Dactylorhiza incarnata*, *Epipactis palustris* [20].

Reed grassy communities are represented by unformed phytocenoses, in their appearance and floristic composition, partially resembling continental dry meadows with a large group of ruderal weeds. Reed grassy communities can be found both on upland areas, and on the slopes of different exposures with steepness up to 20°. The most widespread species are by legumes and cereals – *Calamagrostis epigeios*, *Poa angustifolia*, *Medicago falcata*, *Melilotus officinalis*. Sometimes *Solidago canadensis*, *Equisetum arvense* are in large abundance, various meadow species — *Centaurea jasote*, *Dactylis glomerata*, *Elytrigia repens*, *Phleum pratense*, *Ranunculus acris*. Anthropogenic distortion leads to the penetration of ruderal species into the communities, including *Pastinaca sylvestris*, *Artemisia absinthium*, *Cirsium setosum*. The average height of the grass layer is 40 cm, the projective cover (without rags) is 30-80%.

Reed communities are presented in water-logged soils - along the edges of lakes, in depressions and swale features. Spread along the shores of large lakes in areas with water depths from 10-15 to 40 cm. *Phragmites australis* prevails with a projective cover of 45-90% and a height of 50 to 200 cm. Such phytocenoses can be called conditionally climax because the reed has a wide ecological amplitude , able to form stable monodominant communities. Reeds are accompanied by coastal-aquatic species: *Carex acuta*, *Lycopus europaeus*, *Epilobium palustre*, *Epilobium parviflorum*. Sometimes undergrowth of different *Salix* species. The moss layer is not pronounced. Rare and protected species of the flora of the Kursk region are noted: *Dactylorhiza maculata*, *Epipactis palustris* [20].

6. Conclusion
The carried-out research has shown that the experience of restoration of Mikhailovsky MCC stock heaps could have been more successful if optimal surface topography had been created during the technical stage of formation of the stock heap (sloping surfaces prevail). It should be noted that the formed natural and technogenic landscape is not stable due to the significant dynamics of communities of living organisms, complicated by a number of geological and anthropogenic factors: landslides, suffusion, storm erosion, deflation, fires. However, (within individual clusters) intensive processes of restoration of vegetation is observed, and it is proved by the presence of rare plant species. The rate of
soil formation in such areas is quite high. This gives favorable conditions for the economic use of these landscapes, for example, for the purpose of forest restoration and forest breeding.

7. References
[1] Stifeev A I, Golovastikova A V, Bessonova E A 2011 Changes in the composition and structure of the microbial community under the conditions of technogenic landscape of the dumps of the Mikhailovsky mining and reparative combine of the Kursk Magnetic Anomaly Vestnik of Kursk State Agricultural Academy 4 40-41
[2] Stifeev A I, Nikitina O V, Bessonova E A, Kemov K N 2017 The recultivation of disturbed lands and the technology of their improvement on the territory of the central black soil zone International agricultural journal 6 34-38
[3] Malinina T A, Shurygin V A, Dyukov A N 2012 Biological recultivation of technogenic landscapes of the Kursk Magnetic Anomaly Forestry engineering journal 4 145-147
[4] Hage K 1996 Recultivation in the Lusatian mining region – Targets and prospects Water, air and soil pollution 1-2 43-57
[5] Strzyszcz Z 1996 Recultivation and landscaping in areas after brown-coal mining in Middle-East European Countries Water, air and soil pollution 1-2 145-157
[6] Lukina N V, Chibrik T S, Glazyrina M A, Filimonova E I 2015 Biological reclamation and monitoring of lands disturbed by industry (Yekaterinburg) 356
[7] Treshchevskaya E I and Tihonova E N 2015 Biological productivity of tree species in plantations of technogenic landscapes of the Kursk Magnetic Anomaly Forestry engineering journal 3 122-130
[8] Zvyagincev D G 1991 Methods of soil microbiology and biochemistry (Moscow) 304
[9] Kazeev K Sh, Kolesnikov S I, Val’klov P F 2003 Biological diagnostics and indication of soil: methodology and research methods (Rostov-on-Don) 204
[10] Mineev V G 2001 Agrochemistry workshop (Moscow) 319
[11] Sokolov A V 1975 Agrochemical soil research methods (Moscow) 656
[12] Braun-Blanquet J 1964 Pflanzensoziologie (Wien) 865
[13] Poluyanov A V 2018 Syntaxonomy of the herbal communities of man-made landscapes of the Mikhailovsky mining and processing plant Flora and vegetation of the Central Chernozem Region (Materials of the interregional scientific conference) (Kursk) 100-105
[14] Kovda V A 1973 Fundamentals of Soil Science (Moscow) 448
[15] Klychev D G, Panyushkina O Yu, Shchetinina A V 2018 Ecological assessment of the effect of slag waste on the microbiological activity of light gray forest soils Scientific support of innovative development of the agro-industrial complex of the regions of the Russian Federation (Materials of the international scientific-practical conference) (Lesnikovo: Kurgan State Agricultural Academy named after T S Mal'tseva) 539-543
[16] Stepanova L P, Yakovleva E V, Pisareva A V, Raskatova V A 2016 Environmental assessment of the microbiological structure of the complex anthropogenically-transformed territories Agrochemical Bulletin 3 20-25
[17] Yakovleva E V, Stepanova L P, Pisareva A V Physico-Chemical Evaluation of Fertility Restoration of Damaged Gray Forest Soils under Reclamation Safety in the technosphere 2 27-32
[18] Stefurak V P, Usataya A S, Frunz N I, Kataruk E A 1990 Biological activity of soil in the conditions of anthropogenic impact (Kishinev) 214
[19] Golovastikova A V 2006 Microbiocenoses of the dump areas of the Mikhailovsky Mining and Combining Plant of the Kursk Magnetic Anomaly Environmental problems of our time (Materials of the scientific-practical conference) (Yekaterinburg) 113-115
[20] The Red Book of the Kursk region: rare and endangered species of animals, plants and fungi 2017 (Kursk) 380
Acknowledgements
The research was carried out with support of Grant of the President of the Russian Federation for Young Russian Scientists - Candidates of Sciences MK-4086.2018.5.