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Article

A retrospective analysis of vegetation on the waste rock dump of a Donbass coal mine

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Abstract. The paper provides a retrospective analysis of vegetation on the waste rock dump of Dimitrov coal mine No. 5-6, Donetsk, DPR. The data on the state of vegetation cover in 1977–2010 and 2011–2024 are taken as a basis, which is methodically justified in evaluating results from the first experimental planting of annual and perennial plants as well as the process of the dump colonization with alien species. A close positive correlation is found between the increase in the number of plant species and duration of the reclamation period, which is reflected in the phytodiversity of the waste rock dump during coal mining in Donbas and contributes to the formation of the dump as an established ecotope.

Keywords: phytodiversity, reclamation, ecotope

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Научная статья

Ретроспективный анализ растительности породного отвала угольной шахты Донбасса

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Аннотация. В работе проведен ретроспективный анализ растительности породного отвала ш. 5-6 им. Димитрова, г. Донецк, ДНР. За основу взяты данные о состоянии растительного покрова 1977–2010 гг. и 2011–2024 гг., что методически оправдано при оценке результатов первых экспериментальных посадок однолетних и многолетних растений и процесса заселения отвала заносными видами. Была установлена тесная положительная связь увеличения числа видов растений с длительностью периода рекультивации, что отражается на фиторазнообразии на породном отвале при угледобыче в условиях Донбасса и способствует формированию отвала как устоявшегося экотопа.

Ключевые слова: фиторазнообразие, рекультивация, экотоп

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Introduction

Modern monitoring of anthropogenically transformed ecosystems, including waste rock dumps in Donbas, requires a systematic approach to the comprehensive study of long-term dynamics of their phytodiversity. In particular, studies have been conducted to assess harmful effects on residential areas in large cities (Eprintsev et al., 2019; Kalinina, 2019) and biogeochemical parameters of natural-territorial complexes within industrial zones (Kalinina and Germonova, 2018; Slepnev and Popov, 2019).

Vegetation succession on man-made substrates is manifested in both a directed change in species composition and the formation of its phytocenotic structure. Already at the early stages of succession, there is a set of resistant species that are highly abundant in the subclimax ecosystem. The speed of succession depends on the initial germination of species at a specific point at a specific time (Mironycheva-Tokareva, 1996). Five years after application, about 12–17 t/ha of chernozem and loamy soils are washed off from the waste rock dump at the stage of technical reclamation. In ten years, as a result of natural overgrowth with grasses, soil water erosion decreases by 1.9 times, while on chernozem substrates natural vegetation practically ensures protection of soil from erosion (Navalikhin, 2009). Plant species selection for reclamation requires careful consideration of soil and climatic conditions, terrain, intensity of erosion processes and should be based on such qualitatively important characteristics of the species as oligonitrophilicity, salt and drought tolerance. Plants must be native, similar in species composition to those growing in the forest areas nearest to the waste rock dumps (Rodayeva, 2004). Modeling of ecotopes in a quarry, sowing perennial grasses, planting trees and shrubs of a suitable assortment contribute to higher species and phytocenotic diversity of the quarry's vegetation cover and accelerate its formation by 15-20 years (Glazyrina, 2002; Kulagin, 1998).

For successful restoration of disturbed landscapes, it is essential to use several types of woody plants. This is due to biological characteristics and different selective absorption and accumulation capacities of woody plants which ensure efficient bioremediation of toxic compounds in waste soils. During afforestation of industrial waste dumps, water and wind erosion is reduced, a number of toxic elements accumulate in the perennial parts of woody plants, and the level of secondary pollution of adjacent landscapes is reduced (Vedernikov, 2002).

The best phytomeliorants are Scots pine, Siberian larch, silver birch and sea buckthorn. These species are also promising for the reclamation of disturbed lands (Androkhanov, 2005; Metodicheskie rekomendatsii..., 2017).

A high content of metals in the soil of waste rock dumps determines the increased level of their accumulation in woody plant organs. The highest concentrations of technogenic metals are found in perennial parts of plants (root system, bark and branches), while the lowest are recorded in assimilation organs (leaves). The accumulation of heavy metals in absorbing roots is an adaptive response aimed at the survival of woody plants under extreme conditions of industrial waste dumps (Kulagin, 2014; Stanchenko, 2009; Titov et al., 2007). Under the canopy of tree plantations on waste rock dumps, a soil cover is formed, which characteristics are determined by the composition and properties of the spoil heap soils, the species composition of woody plants, their age and mosaic structure of growth.

The comparison of research materials from 1982–1986 and 2008–2011 studies shows that during the formation of soil cover on waste rock dumps under the canopy of forest plantations, positive changes in such parameters as total carbon, pH, phosphorus, exchangeable calcium and magnesium occur, which indicates the contribution of woody plants to the biological reclamation of industrial waste dumps (Radosteva, 2011).

The aim of this study is to conduct a retrospective analysis of vegetation on the model waste rock dump of Dimitrov mine No. 5-6, Donetsk, DPR.

Materials and methods

In this study, the assessment of tree species vitality, composition, and diversity was carried out for woody plants only, using the method developed by V.A. Alekseev, without measuring the trunk diameter and height (Alekseev, 1989). The characteristic of herbaceous communities is presented only by stating the fact of their existence as formed plantations on a waste rock dump of a certain type.

Results and discussion

The climate in Donetsk (Donetsk People's Republic) is temperate continental and arid. The average monthly air temperature in January is −4 °C and in July is +23 °C. The absolute minimum air temperature of −31 °C was recorded on January 11, 1950 and the absolute maximum of +41 °C was recorded on July 18, 2021. In winter, northeast and east winds prevail, in summer the prevailing winds blow from the northwest and west. Annual precipitation averages 493 mm.

The waste rock dump of mine No. 5-6 (N 48.002605° E 37.843197°) is located within the city limits of Donetsk in close proximity to residential buildings, market pavilions, schools and major highways (Fig. 1). The dump started operating in 1915 and was shut down in 1967, after 52 years of operation, excluding the period of Great Patriotic War and post-war reconstruction (1941–1954). Initially, the dump had 4 conical peaks up to 48 m high and contained a total of more than one and a half million tons of waste rock. The dump covers an area of 58000 m^2 with estimated volume of waste rock of 900 thousand m^2. Spontaneous combustions have been reported in separate areas from the very beginning of the dump operation (Korshikov et al., 1994).

Mining engineering, the first stage of the reclamation process, was fully implemented at the waste rock dump of mine No. 5-6. The dump extinguishing and re-profiling project was carried out by Special Directorate for Extinguishing, Fire Prevention and Reclamation PO «Donetskugol», and the terracing, slope flattening and landscaping project was done by Donetsk Botanical Garden.

The technical stage of reclamation began in 1976, after suppressing a fire at the dump, and involved its reshaping with the removal of conical tips. In the same year of 1976, soil was brought to the flat top and terraces and distributed in a layer between 0.2 and 0.8 m thick. In the spring of 1977, a total of 6670 standard seedlings of false acacia, *Robinia pseudoacacia*, were planted for the first time. Observations showed that plant grew better in areas with a potentially fertile layer of soil. Improved plant growth was also observed on slopes when clay was transported by sediments from plateaus and terraces to lower areas. The average survival rate of seedlings in 1977 was 84%. In 1978, an additional 12000 seedlings of the same species were planted and grass was sown over an area of 30400 m^2 (top and terraces). Legume-cereal grain mixtures and pure crops were used to test various options. Melilot, couch grass, lyme grass, wheatgrass, clover, and various types of alfalfa were also used. To date, experimental plantings at the dump have been carried out by the staff of Donetsk Botanical Garden (Zhukov, 2018; Zhukov and Martynova, 2015).

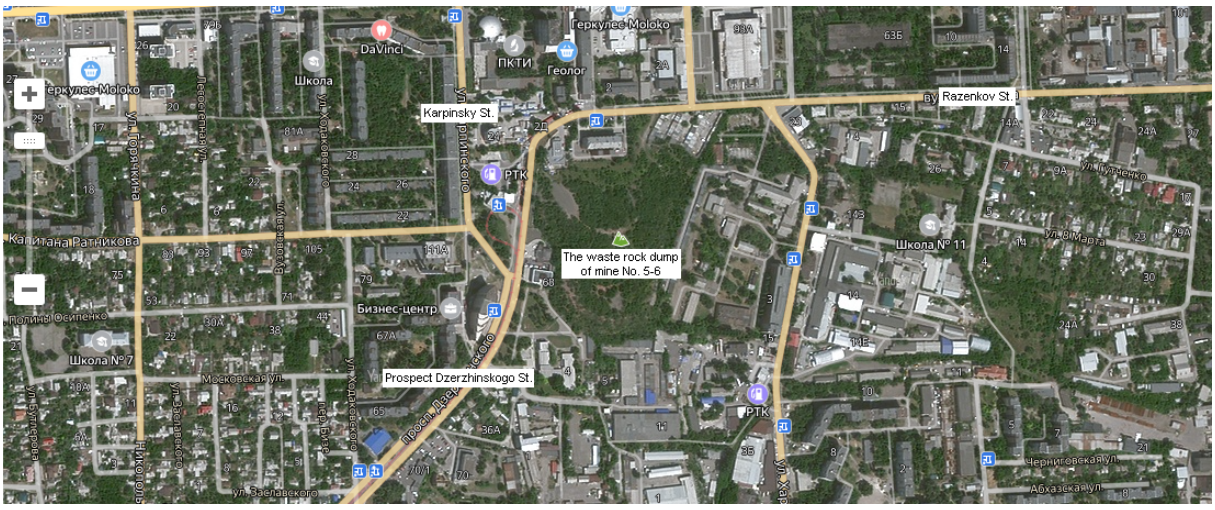

Fig. 1. A schematic map of the location of the waste rock pump of Dimitrov mine No. 5-6.

Based on the comprehensive long-term monitoring of the phytodiversity dynamics of the waste rock dump, conducted over the past 47 years since its landscaping, three distinct time periods are identified:

1) 1977–2000 – the beginning of biological reclamation of the dump, the first experimental plantings;
2) 2001–2023 – new experimental plantings of Donetsk Botanical Garden;
3) 2024 – current phytodiversity of the dump.

The results of monitoring of the plant species composition dynamics on the waste rock dump from 1978 to 2024 (Otchet po nauchno-issledovatelskoi rabote..., 2013; Rekomedatsii po vyrashchivaniyu..., 1982) are presented in Table 1.

Table 1. Vegetation of the waste rock dump of Dimitrov mine No. 5-6.

Year	Observed species of woody plants
1978	*Agropyron cristatum* (L.) Gaertn *Elytrigia repens* L. *Medicago sativa* L. *Melilotus albus* Medik. *Melilotus officinalis* L. *Robinia pseudoacacia* L. *Trifolium pratense* L.
2010	*Agropyron cristatum* (L.) Gaertn *Elytrigia repens* L. *Gypsophila scorzonerifolia* Ser. *Hyssopus officinalis* L. *Medicago sativa* L. *Melilotus albus* Medik. *Melilotus officinalis* L. *Quercus rubra* L. *Robinia pseudoacacia* L. *Trifolium pratense* L.
2024	*Acer negundo* L. *Acer tataricum* L. *Agropyron cristatum* (L.) Gaertn *Ailanthus altissima* Mill. *Betula pendula* Roth *Cornus mas* L. *Crataegus laevigata* Poir. *Elytrigia repens* L. *Fraxinus pennsylvanica* Marsh. *Gypsophila scorzonerifolia* Ser. *Hyssopus officinalis* L. *Juglans regia* L. *Ligustrum vulgare* L. *Malus sylvestris* L. *Medicago sativa* L. *Melilotus albus* Medik. *Melilotus officinalis* L. *Populus balsamifera* L. *Prunus armeniaca* L. *Prunus avium* L. *Prunus cerasifera* Ehrh. *Prunus mahaleb* L. *Quercus robur* L. *Rhus typhina* L. *Robinia pseudoacacia* L. *Rosa cinnamomea* L. *Sorbus intermedia* Ehrh. *Symphoricarpos* Dill. *Syrínga vulgáris* L. *Trifolium pratense* L. *Ulmus pumila* L.

To highlight the dynamics of species diversity of plant organisms on the dump during its anthropogenic transformation into an ecotope, the control years of 1978, 2010, and 2024 were selected, allowing us to trace specific changes in parameters against the background of observed industrial change and development processes, and thus, industrial pollution of natural ecosystems and stabilization of the waste rock dump.

The analysis of the phytodiversity long-term dynamics on the waste rock dump shows that *Robinia pseudoacacia* survives the best and is the most promising species for reclaiming the waste heap. In 2024, there was a spread of self-introduced species (for example, *Ailanthus altissima*, *Juglans regia*, *Prunus cerasifera*), as well as increased growth and dissemination of woody plant species (*Ulmus pumila*, *Betula pendula*, *Quercus robur*, etc.). Also in 2024, *Elytrigia repens* and *Medicago sativa* plantations expanded, compared to 2010.

In general, the condition of green plantations and the mine No. 5-6 waste rock dump itself is characterized as unsatisfactory, and the effectiveness of reclamation measures is insufficient. Health assessment of individual woody plants shows that healthy trees make up 29% of the total number of woody plants, weakened trees – 31%, and severely weakened trees – 40%. The relative vitality of tree plantations on the waste rock dump of the mine No. 5-6 in Donetsk is assessed as "weakened".

The most common injuries in woody plants on the waste rock dump of the mine No. 5-6 are spot necrosis of leaves (60% of the total number of trees examined), marginal leaf necrosis (30%) and leaf chlorosis (70%), as well as the presence of insect galls on the leaf surface (14%).

Conclusion

This study shows that the condition of the waste rock dump substrate has a negative impact on woody plants, their leaf and shoot apparatus get modified, and self-introduced plant species replace the native ones. Further investigation into the chemical composition of the substrate and plant material will allow for a better understanding of contaminant transport from soil to plants.

References

Alekseev, V.A., 1989. Diagnostika zhiznennogo sostoyaniya derev'ev i drevostoev [Diagnostics of the vital condition of trees and stands]. *Lesovedenie [Forestry Science]* **4**, 51–57. (In Russian).

Androkhanov, V.A., 2005. Pochvenno-ekologicheskoe sostoyanie tekhnogennykh landshaftov: dinamika i otsenka [Soil and ecological status of man-made landscapes: dynamics and assessment]. *PhD in Biology thesis.* Novosibirsk, Russia, 314 p. (In Russian).

Glazyrina, M.A., 2002. Osobennosti formirovaniya flory i rastitel'nosti v usloviyakh otvalov i kar'erov otkrytykh ugol'nykh razrabotok (na primere Chelyabinskogo burougol'nogo basseina) [Features of flora and vegetation formation in the conditions of dumps and quarries of open-pit coal mining (on the example of the Chelyabinsk brown coal basin)]. *PhD in Biology thesis abstract.* Ekaterinburg, Russia, 17 p. (In Russian).

Eprintsev, S.A., Klepikov, O.V., Shekoyan, S.V., Zhigulina, E.V., 2019. Issledovanie sotsial'no-ekologicheskikh uslovii, opredelyayushchikh ustoichivoe razvitie regionov Rossii [The study of socio-ecological conditions determining the sustainable development of Russian regions]. *Ekologiya. Ekonomika. Informatika. Seriya: Sistemnyi analiz i modelirovanie ekonomicheskikh i ekologicheskikh system [Ecology. Economy. Computer science. Series: System analysis and modeling of economic and ecological systems]* **1** (4), 212–216. (In Russian). https://doi.org/10.23885/2500-395X-2019-1-4-212-216

Kalinina, A.V., 2019. Populyatsionnyi monitoring tekhnogennykh ekotopov nekotorykh porodnykh otvalov g. Makeevki [Population monitoring of technogenic ecotopes of some rock dumps in Makeyevka]. In: Ashikhmina, T.Ya. (ed.), *Biodiagnostika sostoyaniya prirodnykh i prirodno-tekhnogennykh system [Biodiagnostics of the state of natural and man-made systems]*. Vyatka State University Publishing House, Kirov, Russia, 13–15. (In Russian).

Kalinina, A.V., Germonova, E.A., 2018. Geostrategicheskaya vizualizatsiya fitotsenozov porodnykh otvalov ugol'nykh shakht g. Makeevki v usloviyakh samozarastaniya i rekul'tivatsii [Geostrategic

visualization of phytocenoses of rock dumps of coal mines in Makeyevka in conditions of self-flooding and reclamation]. *Problemy ekologii i okhrany prirody tekhnogennogo regiona [Problems of Ecology and Nature Protection of a Man-Made Region]* **3–4**, 28–34. (In Russian).

Korshikov, I.I., Kotov, V.S., Mikheenko, I.P., 1994. Fitoindikatsiya kachestva okruzhayushchei sredy v tekhnogennykh raionakh [Phyto-indication of environmental quality in man-made areas]. In: Kondratyuk, E.N. (ed.), *Katalog razrabotok Donetskogo botanicheskogo sada [Catalog of developments of the Donetsk Botanical Garden]*. Donetsk, Ukraine, 14–15. (In Russian).

Kulagin, A.Yu., 1998. Ivy: tekhnogenez i problemy optimizatsii narushennykh landshaftov [Willows: technogenesis and problems of optimization of disturbed landscapes]. Gilem, Ufa, Russia, 193 p. (In Russian).

Kulagin, A.Yu., 2014. Lesnaya rekul'tivatsiya otvalov gornodobyvayushchei promyshlennosti v Respublike Bashkortostan: 25-letnii opyt [Forest reclamation of mining dumps in the Republic of Bashkortostan: 25 years of experience]. *Materialy V mezhdunarodnoi nauchnoi konferentsii «Vosstanovlenie narushennykh prirodnykh ekosistem» [Proceedings of the V International Scientific Conference "Restoration of disturbed natural ecosystems"], Donetsk, 12–15.05.2014.* Donetsk, 315–317. (In Russian).

Mironycheva-Tokareva, N.P., 1996. Suktsessii rastitel'nosti i dinamika rastitel'nogo veshchestva pri zarastanii otvalov lesostepnoi zony yuga Srednei Sibiri [Vegetation successions and dynamics of plant matter during overgrowth of dumps in the forest-steppe zone of southern Central Siberia]. *PhD in Biology thesis abstract.* Tomsk, Russia, 21 p. (In Russian).

Metodicheskie rekomendatsii po lesnoi rekul'tivatsii narushennykh zemel' na predpriyatiyakh ugol'noi promyshlennosti v Kuzbasse [Methodological recommendations on forest reclamation of disturbed lands at coal industry enterprises in Kuzbass], 2017. Yu.A. Manakov (ed.). *Kemerovo Regional Environmental Public Organization «Irbis»*, Kemerovo, Russia, 44 p. (In Russian).

Navalikhin, S.V., 2009. Rol' biologicheskoi rekul'tivatsii v zashchite otvalov Lebedinskogo gorno-obogatitel'nogo kombinata KMA ot erozii [The role of biological reclamation in protecting the landfills of the Lebedinsky Mining and Processing Plant KMA from erosion]. *PhD in Biolody thesis abstract*. Volgograd, Russia, 20 p. (In Russian).

Otchet po nauchno-issledovatel'skoi rabote «Obsledovanie 7 nedeistvuyushchikh porodnykh otvalov shakht DP «Artemugol'» (SP «Shakhta im. Gaevogo», SP «Shakhta im. K.A. Rumyantseva», SP «Shakhta im. V.I. Leinina», SP «Shakhta im. M.I. Kalinina»), i vydacha rekomendatsii po ikh biologicheskoi rekul'tivatsii [The report on the research work "Survey of 7 inactive rock dumps of mines DP "Artemugol" (JV "Mine named after Gaeva", JV "K.A. Rumyantsev Mine", JV "V.I. Leinin Mine", JV "M.I. Kalinin Mine"), and the issuance of recommendations for their biological reclamation], 2013. *Natsional'naya Akademiya Nauk Ukrainy – Donetskii botanicheskii sad [National Academy of Sciences of Ukraine – Donetsk Botanical Garden*]. Donetsk, Ukraine, 32 p. (In Russian).

Radosteva, E.R., 2011. Ekologo-biologicheskaya kharakteristika nasazhdenii sosny obyknovennoi (*Pinus sylvestris* L.) i berezy povisloi (*Betula pendula* Roth) pri lesnoi rekul'tivatsii otvalov gornodobyvayushchei promyshlennosti (Respublika Bashkortostan) [Ecological and biological characteristics of stands of Scots pine (*Pinus sylvestris* L.) and birch (*Betula pendula* Roth) during forest reclamation of mining dumps (Republic of Bashkortostan)]. *PhD in Biology thesis abstract.* Ufa, Russia, 21 p. (In Russian).

Rekomendatsii po vyrashchivaniyu i ispol'zovaniyu novykh perspektivnykh drevesnykh ekzotov dlya ozeleneniya Donbassa [Recommendations on the cultivation and use of new promising tree exotics for landscaping Donbass], 1982. Kondratyuk, E.N. (ed.). Donetsk Botanical Garden of the Academy of Sciences of the Ukrainian SSR, Donetsk, USSR, 133 p. (In Russian).

Rodaeva, V.V., 2004. Vosstanovlenie rastitel'nogo pokrova na otvalakh burougol'nykh mestorozhdenii Yuzhnogo Primor'ya [Restoration of vegetation cover on the dumps of the lignite deposits of Southern Primorye]. *PhD in Biology thesis abstract.* Ussuriisk, Russia, 28 p. (In Russian).

Slepnev, M.A., Popov, A.V., 2019. Ekologicheskaya emkost' gorodskikh prirodno- antropogennykh territorial'nykh kompleksov [Ecological capacity of urban natural and anthropogenic territorial complexes]. *Zhilishchnoe stroitel'stvo [Housing Construction]* **3**, 57–60. (In Russian). https://doi.org/10.31659/0044-4472-2019-3-57-60

Stanchenko, L.Yu., 2009. Raspredelenie tyazhelykh metallov v pochvakh i rastitel'nosti gorodskikh ekosistem Kaliningradskoi oblasti [Distribution of heavy metals in soils and vegetation of urban ecosystems of the Kaliningrad region]. *Vestnik Rossiiskogo gosudarstvennogo universiteta im. I. Kanta [Bulletin of the I. Kant Russian State University]* **1**, 81–85. (In Russian). https://doi.org/10.5922/2223-2095-2009-1-13

Titov, A.F., Talanova, V.V., Kaznima, N.M., Laidinen, G.F., 2007. Ustoichivost' rastenii k tyazhelym metallam [Plant resistance to heavy metals]. *Karelian Scientific Centre RAS,* Petrozavodsk, Russia, 169 p. (In Russian).

Vedernikov, K.G., 2002. Lesnaya rekul'tivatsiya i optimizatsiya tekhnogennykh landshaftov (na primere promyshlennykh otvalov Kumertautskogo burougol'nogo razreza) [Forest reclamation and optimization of man-made landscapes (on the example of industrial dumps of the Kumertaut brown coal mine)]. *PhD in Biology thesis abstract.* Tol'yatti, Russia, 16 p. (In Russian).

Zhukov, S.P., 2018. Sliyanie rekul'tivirovannykh otvalov shakht s gorodskim landshaftom kak variant ekologicheskoi optimizatsii staropromyshlennykh territorii [Merging of reclaimed mine dumps with the urban landscape as an option for environmental optimization of old industrial territories]. *Sbornik nauchnykh trudov GNBS [Collection of scientific papers of State Nikitsky Botanical Garden]* **147**, 210–211. (In Russian).

Zhukov, S.P., Martynova, E.A., 2015. Otval shakhty № 5-6 g. Donetska: 100-letnii yubilei, retrospektivy i perspektivy [Mine dump No. 5-6 Donetsk: 100th anniversary, retrospectives and prospects]. *Sbornik nauchnykh rabot regional'noi konferentsii «Kompleksnoe ispol'zovanie prirodnykh resursov» [Collection of scientific papers of the regional conference "Integrated use of Natural resources"], Donetsk, 10.12.2015.* Donetsk National Technical University, Donetsk. (In Russian).

Список литературы

Алексеев, В.А., 1989. Диагностика жизненного состояния деревьев и древостоев. *Лесоведение* **4**, 51–57.

Андроханов, В.А., 2005. Почвенно-экологическое состояние техногенных ландшафтов: динамика и оценка. *Диссертация на соискание ученой степени кандидата биологических наук.* Новосибирск, Россия, 314 с.

Ведерников, К.Г., 2002. Лесная рекультивация и оптимизация техногенных ландшафтов (на примере промышленных отвалов Кумертаутского буроугольного разреза). *Автореферат диссертации на соискание ученой степени кандидата биологических наук*. Тольятти, Россия, 16 с.

Глазырина, М.А., 2002. Особенности формирования флоры и растительности в условиях отвалов и карьеров открытых угольных разработок (на примере Челябинского буроугольного бассейна). *Автореферат диссертации на соискание ученой степени кандидата биологических наук*. Екатеринбург, Россия, 17 с.

Епринцев, С.А., Клепиков, О.В., Шекоян, С.В., Жигулина, Е.В., 2019. Исследование социально-экологических условий, определяющих устойчивое развитие регионов России. *Экология. Экономика. Информатика. Серия: Системный анализ и моделирование экономических и экологических систем* **1** (4), 212–216. https://doi.org/10.23885/2500-395X-2019-1-4-212-216

Жуков, С.П., 2018. Слияние рекультивированных отвалов шахт с городским ландшафтом как вариант экологической оптимизации старопромышленных территорий. *Сборник научных трудов ГНБС* **147**, 210–211.

Жуков, С.П., Мартынова, Е.А., 2015. Отвал шахты №5-6 г. Донецка: 100-летний юбилей, ретроспективы и перспективы. *Сборник научных работ региональной конференции «Комплексное использование природных ресурсов», Донецк, 10.12.2015*. ДонНТУ, Донецк, Украина.

Калинина, А.В., 2019. Популяционный мониторинг техногенных экотопов некоторых породных отвалов г. Макеевки. В: Ашихмина, Т.Я. (ред.), *Биодиагностика состояния природных и природно- техногенных систем. Издательство ВятГУ*, Киров, Россия, 13–15.

Калинина, А.В., Гермонова, Е.А., 2018. Геостратегическая визуализация фитоценозов породных отвалов угольных шахт г. Макеевки в условиях самозарастания и рекультивации. *Проблемы экологии и охраны природы техногенного региона* **3–4**, 28–34.

Коршиков, И.И., Котов, В.С., Михеенко, И.П., 1994. Фитоиндикация качества окружающей среды в техногенных районах. В: Кондратюк, Е.Н. (ред.), *Каталог разработок Донецкого ботанического сада.* Донецк, Украина, 14–15.

Кулагин, А.Ю., 1998. Ивы: техногенез и проблемы оптимизации нарушенных ландшафтов. Гилем, Уфа, Россия, 193 с.

Кулагин, А.Ю., 2014. Лесная рекультивация отвалов горнодобывающей промышленности в Республике Башкортостан: 25-летний опыт. *Материалы V международной научной конференции «Восстановление нарушенных природных экосистем», Донецк, 12–15.05.2014.* Донецк, 315–317.

Миронычева-Токарева, Н.П., 1996. Сукцессии растительности и динамика растительного вещества при зарастании отвалов лесостепной зоны юга Средней Сибири. *Автореферат диссертации на соискание ученой степени кандидата биологических наук*. Томск, Россия, 21 с.

Методические рекомендации по лесной рекультивации нарушенных земель на предприятиях угольной промышленности в Кузбассе, 2017. Ю.А. Манаков (ред.). КРЭОО «Ирбис», Кемерово, Россия, 44 с.

Навалихин, С.В., 2009. Роль биологической рекультивации в защите отвалов Лебединского горно-обогатительного комбината КМА от эрозии. *Автореферат диссертации на соискание ученой степени кандидата биологических наук*. Волгоград, Россия, 20 с.

Отчет по научно-исследовательской работе «Обследование 7 недействующих породных отвалов шахт ДП «Артемуголь» (СП «Шахта им. Гаевого», СП «Шахта им. К.А. Румянцева», СП «Шахта им. В.И. Леинина», СП «Шахта им. М.И. Калинина»), и выдача рекомендаций по их биологической рекультивации, 2013. Национальная Академия Наук Украины – Донецкий ботанический сад, Донецк, Украина, 32 с.

Радостева, Э.Р., 2011. Эколого-биологическая характеристика насаждений сосны обыкновенной (*Pinus sylvestris* L.) и березы повислой (*Betula pendula* Roth) при лесной рекультивации отвалов горнодобывающей промышленности (Республика Башкортостан). *Автореферат диссертации на соискание ученой степени кандидата биологических наук*. Уфа, Россия, 21 с.

Рекомендации по выращиванию и использованию новых перспективных древесных экзотов для озеленения Донбасса, 1982. Кондратюк, Е.Н. (ред.). Донецкий ботанический сад АН УССР, Донецк, СССР, 133 с.

Родаева, В.В., 2004. Восстановление растительного покрова на отвалах буроугольных месторождений Южного Приморья. *Автореферат диссертации на соискание ученой степени кандидата биологических наук*. Уссурийск, Россия, 28 с.

Слепнев, М.А., Попов, А.В., 2019. Экологическая емкость городских природно- антропогенных территориальных комплексов. *Жилищное строительство* **3**, 57–60. https://doi.org/10.31659/0044-4472-2019-3-57-60

Станченко, Л.Ю., 2009. Распределение тяжелых металлов в почвах и растительности городских экосистем Калининградской области. *Вестник Российского государственного университета им. И. Канта* **1**, 81–85. https://doi.org/10.5922/2223-2095-2009-1-13

Титов, А.Ф., Таланова, В.В., Казнима, Н.М., Лайдинен, Г.Ф., 2007. Устойчивость растений к тяжелым металлам. КарНЦ РАН, Петрозаводск, Россия, 169 с.