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Mining and Industrial Landscapes of Podillia as Potential Structural Elements of the Regional Eco-Network

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Abstract. The current state of the environment caused by irrational nature management necessitates the search for new approaches in the field of restoration and protection of biotic and landscape diversity. The new strategy for its protection is an ecological network that is being developed in Ukraine according to European requirements at the national, regional, and local levels. An integral part of the national eco-network is the territory of Podillia, for which an important topical issue is increasing the productivity of ecosystems and stabilising the ecological balance. One of the ways to optimise the regional eco-network of Podillia is to search for promising territories and include them in structural elements that will ensure its spatial integrity and representativeness. The most common objects of mining and industrial landscapes are quarry-dump complexes that are original in their origin, structure, conditions, natural properties, spatial location, features of the geological structure, the nature of the biotic-landscape structure, and economic development. Therefore, the purpose of this study is to identify and describe the specific features of mining and industrial landscapes that require a set of measures for renaturalisation (reclamation, restoration of natural vegetation, reintroduction, etc.) within the latitudinal Buzhotsko-Buzko-Vovksko-Smotrytskyi eco-corridor of the regional eco-network of Podillia. General scientific (analysis, synthesis), laboratory and field methods, monitoring, comparison and statistical processing methods were used in this study. Factors of influence for the restoration of disturbed ecosystems of mining and industrial landscapes of Podillia were determined on the example of the Andriikovetskyi sand quarry and dump complex. It is established that edaphic conditions, elemental composition and organic matter content in the newly formed substrate, atypical relief, which differs sharply from the natural one, have the greatest influence. With the implementation of a set of measures for renaturalisation, the proposed quarry-dump complex can become a centre of zonal biodiversity as a renewable site – as a structural element of the regional eco-network

Keywords: restoration areas, quarries, mining, environmental protection measures, reclamation, renaturalisation, self-regeneration



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INTRODUCTION

Intensive human use of natural resources and anthropogenic burden associated with irrational use of natural resources contribute to the partial or complete destruction of biodiversity in certain areas of the environment. The creation of nature reserves for the preservation of entire ecosystems and landscape complexes constitutes an effective conservation strategy since apart from the function of protecting and enriching biota, such territories can perform a complex soil protection, water regulation, wind protection role, and positively influence the climatic features of the respective region (Yuhlichek & Vyhovska, 2011). According to the State Cadastre of the Nature Reserve Fund (Ministry of Environmental Protection and Natural Resources of Ukraine, 2022), as of 01/01/2021, there were 8,633 territories and objects of the nature reserve fund in Ukraine, with a total area of more than 41,000 km². In percentage terms, the reserve indicator (the ratio of the factual area of the nature reserve fund to the total area of the state) is only 6.8%, with a norm of 12-15% and an optimal indicator of 18-20%. This is an extremely low indicator of protected areas compared to pan-European standards, where it is 15.33% (the area of protected land per 1 person in Ukraine is 1,054 m², in Europe – 2,220 m²), and insufficient to maintain the overall ecological balance and ensure proper protection of species. In this regard, there is an urgent need to optimise the system of protection of biotic and landscape diversity to ensure the conservation and restoration of ecosystems (Mudrak & Mudrak, 2020).

A modern integral concept on the way to sustainable development is the creation of a comprehensive multifunctional environmental protection system – an ecological network. The pan-European ecological network, as a single spatial system comprising natural and semi-natural territories, was defined as the main vector for implementing the pan-European strategy for Biodiversity and Landscape Conservation (Pan-European strategy for Biodiversity and Landscape Conservation, 1995), adopted at the conference “Environment for Europe” (Sofia, 1995). Most countries in the European community have made the transition from conservation strategies for biotic diversity units to the creation of national ecological networks (NENs) (Mudrak *et al.*, 2018). Considering European regulatory practices (Smyrnova *et al.*, 2021), protection and use of nature reserves, development of the national eco-network in Ukraine is carried out according to the basic requirements of the functioning of the pan-European eco-network at the national, regional, and local levels. An integral part of the ecological network of Ukraine is Podillia, which makes up 10.1% of its territory, for which the problems of preserving biotic and landscape diversity, increasing ecosystem productivity and stabilising the ecological balance of the region are a critical issue (Mudrak, 2012).

According to the Law of Ukraine “On the Ecological Network” (2018), the eco-network is a single territorial system formed to improve conditions for the development and restoration of the environment, increase the

natural resource potential, preserve landscape and biodiversity, places of settlement and growth of valuable species of the animal and plant world, gene pool, animal migration routes through the association of territories and objects of the nature reserve fund, territories of agricultural land that have special value and, according to the laws and international obligations of Ukraine, are subject to special protection. The process of transition from local protection to the creation of a system of protected areas has several obstacles, namely the emergence of new forms of ownership, licensing of land, forest, and water use, and the land market (Mudrak, 2012). Land, forest, and environmental legislation requires amendments and adoption of new legislative provisions regarding the priority of reserving natural territories over all other land purposes (Hrytsku & Danilova, 2018).

According to the functional principles and approaches of the pan-European strategy for preserving biotic and landscape diversity, as well as regulatory support for Ukraine, the structural elements of the national eco-network include key, connecting, buffer, and renewable territories. Key territories ensure the preservation of the most valuable and typical components of landscape and biodiversity for a given region. Connecting territories (eco-corridors) join key territories, ensure the migration of animals and the exchange of genetic material. Buffer territories protect key and connecting territories from external influences. Restored territories ensure the formation of the spatial integrity of the eco-network, for which priority measures must be taken to restore the primary natural state. Potential territories for research are territories that require additional measures to restore the natural state (renaturalisation, reclamation, repatriation, afforestation, regrassing, etc.) – restored territories that, as part of the eco-network, ensure the formation of its spatial integrity and achievement of an ecological balance (Mudrak & Mudrak, 2020; Law of Ukraine 1864-IV “On Ecological Network of Ukraine”, 2018). With the successful implementation of restoration measures, such facilities constitute a potential reserve of biodiversity for further transformation and inclusion as structural elements of the regional eco-network. For the territory of Podillia, this is an urgent issue, which is still understudied.

Therefore, the purpose of this study is to determine the features of the functioning of mining and industrial landscapes covering an area of more than 650 km² of the region and require restoration measures to perform further environmental protection functions as restored territories as structural elements of the eco-network. As the object of this study, the authors chose the Andriikovetskyi quarry and dump complex of mining and industrial landscapes within the Buzhotsko-Buzko-Vovksko-Smotrytskyi eco-corridor of the Central Podillia (Mudrak, 2012).

LITERATURE REVIEW

The first basic principles of creating an ecological network of Ukraine, proposals for the development of its

structure, criteria for identifying the main elements of the ecological network were proposed by Yu.R. Sheliah-Sosonko (1999); Ya.I. Movchan (2001) considered the main functions and principles of developing an eco-network, legal and economic aspects. Yu.R. Sheliah-Sosonko *et al.* (2005), based on the main principles of building an eco-network and analysing biodiversity, proposed a variant of the territorial location of eco-corridors at the national level. Theoretical justification and scientific and methodological development of the foundations for the development of the ecological network of Ukraine is an essential stage for analysing the territorial structure and developing a policy of rational use of natural resources in the regions, namely Podillia. It is relevant to investigate the applied aspects of the regional eco-network development since the natural complex of Podillia has a special local and state ecological and environmental significance. P.L. Tsaryk (2005) identified geographical aspects of the eco-network development in the Ternopil Oblast with justification for the creation of new protected areas; T.L. Andriienko (2006) defined and characterised the territories of the nature reserve fund of the Khmelnytskyi Oblast; in the future, these territories were fully included in the ecological network, which was developed and scientifically justified by L.S. Yuhlichek & T.V. Vyhovska (2012), indicating the place of the Khmelnytskyi Oblast eco-network in national and transnational eco-networks; O.V. Mudrak (2012) focused on the development of scientific justifications for the effective introduction of elements of the ecological framework of the regional eco-network of Podillia in the general scheme of planning the territory of Ukraine, which were formed based on complex studies of flora, defined and described main elements of the eco-network and representative natural and artificial territories. H.V. Mudrak (2018) identified the main stages of development and conditions for the effective functioning of the eco-network within the Eastern Podillia; Yu.Yu. Ovchynnykova (2019) evaluated the natural cores of the eco-network according to the main criteria for their development; Ye.D. Tkach & V.I. Shavrina (2019), N.S. Kovka (2020) identified the role of eco-network elements in the spectrum of conservation and protection of biodiversity; N.S. Kovka (2019) noted representative territories for further inclusion in eco-networks; the study by O.V. Mudrak *et al.* (2021) justifies the creation of new nature reserves in the context of expanding the eco-network.

Quarry-dump complexes for mineral development are promising in terms of research and use as reserve territories for further inclusion and expansion of the eco-network. The search for methods for their renaturalisation depends on several individual conditions, as evidenced by studies of ecosystem reproduction at sulphur (Nazarovets *et al.*, 2017), basalt (Savchuk & Vyhovskyi, 2019), clay (Bonchkovskiy & Bezsmertna, 2020), granite (Savosko *et al.*, 2019) extraction sites, etc. The results of foreign studies confirm the importance of developing holistic approaches with the correlation between biotic and abiotic factors. Spontaneous succession can make

a valuable contribution to nature protection, eliminating the need for expensive reclamation methods, but mineral properties, pH level, and low nutrient content of unstable substrate, disturbed hydrological regime, steep slopes are unfavourable conditions, as a result, vegetation in these areas rarely appears, the slopes remain bare, and a cascade effect can be observed. It is possible to preserve the newly formed topography as a secondary or replacement habitat for species, but these areas may become an ecological trap (Salguiero *et al.*, 2020). To stabilise soil conditions, it is proposed to introduce engineering solutions for strengthening or constructing new artificial slopes (Wang *et al.*, 2018), implementation of identification of water erosion processes by remote sensing (Padro *et al.*, 2022) and filling with additional materials to protect groundwater (Semeraro *et al.*, 2019), improvement of the organic component by sewage sludge (Carabassa *et al.*, 2020) or carrying out transplanting of soil and plant litter from undisturbed areas (Benetkova *et al.*, 2020). In the case of a slow succession, it is advisable to perform a biological stage of reclamation, provided that the ecological plant species inherent in the region are selected (Sampaio *et al.*, 2021). Indicators of the success of recovery activities are the level of biodiversity: settlement of atypical (invasive) species, decrease in species richness (Salgueiro *et al.*, 2020; Sampaio *et al.*, 2021; Gentili *et al.*, 2020), atypical ratios of trophic levels (Twerd *et al.*, 2021) compared to surrounding natural areas indicate incorrectly selected renaturalisation methods and strategies.

MATERIALS AND METHODS

During the study, the authors applied such methods as general scientific (analysis, synthesis), laboratory, statistical, field, comparative, monitoring. Based on the processed information sources, potential renewable territories of the regional eco-network of the Central Podillia are identified, which are located within the Buzhotsko-Buzko-Vovksko-Smotrytskyi eco-corridor and are depicted using Adobe Illustrator and SketchBook graphic software.

Research within the territory of the selected quarry and dump complex, with an area of 0.015 km², were conducted during 2019-2021. The quarry-dump sand complex as a renewable territory of the natural eco-corridor of the regional eco-set was described according to the generally accepted methodology (Mudrak, 2012) and data was included on its location (geographical and administrative affiliation in the eco-corridor), configuration, length, width, area, status in the eco-set, the degree of violations, natural conditions, formed relief, typical groupings, the degree of naturalness of the territory, data on succession transformations, features of the settlement of species, the level of biodiversity.

Since the primary settlement and reproduction of vegetation cover depends on many factors and most relate to geological, orographic, and edaphic conditions (mechanical and physical properties of the geological rock layer, exposure to dumps, instability of substrates, the presence of steep slopes, etc.), the authors identified the conditions within the object under study. To

investigate the trends and rates of change in the area, the dynamics of their development are tracked using images in different years of existence. The terrain in the conditions of the quarry-dump complex was investigated using remote sensing of the earth (aerial photography and analysis of data from artificial Earth satellites). Materials of aerospace surveys provide information about the features of the structure and dynamics of mining and industrial landscapes and can be used to monitor spent territories, determine the effectiveness of the stages of reclamation work, the spread of hazardous phenomena, etc.

Using satellite data, one can calculate the NDVI (Normalised Difference Vegetation Index) – one of the most common and widespread indices for solving problems that use quantitative assessment of vegetation cover. Using this indicator, the authors of this study analysed the features of the development and distribution of diverse types of vegetation within the quarry during the active growing season. NDVI data was systematised and analysed based on the Crop monitoring system (EOS, 2022).

To analyse the territory for the presence of necessary elements in the substrate, such agrochemical studies were carried out as determination of active acidity and hydrolytic acidity (DSTU 7862:2015, 2016B; DSTU 7537:2014, 2015); determination of the sum of absorbed bases (calcium and magnesium ions) in water extract (DSTU 7945:2015, 2016C); determination of humus content according to the Tiurin method (DSTU 7828:2015, 2016A); content of nutrients: nitrogen (DSTU 4729:2007, 2008), phosphorus and potassium according to the Chyrykov method (DSTU 4115-2002, 2003). The growth and development of vegetation cover can be affected by such a limiting factor as the content of heavy metals in the substrate: the content of cadmium (DSTU 4770.3:2007, 2009B), lead (DSTU 4770.9:2007, 2009d), copper (DSTU 4770.6:2007, 2009c), zinc (DSTU 4770.2:2007, 2009a) was determined. To conduct these studies, samples were taken according to the method of a combined sample from 3 localities: sample No. 1 – the selected soil sample of agricultural land that surrounds the territory of the quarry-dump complex comprehensively, on which sunflower and corn are grown; sample No. 2 – the selected soil sample, near agricultural land as a sample of the reference undisturbed zonal soil; sample No. 3 – a sample of the substrate directly from the site of the sandy quarry-dump complex, on which there was no settlement of species.

RESULTS AND DISCUSSION

Within Podillia there are all the necessary conditions and resources for the development of a regional eco-network: nature reserves and objects of national and local significance, water bodies, forest ecosystems, recreation areas, resort territories, remnants of semi-natural and natural vegetation, a considerable part of which belongs to agro-landscapes with single- and perennial plantings. Podillia is described by a unique geological and geomorphological structure and favourable weather, climatic

and soil conditions. Within the region under study, the climate is described as temperate continental with a long warm period, and critically low temperatures are not recorded in winter. The average annual temperature ranges from 8.9°C to 8.1°C, and precipitation ranges from 570 mm/year to 600 mm/year. All these conditions contributed to the specific mosaic spread of the soil cover and the development of various landscape complexes. However, the proportion of undisturbed soils is decreasing due to the increased exploitation of natural resources due to human activities and the lack of proper renaturalisation measures. Agricultural and mining activities have a considerable anthropogenic impact on the natural landscapes of Podillia.

An essential resource in the development of a regional eco-network is the use of mining and industrial landscapes, which currently occupy over 650 km² of lands in Podillia (Mudrak, 2012). Within the framework of Podillia, the study of recovery areas of local and regional eco-networks is at the initial stage (Yatsentiuk *et al.*, 2020), studies conducted in this area include the identification of potential renaturalisation zones with subsequent planning of environmental measures. The criteria for selecting such sites have not yet been fully developed, but there are two main ones – the criteria for conditional compliance and the criteria for real opportunities. In the first case, potential lands are evaluated according to criteria that are assigned to the main structural elements of the eco-network – natural cores, buffer zones, and ecological corridors. The territory is considered to meet the established criteria after proper renaturalisation measures are carried out: restoration of natural vegetation, reintroduction, population settlement, changes in the size and configuration of the territory, etc. In the second case, they assess the factual state and feasibility of renaturalisation: territories that are proposed as restored territories can fully meet the criteria for conditional compliance of structural elements of the eco-network. Next, the authors of this study consider the state of such sites within the Buzhotsko-Buzko-Vovksko-Smotrytskyi eco-corridor.

Buzhotsko-Buzko-Vovksko-Smotrytskyi eco-corridor is a connecting territory at the local level and includes the valleys of the Buzhok, Pivdennyi Buh, Vovk, and Smotrych rivers and has a total length of 172 km. The eco-corridor connects the Verkhnopobuzke, Horodotske, and Tovtrynske natural cores, connects the Yuzhnobuh national long-term eco-corridor with the Dniester transnational eco-corridor and is part of the latitudinal Halytsko-Slobozhanskyi eco-corridor (Yuhlichek & Vyhovska, 2011). There are 26 nature reserves and objects located along the Buzhotsko-Buzko-Vovksko-Smotrytskyi eco-corridor. Part of the territory is deeply eroded, and considerable areas are occupied by agricultural land. Within the borders of this eco-corridor are mineral deposits that are currently under development, and anthropogenically disturbed lands after the cessation of production, which require further measures to restore and stabilise the ecological balance. A considerable part of the land affected by mining is accounted for by localised deposits of minerals such as clay, loam, limestone, and sand. Quarries in the region are unique

in their origin, structure, conditions, natural properties, spatial location, features of the geological structure, the nature of the biotic-landscape structure, and economic

development. The list of identified areas of non-metallic minerals according to the State Enterprise “Derzhheoinform” (2022) is given in Table 1.

Table 1. List of mineral deposits identified within the Buzhotsko-Buzko-Vovksko-Smotrytskyi eco-corridor

Item No.	Item name	Area, km ²	Type of minerals	Development status
1	Perehinka-Pivnich	0.161	Productive part – loam, sole – clay	Not being developed
2	Nyzhchevovkivetske	0.128	Productive part – clay	Not being developed
3	Andriikovetske	0.015	Productive part – sand, sole – clay	Not being developed
4	Hvardiiske	0.0583	Productive part – loam, sole – clay	Not being developed
5	Dobrohorshchanske	0.057	Productive part – loam, sole – sand	Being developed
6	Zhuchkovetske	0.054	Superface – clay, productive part – limestone, sole – sand.	Not being developed
7	Horodotske	0.142	Productive part – loam, sole – clay	Being developed
8	Pivdenosmotrytske	–	Productive part – clay, sole – clay + loam	Not being developed
9	Smotrytske	0.3704	Superface – clay, productive part – limestone, sole – clay	Being developed

Within the territory, there are also promising areas for the development of fuel and energy raw materials – peat, upon the development of which over 26 thousand hectares of productive land in the region of the Andriikovetske and Heletynske deposits are annually disturbed. Andriikovetske deposit is promising for further development, while Heletynske is limed. Within peat deposits and quarries, the process of natural self-regeneration is long, the productivity of phytocenoses is low and

depends on environmental conditions and other factors. Such sites should be restored according to landscape and ecological principles that will consider natural factors and contribute to the development of highly productive phytocenoses, terminating adverse impacts, etc. A schematic representation of the location of quarries within the Buzhotsko-Buzko-Vovksko-Smotrytskyi eco-corridor is presented in Figure 1.

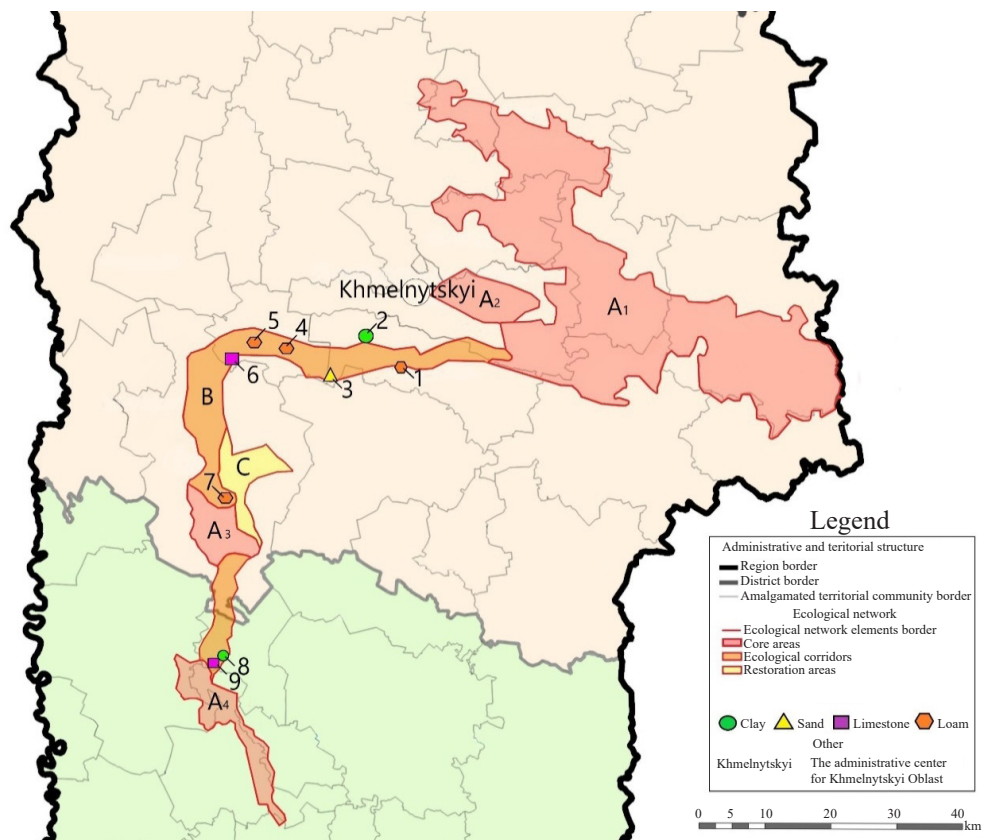


Figure 1. Location of mineral deposits within the Buzhotsko-Buzko-Vovksko-Smotrytskyi eco-corridor

Note: eco-network elements: A1 – Verkhnepobuzke natural core, A2 – Davydkovetske natural core, A3 – Horodotske natural core, A4 – Chernetsko-Kolubaivske sub-core of the local eco-network, B – Buzhotsko-Buzko-Vovksko-Smotrytskyi eco-corridor, C – Zhyshchynetska renewable territory; deposits: 1 – Perehinka-Pivnich, 2 – Nyzhchevovkivetske, 3 – Andriikovetske, 4 – Hvardiiske, 5 – Dobrohorshchanske, 6 – Zhuchkovetske, 7 – Horodotske, 8 – Pivdenosmotrytske, 9 – Smotrytske)

After the cessation of mining, one of the stages necessary for the design of measures for recultivation and restoration of the natural potential of territories is the identification of these sites in geospatial space and determining the level of anthropogenic impact according to types of violations within the devastated lands. The current state of mining sites was assessed using aerospace and aerial photographs. According to the obtained satellite data, within the quarries that are not currently being developed, the emergence of vegetation

cover is recorded, which is an essential factor in soil formation: elements and humus compounds accumulate, the water regime changes, and the anthropogenic substrate is transformed into soil. Under favourable conditions, the process of self-growth passes from the initial successive stage of pioneer development by individual foci to the development of complex stable phytocenoses. Satellite data (as of 2021) of the detected devastated areas are presented in Figure 2.



Figure 2. State of mining and industrial landscapes according to satellite images

Other studies were conducted to characterise the Andriikovetske sand quarry and dump complex as a recovery area, predict the further state and plan measures for its renaturalisation. The climatic conditions within the quarry under study are favourable for vegetation development, but the ability of sandy substrates to provide plants with the necessary amount of moisture is minimal (precipitation quickly seeps down, the capillarity of sand is very low, and the reverse rise of water is practically not observed). According to the results of route studies, a variation in species diversity through

different ecotones was revealed. A similar trend was identified as a result of studies of other quarry-dump complexes: the authors A. Bonchkovskyi & O. Bezsmertna (2020) indicated that the main influence on the dispersal of species is exerted by factors such as topography and lithological substrate, which determine the heterochrony of succession; a considerable influence of topography on vegetation development is noted by L.K. Savchuk (2020). The general view and terrain of the quarry is presented in Figure 3.

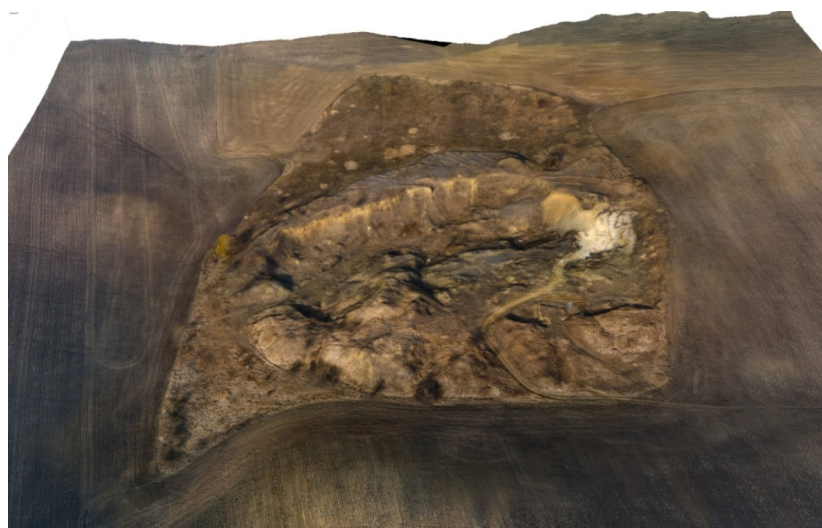


Figure 3. General view and terrain

Studies of quarry-dump complexes confirm that self-regeneration can occur in various scenarios, depending on the type of quarry and the degree of impact: according to the results of L.K. Savhuk & I.V. Vyhovsky (2019), succession stages can occur immediately after the completion of anthropogenic impact with the development of zonal flora and rare inclusions; based on the results of U.R. Nazarovets *et al.* (2017), the development of stable phytocenoses is carried out gradually, provided that erosion processes weaken, the hydrological regime stabilises, and biogenic elements accumulate moderately in the substrate. V.M. Savosko *et al.* (2019) identified a distinctive trend: the data obtained indicate that

the specific conditions of devastated lands at mining sites can become foci of synanthropisation with the localisation of invasively dangerous species. In such cases, it is advisable to engage in the technical and biological stage of reclamation to stabilise the conditions.

Using the NDVI indicator, the authors analysed the features of vegetation development and distribution within the quarry-dump complex under study during the active vegetation season (from May to October). Red and light-yellow colours indicate the absence of vegetation or the distribution of segetal-ruderal species. A graphical representation of the NDVI index is presented in Figure 4.

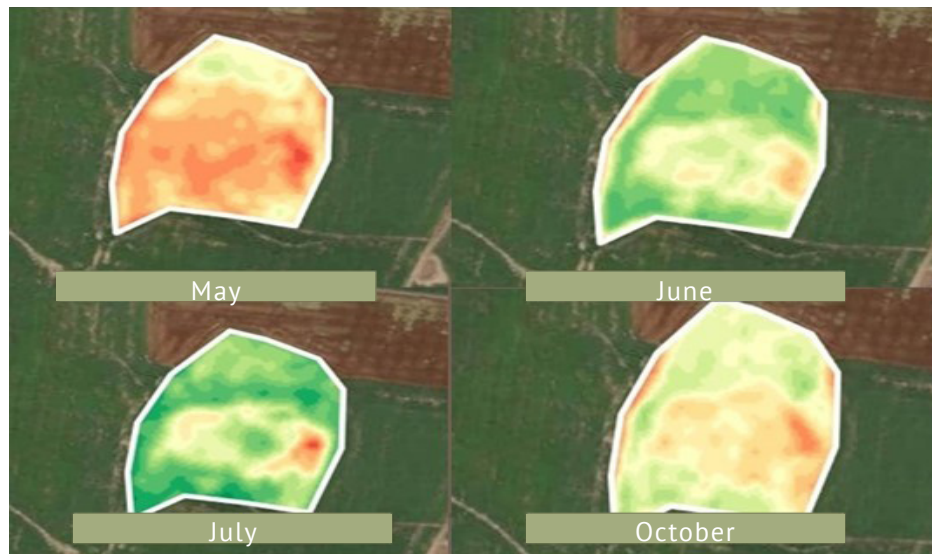


Figure 4. Data on changes in the NDVI index during the year

The growth and development of vegetation on the territory of the quarry-dump complex also depends on the content of nutrients in the substrate. This is confirmed by the data obtained by A. Bonchkovskyi & O. Bezsmertna (2020): the authors found that the abnormally rapid colonisation of the quarry under study with vegetation occurred due to the opening of the rock horizon with a relatively high content of nutrients in it. Their total content indicates a corresponding indicator of potential fertility. In

conditions of deficiency and lack of nutrients, the normal functioning of phytocenoses is impossible, since they take part in such essential processes as the growth of vegetative mass, the development of organic compounds, photosynthesis, root system growth, regulation of water balance, transport of substances, resistance to diseases and pests, etc. The results of the agrochemical study to determine the influence of the elemental composition of the substrate are presented in Table 2.

Table 2. Results of agrochemical study of the Andriikovetske sand quarry and dump complex

Sample No.	Acidity, mmol/100 g		Sum of absorbed bases (Ca+Mg), mg-eq/100 g of soil	Humus, %	Content of nutrients, mg/kg of soil		
	Hr	pH			N	P ₂ O ₅	K ₂ O
1	0.91	6.7	32.4	2.68	114.8	90	227
2	4.92	5.0	16.4	1.88	95.2	138	198
3	0.43	7.1	45.0	0.3	28.0	135	270

The content of heavy metals in the substrate can not only affect succession transformations, but also the choice of further measures for renaturalisation: for their detection in the soil, it is necessary to select biological agents that will perform a dual function – structuring

and improving the substrate performance and removing heavy metals, but this method has several disadvantages, namely the problem of further disposal of the extracted metals. The results of the study are presented in Table 3.

Table 3. Heavy metal content in samples of the Andriikovestke sand quarry and dump complex

Sample No.	Level of heavy metal contamination, mg/kg			
	Cu	Zn	Cd	Pb
1	0.16	0.34	0.08	0.91
2	0.28	0.39	0.06	0.96
3	1.37	0.70	0.28	0.45
MPC, mg/kg	3.0	23.00	0.7	6.0

None of the declared heavy metals exceeds the maximum permissible concentrations, which means that this factor can be excluded as affecting the development of phytocenoses.

Based on the conducted research, the characteristics of the quarry-dump complex as a recovery territory of the regional eco-network are formed as follows:

Ecosystem restoration site – Andriikovestke sand quarry and dump complex.

Administrative regulations. Andriikovestke sand quarry, which is located 2 km south of the village of Andriikivtsi of the Rozsoshanska Rural Territorial Community of the Khmelnytskyi District of the Khmelnytskyi Oblast (geographical coordinates 49°18'21.1"N 26°48'10.7"E).

Area – 0.015 km².

Typical characteristics. Official development was discontinued in 2015. The territory of the Andriikovestke quarry and dump complex is located in a group of landscapes of the Central Podolsk type in the Vovchko-Buzhotsky natural area. The deposit is part of the deposits of the Sarmatian tier – the lower geological tier of the upper Miocene of the Neogene period. Violations that were caused by mining processes are marked by the formed anthropogenic accumulative relief: the inclined parts of the quarry are steep, uneven, in the northern and western parts from 70° to 80°, gentler in the southern part – up to 40°. The territory is described by sharp elevation differences in comparison with the surrounding areas of agricultural land. The deepest point is located in the north-eastern part of the quarry and is 328 m above sea level, the highest point is 340 m above sea level. The territory is described by rock displacements from slopes, dumps, the presence of wind and partially water erosion, uneven distribution of moisture, and surface overheating (various ecotopes). In one of the inclined ledges there is a nesting of the Common swift (*Apus apus*). Such edaphic conditions at the level of low availability of humus compounds on the sandy substrate and the lack of proper stages of mining reclamation are the main factors influencing the development of stable phytocenoses. There is a variation in the species diversity of plant communities, the ecological and cenotic structure is dominated by meadow-steppe, meadow, segetal/ruderal plant types, which indicates the beginning of the formation of zonal vegetation, but the stages of succession are heterogeneous. Pioneer settlements of vegetation are described by the occurrence of such species as coltsfoot (*Tussilago farfara* L.), wild carrots (*Daucus carota* L.), common meadow-grass (*Poa pratensis* L.) in small areas, with a flatter surface,

where the sand layer is smaller and reaches the clay sole. Within the eastern (productive) part of the quarry and the inner part of the slopes, there is no/practically no vegetation cover, minor coverage includes the occurrence of segetal vegetation (there are such species as annual fleabane (*Erigeron annuus* L. Pers), couch grass (*Elymus repens* (L.) Gould), shepherd's purse (*Capsella bursa-pastoris* L.), etc.). The occurrence of the black poplar species (*Populus nigra* L) is observed in all parts of the quarry-dump complex, but individuals have certain differences in phenotype, which is associated with uneven growing conditions. Renaturalisation measures aimed at stabilising edaphic conditions will contribute to the uniform settlement of species within the quarry, the accumulation of humus compounds and necessary elements for the development of stable zonal phytocenoses. During further restoration of vegetation cover, the territory of the quarry-dump complex will represent the diversity of meadow, meadow-steppe ecosystems within the Buzhotsko-Buzko-Vovksko-Smotrytskyi eco-corridor.

CONCLUSIONS

The increased anthropogenic impact on the environment necessitates the prediction of possible threats to biotic, especially floral and phytocenotic diversity. Urgent tasks of scientific research are to identify valuable promising areas for further conservation and protection of nature, especially those that can become valuable hotbeds of biodiversity. Ecosystems that require special attention and, while reducing the anthropogenic impact, are promising for the further development and functioning of the eco-network are those formed at the mining sites. Such areas were identified within the Buzhotsko-Buzko-Vovksko-Smotrytskyi eco-corridor, and they require the search for optimal ways for renaturalisation for further improvement and expansion of the regional eco-network. An example of the restoration of disturbed ecosystems of mining and industrial landscapes of Podillia is the Andriikovestke sand quarry-dump complex, where the main influence on the development of phytocenoses is carried out by geological, orographic, and edaphic conditions. Therefore, the authors of this paper recommend the following reclamation measures with a mandatory engineering stage: waterlogging, strengthening slopes, removing the unproductive substrate layer, and filling with potentially fertile rocks. This will further contribute to the rapid spread of zonal biodiversity and bring the conditions of the quarry-dump complex closer to natural ones.

REFERENCES

- [1] Andriienko, T.L. (Ed). (2006). *Reserved pearls of Khmelnytskyi region*. Khmelnytskyi: PAVF "Intrada".
- [2] Benetkova, P., Tichy, L., Hanel, L., Kukla, J., Vicentini, F., & Frouz, J. (2020). The effect of soil and plant material transplants on vegetation and soil biota during forest restoration in a limestone quarry: A case study. *Ecological Engineering*, 158, article number 106039. doi: 10.1016/j.ecoleng.2020.106039.
- [3] Bonchkovskiy, A., & Bezsmertna, O. (2020). Features of vegetation succession in the loess quarry of the brick factory in Novyi Tik village (Rivne region, Ukraine). *Bulletin of Kyiv Taras Shevchenko National University. Biology*, 1(80), 44-49. doi: 10.17721/1728_2748.2020.80.
- [4] Carabassa, V., Domene, X., Dnaz, E., & Alcaciz, J.M. (2020). Mid-term effects on ecosystem services of quarry restoration with Technosols under Mediterranean conditions: 10-year impacts on soil organic carbon and vegetation development. *Restoration Ecology*, 28(4), 960-970. doi: 10.1111/rec.13072.
- [5] DSTU 4115-2002 "Soils. Determination of Mobile Phosphorus and Potassium Compounds by the Modified Chirikov Method". (2003, January). Kyiv: Derzhspozhyvstandart Ukrainy.
- [6] DSTU 4729:2007 "Soil Quality. Determination of Nitrate and Ammonium Nitrogen in the Modification of NSC IGA. O.N. Sokolovsky". (2008, January). Kyiv: Derzhspozhyvstandart Ukrainy.
- [7] DSTU 4770.2:2007 "Soil Quality. Determination of the Content of Mobile Zinc Compounds in the Soil in a Buffer Ammonium Acetate Extract with a pH of 4.8 by Atomic Absorption Spectrophotometry". (2009a, January). Kyiv: Derzhspozhyvstandart Ukrainy.
- [8] DSTU 4770.3:2007 "Soil Quality. Determination of the Content of Mobile Cadmium Compounds in the Soil in a Buffer Ammonium Acetate Extract with a pH of 4.8 by Atomic Absorption Spectrophotometry" (2009b, January). Kyiv: Derzhspozhyvstandart Ukrainy.
- [9] DSTU 4770.6:2007 "Soil Quality. Determination of the Content of Mobile Copper Compounds in the Soil in a Buffer Ammonium Acetate Extract with a pH of 4.8 by Atomic Absorption Spectrophotometry". (2009c, January). Kyiv: Derzhspozhyvstandart Ukrainy.
- [10] DSTU 4770.9:2007 "Soil Quality. Determination of the Content of Mobile Lead Compounds in the Soil in a Buffer Ammonium Acetate Extract with a pH of 4.8 by Atomic Absorption Spectrophotometry". (2009d, January). Kyiv: Derzhspozhyvstandart Ukrainy.
- [11] DSTU 7537:2014 "Soil Quality. Determination of Hydrolytic Acidity". (2015, April). Kyiv: Derzhspozhyvstandart Ukrainy.
- [12] DSTU 7828:2015 "Soil Quality. Determination of Group and Fractional Composition of Humus by the Turin Method in the Modification of Ponomareva and Plotnikova". (2016a, July). Kyiv: Derzhspozhyvstandart Ukrainy.
- [13] DSTU 7862:2015 "Soil Quality. Determination of Active Acidity". (2016b, July). Kyiv: Derzhspozhyvstandart Ukrainy.
- [14] DSTU 7945:2015 "Soil Quality. Determination of Calcium and Magnesium Ions in Water Wxtract". (2016c, September). Kyiv: Derzhspozhyvstandart Ukrainy.
- [15] Earth observing system (EOS). (2022). Retrieved from: <https://eos.com/>.
- [16] Gentili, R., Casati, E., Ferrario, A., Monti, A., Montagnani, C., Caronni, S., & Citterio, S. (2020). Vegetation cover and biodiversity levels are driven by backfilling material in quarry restoration. *Catena*, 195, article number 104839. doi: 10.1016/j.catena.2020.104839.
- [17] Hrytsku, V., & Danilova, O. (2018). Eco-network development in Ukraine: European, national and regional aspects. *Present Environment and Sustainable Development*, 12(1), 295-308. doi: 10.2478/pesd-2018-0023
- [18] Kovka, N.S. (2019). Major resources formation of environmental network Eastern Podillia: Condition and prospects of use. *Balanced Nature Using*, 4, 53-62. doi: 10.33730/2310-4678.4.2019.199078.
- [19] Kovka, N.S. (2020). The role of the ecological network of the Eastern Podillia in the structure of the national eco-network of Ukraine. *Slovak International Scientific Journal*, 40(2), 18-23.
- [20] Law of Ukraine No. 1864-IV "On Ecological Network of Ukraine". (2018, April). Retrieved from: <https://zakon.rada.gov.ua/laws/show/1864-15#Text>.
- [21] Movchan, Ya.I. (2001). National ecological network of Ukraine: Concept and implementation scenarios. *Scientific Papers*, 19, 411-414.
- [22] Mudrak, H.V. (2018). Functioning of the regional ecological network of Eastern Podillia. *Agroecological Journal*, 3, 27-33. doi: 10.33730/2077-4893.3.2018.148045.
- [23] Mudrak, O., Ovchynnykova, Y., Mudrak, G., & Nagornyuk, O. (2018). Eastern Podillia as a structural unit of PanEuropean environmental network. *Environmental Research, Engineering and Management*, 74(3), 55-63. doi: 10.5755/j01.erem.74.3.21521.
- [24] Mudrak, O.V. (2012). *Balanced development ecological network of Podillia: state, problems, prospects*. Vinnytsia: SPD Hlavatska R.V.
- [25] Mudrak, O.V., & Mudrak, H.V. (2020). *Protected area*. Kherson: OLDI-PLUS.
- [26] Mudrak, O.V., Mudrak, H.V., Serebriakov, V.V., Shcherbliuk, A.L., & Klochaniuk, V.V. (2021). Rationale for the creation of the National natural park "Central Podillia". *Agroecological Journal*, 2, 87-100. doi: 10.33730/2077-4893.2.2021.234462.
- [27] Nazarovets, U.R., Oliferchuk, V.P., Kopii, L.I., & Kopii, M.L. (2017). Succession of plant communities within Podorozhnenskyi sulfur career. *Agroecological Journal*, 1, 121-127. doi: 10.33730/2077-4893.1.2017.221031.

- [28] Official site of the Ministry of Environmental Protection and Natural Resources of Ukraine. (2022). Retrieved from: <https://mepr.gov.ua/>.
- [29] Ovchynnykova, Yu.Yu. (2019). Criteria for determining natural nuclear equipment easy subsidiary in the context of the strategy of sustainable development of the region. *Agroecological Journal*, 1, 117-129. doi: 10.33730/2077-4893.1.2019.163292.
- [30] Padro, J.C., Cardozo, J., Montero, P., Ruiz-Carulla, R., Alcaniz, J.M., & Serra, D. (2022). Drone-based identification of erosive processes in open-pit mining restored areas. *Land*, 11(2), article number 212. doi: 10.3390/land11020212.
- [31] Pan-European Strategy for Biodiversity and Landscape Conservation. International document of the Council of Europe 994-711. (1995, October). Retrieved from https://zakon.rada.gov.ua/laws/show/994_711#Text.
- [32] Salgueiro, P.A., Prach, K., Branquinho, C., & Mira, A. (2020). Enhancing biodiversity and ecosystem services in quarry restoration – challenges, strategies, and practice. *Restoration Ecology*, 28(3), 655-660. doi: 10.1111/rec.13160.
- [33] Sampaio, A.D., Pereira, P.F., Nunes, A., Clemente, A., Salgueiro, V., Silva, C., Mira, A., Branquinho, C., & Salgueiro, P.A. (2021). Bottom-up cascading effects of quarry revegetation deplete bird-mediated seed dispersal services. *Journal of Environmental Management*, 298(15), article number 113472. doi: 10.1016/j.jenvman.2021.113472.
- [34] Savchuk, L.K. (2020). Variety of flora's ecotops and species composition in the territories of basalt operating and abandoned quarries in Volyn Polesia. *Biology and Ecology*, 6(1-2), 30-36. doi: 10.33989/2020.6.1-2.225035.
- [35] Savchuk, L.K., & Vyhovskyi, I.V. (2019). Rare species of plants in the floristic composition of basalt quarries of Volyn Polesia. *Scientific Issues Ternopil Volodymyr Hnatiuk National Pedagogical University. Series Biology*, 2(76), 8-13. doi: 10.25128/2078-2357.19.2.1.
- [36] Savosko, V.M., Lykholat, Yu.V., Bielyk, Yu.V., & Hryhoriuk, I.P. (2019). Apophyte and adventives woody species in granite quarry devastated land at Kryvyi Rih district. *Bioresources and Nature Management*, 11(1-2), 14-25. doi: 10.31548/bio2019.01.002.
- [37] Semeraro, T., Arzeni, S., Turco, A., Margiotta, S., La Gioia, G., Aretano, R., & Medagli, P. (2019). Landscape project for the environmental recovery of a quarry. *IOP Conference Series: Materials Science and Engineering*, 603(3), article number 032020. doi: 10.1088/1757-899X/603/3/032020
- [38] Sheliakh-Sosonko, Yu.R. (1999). The main features of the ecological network of Ukraine. *Development of the Ecological Network of Ukraine*, 13-22.
- [39] Sheliakh-Sosonko, Yu.R., Tkachenko, V.S., Andriienko, T.L., & Movchan, Ya.I. (2005). Econet of Ukraine and its natural kernels. *Ukrainian Botanical Journal*, 62(2), 142-158.
- [40] Smyrnova, S.M., Mas, A.Yu., & Koval, A.O. (2021). European experience of land use of nature reserve fund. *Economy and State*, 1, 77-82. doi: 10.32702/2306-6806.2021.1.77.
- [41] State Information Geological Fund of Ukraine (DNVP "Heoinform Ukrainy"). (2022). Mineral resources of Ukraine. Retrieved from <http://minerals-ua.info>.
- [42] Tkach, Ye.D., & Shavrina, V.I. (2019). Environmental role of connecting territories in the formation of the ecological network of the Eastern Podillia. *Agroecological Journal*, 3, 20-27. doi: 10.33730/2077-4893.3.2019.183465.
- [43] Tsaryk, P.L. (2005). *Regional ecological network: Geographical aspects of formation and development (based on materials from Ternopil region)*. Ternopil: Vydavnychiy vidil TNPU.
- [44] Twerd, L., Szefer, P., Sobieraj-Betlińska, A., & Olszewski, P. (2021). The conservation value of Aculeata communities in sand quarries changes during ecological succession. *Global Ecology and Conservation*, 28, article number 01693. doi: 10.1016/j.gecco.2021.e01693.
- [45] Wang, H., Zhang, B., Bai, X., & Shi, L. (2018). A novel environmental restoration method for an abandoned limestone quarry with a deep open pit and steep palisades: A case study. *Royal Society Open Science*, 5(5), article number 180365. doi: 10.1098/rsos.180365.
- [46] Yatsentiuk, Yu.V., Kanskyi, V.S., & Ataman, L.V. (2020). The recovery territories of the ecological network in Zhmerinsky District of Vinnytsia Region. *Man and Environment. Issues of Neoecology*, 33, 57-67. doi: 10.26565/1992-4224-2020-33-05.
- [47] Yuhlichek, L.S., & Vyhovska, T.V. (2011). *Ecological network of Khmelnytskyi region*. Khmelnytskyi: Vydavnytstvo KHUP.

Гірничо-промислові ландшафти Поділля як потенційні структурні елементи регіональної екомережі

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Анотація. Сучасний стан навколишнього середовища, спричинений нераціональним природокористуванням, потребує пошуку нових підходів у сфері відновлення та охорони біотичного і ландшафтного різноманіття. Новою стратегією його охорони є екологічна мережа, яка розвивається в Україні відповідно до європейських вимог на національному, регіональному і локальному рівнях. Невід'ємною складовою національної екомережі є територія Поділля, для якої важливим актуальним питанням є підвищення продуктивності екосистем та стабілізація екологічної рівноваги. Одним із шляхів оптимізації регіональної екомережі Поділля є пошук перспективних територій та їх включення до структурних елементів, які забезпечуватимуть її просторову цілісність та репрезентативність. Найпоширенішими об'єктами гірничо-промислових ландшафтів є кар'єрно-відвальні комплекси, оригінальні за своїм походженням, структурою, умовами, природними властивостями, просторовим розташуванням, особливістю геологічної будови, характером біотично-ландшафтної структури, господарським освоєнням. Тому метою дослідження є ідентифікація та характеристика особливостей гірничо-промислових ландшафтів, які потребують проведення комплексу заходів з ренатуралізації (рекультивациі, відновлення природної рослинності, реінтродукції тощо) в межах широтного Бужоцько-Бузько-Вовксько-Смотрицького екокоридору регіональної екомережі Поділля. Під час дослідження використовувались загальнонаукові (аналіз, синтез), лабораторні та польові методи, моніторинг, порівняння та методи статистичної обробки. Фактори впливу для відновлення порушених екосистем гірничо-промислових ландшафтів Поділля було визначено на прикладі Андрійковецького піщаного кар'єрно-відвального комплексу. Встановлено, що найбільший вплив мають едафічні умови, елементний склад і вміст органіки в новоутвореному субстраті, нетиповий рельєфом, який різко відрізняється від природного. За проведення комплексу заходів з ренатуралізації, запропонований кар'єрно-відвальний комплекс може стати осередком зонального біорізноманіття в якості відновлюваної ділянки – як структурного елемента регіональної екомережі

Ключові слова: відновні території, кар'єри, видобування, природоохоронні заходи, рекультивациа, ренатуралізація, самовідновлення