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T. S. KOPTIEVA
Vinnytsia Mykhailo Kotsiubynskyi State Pedagogical University,
32 Ostrozkyi Str., Vinnytsia, 21000, Ukraine

e-mail: koptevatania36@gmail.com ORCID ID: https://orcid.org/0000-0001-9405-1674

MINING LANDSCAPES OF KRYVYI RIH LANDSCAPE TECHNICAL SYSTEM

Purpose. Identify the main landscape structures of mining landscapes of Kryvyi Rih landscape technical system.

Methods. Historical analysis, cartographical method of spatial analysis, forecasting method.

Results. In this regard, the analysis of scientific works has been carried out and the landscape factors that cause the emergence of mining landscapes in Kryvyi Rih landscape and technical system have been considered. Mining landscapes were formed as a result of the interaction of technology and nature. Landscape processes and phenomena play a leading role in the formation and development of mining landscapes. Kryvyi Rih landscape technical system underwent significant changes during the 1880s – 2019s. The biggest changes occurred as a result of iron ore mining and storage of industrial waste. In particular, the northern steppe landscapes, the Saksagan and Ingulets riverbeds were completely destroyed along the iron ore deposits of Kryvyi Rih structure. The structure of mining landscapes has been analyzed, their classification has been developed and the detailed characteristic of each of types of mining landscapes has been given. A map has been developed that reflects the territorial organization of the main landscape complexes of the mining landscapes of Kryvyi Rih landscape technical system.

Conclusions. The mining landscapes were formed and are developing, which today are leading in the landscape structure of Kryvbas. Emphasis has been placed on the mining and dumping type of mining landscapes. Recommendations for optimization of landscape structures of mining landscapes of Kryvyi Rih landscape technical system have been substantiated.

KEYWORDS: landscape technical system, mining landscape, landscape structure, quarry and dump complexe, territorial organization

Коптєва Т. С.
Вінницький державний педагогічний університет імені Михайла Коцюбинського, вул. Острозького, 32, Вінниця, 21000, Україна

ГІРНИЧОПРОМИСЛОВІ ЛАНДШАФТИ КРИВОРІЗЬКОЇЛАНДШАФТНО-ТЕХНІЧНОЇ СИСТЕМИ

Мета. Виявлення основних ландшафтних структур гірничопромислових ландшафтів Криворізької ландшафтно-технічної системи.

Методи. Історичний аналіз, картографічний, метод просторового аналізу, метод прогнозування.

Результати. На підставі аналізу наукових праць, розглянуто ландшафтні чинники, які обумовлюють виникнення гірничопромислових ландшафтів на території Криворізької ландшафтно-технічної системи. Гірничопромислові ландшафти утворилися в результаті взаємодії техніки і природи. Провідну роль у формуванні і розвитку гірничопромислових ландшафтів відіграють ландшафтоутворюючі процеси та явища. Криворізька ландшафтно-технічна система упродовж 1880-х–2019-х рр. зазнала значних змін. Найбільші зміни відбулися в результаті видобутку залізної руди та складування відходів виробництва. Зокрема, уздовж простягання покладів залізної руди Криворізької структури повністю знищені північно-степові ландшафти, русло р. Саксагань та р. Інгулець. Проаналізовано структуру гірничопромислових ландшафтів, розроблено їх класифікацію та наведено детальну характеристику кожного із типів гірничопромислових ландшафтів. Розроблена карта, яка відображає територіальну організацію основних ландшафтних комплексів гірничопромислових ландшафтів Криворізької ландшафтно-технічної системи.

Висновки. Утворилися та розвиваються гірничопромислові ландшафти, які сьогодні є провідними у ландшафтній структурі Кривбасу. Акцентована увага на кар'єрно-відвальному типі гірничопромислових ландшафтів. Обґрунтовано рекомендації, щодо оптимізації ландшафтних структур гірничопромислових ландшафтів Криворізької ландшафтно-технічної системи.

КЛЮЧОВІ СЛОВА: ландшафтно-технічна система, гірничопромисловий ландшафт, ландшафтна структура, кар'єрно-відвальний комплекс, територіальна організація

Коптева Т. С.

Винницкий государственный педагогический университет имени Михаила Коцюбинского, ул. Острожского, 32, Винница, 21000, Украина

ГОРНОПРОМЫШЛЕННЫЕ ЛАНДШАФТЫ КРИВОРОЖСКОЙ ЛАНДШАФТО - ТЕХНИЧЕСКОЙ СИСТЕМЫ

Цель. Выявление основных ландшафтных структур горнопромышленных ландшафтов Криворожской ландшафтно-технической системы.

Методы. Исторический анализ, картографический, метод пространственного, метод прогнозирования.

Результаты. На основе анализа научных трудов рассмотрены ландшафтные факторы, обусловливающие возникновение горнопромышленных ландшафтов на территории Криворожской ландшафтно-технической системы. Горнопромышленные ландшафты образовались в результате взаимодействия техники и природы. Ведущую роль в формировании и развитии горнопромышленных ландшафтов играют ландшафтообразующие процессы и явления. Криворожская ландшафтно-техническая система в течение 1880-х–2019-х гг. претерпела значительные изменения. Наибольшие изменения произошли в результате добычи железной руды и складирования отходов производства. Вдоль простирания залежей железной руды Криворожской структуры полностью уничтожены северо-степные ландшафты, русло р. Саксагань и р. Ингулец. Проанализирована структура горнопромышленных ландшафтов, разработана их классификация и приведена подробная характеристика каждого из типов горнопромышленных ландшафтов. Разработана карта, отражающая территориальную организацию основных ландшафтных комплексов горнопромышленных ландшафтов Криворожской ландшафтно-технической системы.

Выводы. Образовались и развиваются горнопромышленные ландшафты, которые сегодня являются ведущими в ландшафтной структуре Кривбасса. Акцентировано внимание на карьерно-отвальном типе горнопромышленных ландшафтов. Обоснованы рекомендации по оптимизации ландшафтных структур горнопромышленных ландшафтов Криворожской ландшафтно-технической системы.

Ключевые слова: ландшафтно-техническая система, горнопромышленный ландшафт, ландшафтная структура, карьерно-отвальный комплекс, территориальная организация

Introduction

Active development of technogenesis on the territory of Kryvyi Rih landscape technical system leads to the emergence of radically changed landscapes. The mining industry has been operating in Kryvyi Rih for about 150 years and in this short period of time has transformed natural landscapes into anthropogenic ones. Every year their area increases, mainly due to mining landscapes. Mining landscapes are distributed throughout Kryvyi Rih landscape technical system, which is due primarily to the peculiarities of the spatial occurrence of iron ore deposits of Kryvyi Rih iron ore basin. The main reason for the emergence of landscape structures of mining landscapes is the open and closed method of iron ore mining, respectively, quarry and mine types. At the beginning of the 21st century the problem of analyzing the functioning of Kryvyi Rih landscape technical system in connection with the scale of development of mining landscapes, the place of mining landscapes in the structure of landscape complexes of Kryvyi Rih, landscape factors that determine the formation of mining and industrial landscapes remains relevant.

Scientists pay a lot of attention to the study of landscape and economic factors that contribute to the formation of mining landscapes. The first person who drew attention to mining landscapes and singled them out in the structure of industrial landscapes was F. Milkov [1]. His student V. Fedotov compared natural landscape-forming and technological factors and, as a consequence, found the formation of man-made relief, biocenoses and soils within mining landscapes [2].

Denysyk H. studied man-made origin of mining landscapes on the example of mining landscapes of Podillia and made the classification of man-made landscapes of Podillia [3]. Ecological and landscape research within the mining areas of Lviv region was conducted by E. Ivanov [4]. Within Kryvyi Rih landscape technical system, landscape research was conducted by L. Bulava, who noted that man-made landscape formation was in progress on the disturbed lands, which meant a set of correlated processes (transformation of rocks and original landforms, "completion" of biota and soil), which restores the integrity of the disturbed area

of the landscape, gradually forming a vertical spatial morphological structure of man-made landscapes "[5]. I. Paranko studied the geological aspects of Kryvyi Rih and proved that Kryvyi Rih landscape technical system is a zone of ecological risk due to the development of man-made fractures, which leads to reduced seismic resistance, and disturbances in the monolithic massifs of Precambrian rocks [6]. V. Kazakov described the post-technogenic forms of relief of the mining landscapes of Kryvyi Rih and showed that after forming dumps and working out quarries, the process of their self-development begins. He first gave the geomorphological characteristics of dip zones, individual quarries and dumps of Kryvyi Rih landscape technical system [7]. V. Palienko found that the territory of Kryvyi Rih landscape technical system is 29% occupied by landscape technical complexes such as urban, mining, reservoirs and sites of industrial enterprises [8].

The influence of hydrological factors on the self-flooding of poisoned quarries was studied by L. Zolotareva [9] and employees of the Dnipropetrovsk Geophysical Expedition "Dniprogeophysics". Geobotanical and floristic studies aimed at studying plant communities formed on the mining landscapes of Kryvyi Rih landscape technical system, their species composition, plant herbarium, study of successions, the process of ruderalization, conditions for biological reclamation were studied by M. Smetana [10].

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Ye. A. Ivanov [4, 15, 20] and I.P. Kovalchuk [4] studied the destruction of mining landscapes and the features of the emergence and disappearance of mining landscapes.

In turn, M.Ya. Syvyi [19] in his work noted the mining regionalization of combinations of mineral deposits. H.I. Denysyk [14] and L.I. Stefankov [14] singled out modern areas of research of anthropogenic landscapes in Ukraine. Landscape and ecological condition and problems of optimization of the natural environment of the regions were described by V.B. Mikhno [16], K.N. Diakonov [16] and others. Yu.V. Yatsentiuk [17] researched and singled out paradynamic connections in mining paradynamic anthropogenic landscape systems of Ukraine. Constructive and geographical principles of regional landscape planning were singled out by V.V. Udovychenko [18]. The concept of geoecological systems was covered in the textbook "Methodological foundations of geography" by O.H. Topchiev [21], D.S. Malchikova [21] and others.

The aim of the study is to identify the main landscape structures in the mining landscapes of Kryvyi Rih landscape technical system. The main tasks are the analysis of factors of formation of mining landscapes, their classification, the detailed characteristic of the basic landscape structures of mining landscapes of Kryvyi Rih landscape technical system and the substantiation of possibilities of their rational use.

Results and discussion

The dynamic development of industrial landscapes in Kryvyi Rih is going due to the active development of the mining industry. Kryvyi Rih has significant reserves of iron ore, reaching 18 billion tons. Iron ore mining began here in the second half of the nineteenth century thanks to the exploration of iron ores by geologists R. Kulshin, M. Barbot-de-Marne, L.Strippelman, S.Gartung, L.Semechkin, S. Kontkevich, V. Domger and P. Piatnitskiy. This has led to the emergence of a powerful industrial development of Kryvyi Rih, and, accordingly, the active formation of mining landscapes. In the initial stages, since the thickness of the overburden did not exceed 1–9 m from the surface of the ore body, it was used mainly open method of mining. The commissioning of the first lifting equipment has led to an increase in the depth of quarries and, consequently, the expansion of the area of dumps [11]. The active development of the mining industry contributed to the growth of the area of mining throughout Kryvyi Rih. In the 50's and 60's of the 20th century the main mining and processing plants were built. Their

number is growing at the beginning of the 21st century. Industrial enterprises and their associated mining landscapes now form the background of powerful Kryvyi Rih landscape technical system. According to estimates by V. Kazakov within Kryvyi Rih landscape technical system, the total area of mining landscapes is 17.1 thousand hectares, the area of quarries is more than 4.2 thousand hectares; area of dumps is 7.0 thousand hectares; area of extractive sludge storages is 5.5 thousand hectares; the area of mine dips and landslide zones is 3.4 thousand hectares [7]. Such a variety of landscape structures made it possible to classify them (Fig. 1)

In the mining landscapes of Kryvyi Rih landscape technical system, quarry and dump complexes predominate. The most typical are the following types: dump and monoexcavation, plateau-like multilayered, ridge-like multilayered dumping, quarry and dumping and lake, quarry and dumping and terraced, quarry and lake and terraced, quarry and terraced and others.

Dump and monoexcavation type is created as a result of anthropogenic denudation: shallow (10–25 m) quarry excavations filled with debris. They occur in the process of mining iron ore, which lies close to the surface. Most of these quarries were the first in the territory of Kryvyi Rih and functioned from 1880 to 1930. These are quarry and dump complexes of the Ore Management named after S. Kolachevsky, the quarry of the Shmakovs whose dump did not survive and the quarry-dump complex Joint-Stock Company "Kryvyi Rih Ore Plant", located in the central and southern part of Kryvyi Rih.

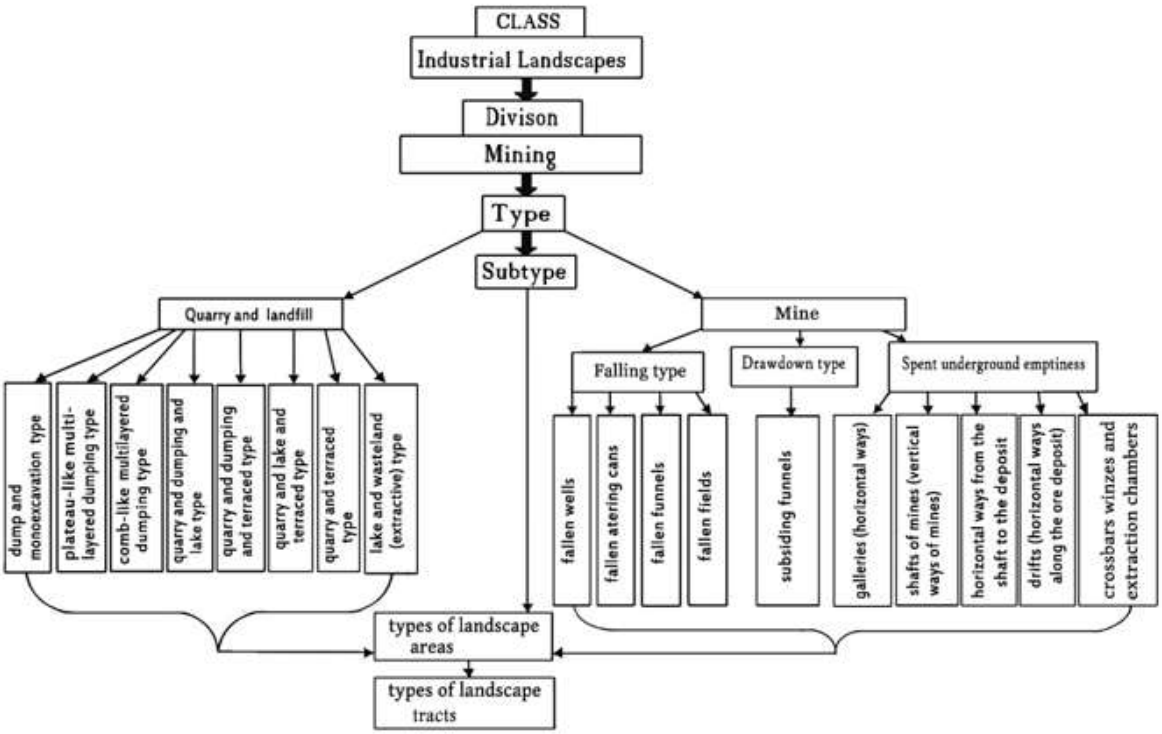

Fig. 1 – Taxonomic system of mining landscapes of Kryvyi Rih landscape technical system [15]

Plateau-like multilayered dumping type was formed due to automobile or railway dumping of dump rocks. Multilevel dumps were formed, with leveled and plateau-like surfaces. According to the available rocks, multilayered dumps are divided into rocky, loose and mixed [11]. Rock dumps are characterized by the presence of rock fragments, namely granites, shales, quartzites and brown iron ore. As a rule, such heaps are loose, gravitational processes develop here and there is no vegetation at all. They are distributed throughout Kryvyi Rih. Among the rock dumps that were in operation from 1960 to 1990 are the dump of the quarry of the Northern mine of the former Ore Management named after Kirov, dumps of former mines Valiavka, named after Ilyich, Skelevatsky dump of NKGZK (New Kryvyi Rih mining and processing plant) of OJSC ArcelorMittal Kryvyi Rih, Shimakivsky dump of quarry № 3 NKGZK

of OJSC ArcelorMittal of Kryvyi Rih, East Hannivsky dump of PnGZK (Northern mining and processing plant), dump in the zone of shift of the mine named after Ordzhonikidze OJSC TsGZK (Central mining and processing plant). Also there are active ones, which have been working since 1960 and to this day - dump №1 quarry InGZK (Inhuletskyi mining and processing plant), dump № 2 quarry InGZK. Loose heaps with the help of backfilling of loose rocks, mostly loose and aqueduct, composed mainly of limestone, clay, marl, loam. Loose dumps are characterized by significant turfing and active development of grassy and woody vegetation.

Loose dumps include Kochubeyevskyi mine dump, the RU dump named after S. Kolachevsky, dump of Oleksandriivsky mine in the field of the former Komsomol mine, dump of JSC KZR, dumps of the Northern quarry of Ore Management Starodobrovolske, dumps of southern quarries of Ore Management Starodobrovolske, Northern dump of Oktyabrskyi granite quarry, dumps of quarries - southern, vizier - western of the former Inguletskyi Ore Management. Mixed dumps are formed due to the presence of both rock and loose rocks. These include small-sized heaps of iron ore quarry in the beam of the Northern Red former of Ore Management. Lenin, the dump of the Dubova Balka Ore Management, the dump of the quarry of the Shimakivsky mine, the Lenin dump of the former Ore Management named after Lenin, the western dumps of the Gleivatsky quarry of OJSC TsGZK, the Novobolshevytskyi dumps of the Gleyuvatsky quarry of OJSC TsGZK, the dumps of the former Ore Management named after The Comintern, the southern heap of the October granite quarry, the heaps of the quarries of the former Ore Management named after Kirov and them. Dzerzhinsky, Burshchitsky dump of NKGZK of JSC ArcelorMittal Kryvyi Rih, dump of the quarry Soviet of the former Ore Management named after Ilyich, Right-Bank Dump of OJSC PdGZK, dump of quarry №2 OJSC TsGZK, dump №6 quarry №2 of OJSC TsGZK, dump of Gleyuvatsky quarry of OJSC TsGZK - all dumps are inactive, years of their activity 1890–1990.

Ridge-like multilayered dumping type is formed due to the specialized dumping of dumps, namely cyclic flow technology, when "ridges" are formed on the surface of the dumps. Due to the ridges on the dumps are formed "technogenic valleys". Dumps are favorable for the formation of vegetation. They are concentrated in the central part of Kryvyi Rih [11].

Quarry and dumping and lake type. With the development of the mining industry the depth of iron ore production increases, the abandoned quarries are eventually filled with water and "blue lakes" are formed. The slopes of the dormant dumps are well mowed with grassy and woody plants. Landscape processes are actively developing on the dumps, including gravitational, fluvial, and where there is limestone, karst landforms are formed. Quarry and dumping and lake type of mining landscapes is confined to the southern part of Kryvyi Rih.

Quarry and dumping and terraced type is characterized by considerable depth of quarries and height of dumps. Iron ore is mined by specialized mining equipment, quarries are not flooded due to the constant pumping of groundwater. Developed gravitational and fluvial relief. Quarry and dumping and terraced type of mining landscapes is common in the central part of Kryvyi Rih [11].

Quarry and lake and terraced type is formed as a result of flooding of deep previously excavated quarries. The depth of such quarry excavations is up to 30m. There are about 20 quarry reservoirs on the territory of Kryvyi Rih landscape technical system. Vegetation, including wood, is formed near water bodies. On the territory of Kryvyi Rih landscape technical system there are two variants of quarry and lake and terraced landscape complexes: iron ore, to which the Soviet quarry belongs and granite, to which the Octiabrskyi and Karachunovskyi granite quarries belong.

Quarry and terraced type forms a modern powerful zone in which all operating quarries are concentrated in Kryvyi Rih, up to 520m deep and more than 4km long. Landscaping processes such as talus, landslides, landslides and vegetation are not detected in the existing quarries. This type includes spent careers named after K. Liebknecht. Now the quarry of RU named after K. Liebknecht is inactive, operated from 1950 to 1960, currently not flooded, because groundwater is being pumped out. The vegetation is ruderal, the bottom of the quarry is covered with woody vegetation. Quarry and terraced type includes the existing quarries: NGZKa quarry № 1, NGZKa quarry № 2, NGZKa quarry №3, PdGZK quarry, Gleyuvatsky quarry (GGZK), Pervomaisky quarry

(PnGZK), Hannivsky quarry (PnGZK), Inguletsky quarry (InGZK). The largest quarry is of PdGZK. The length of this quarry is over 3km, width is 2.5km, and the depth reaches 400m. The deepest quarry in Ukraine is Inguletskyi, the depth of which reaches 420m (Fig. 2).

The significant diversity of mining landscapes of Kryvyi Rih landscape technical system significantly complicates the substantiation of general measures and the development of individual projects for their optimization and rational use. M. Hrodzynskyi notes that "optimization of geosystems is an action aimed at their transformation into states in which they are able to most effectively perform certain economic functions, without noticing undesirable changes over time [12]. At the beginning of the 21st century reclamation is considered to be the most effective measure for the restoration of the mining landscapes of Kryvbas. According to Ivanov E., reclamation is a complex set of engineering, mining, reclamation, biotic, sanitary and hygienic and other measures aimed at returning the areas affected by industry to various types of nature: agricultural, forestry and recreational, etc. [13].However, recent scientific studies of the landscapes of Kryvbas have shown that reclamation as a way to optimize mining landscapes has a number of disadvantages, among which the main ones are:

• ignoring the syngenesis of vegetation as a starting point for further recommendations for the optimization of mining landscapes;

• the main task of reclamation is full positioning of the meso-relief and reduction of the area of slopes of dump complexes turned out to be inexpedient, as it leads to compaction, reduces the filtration capacity of rocks, enhances erosion processes;

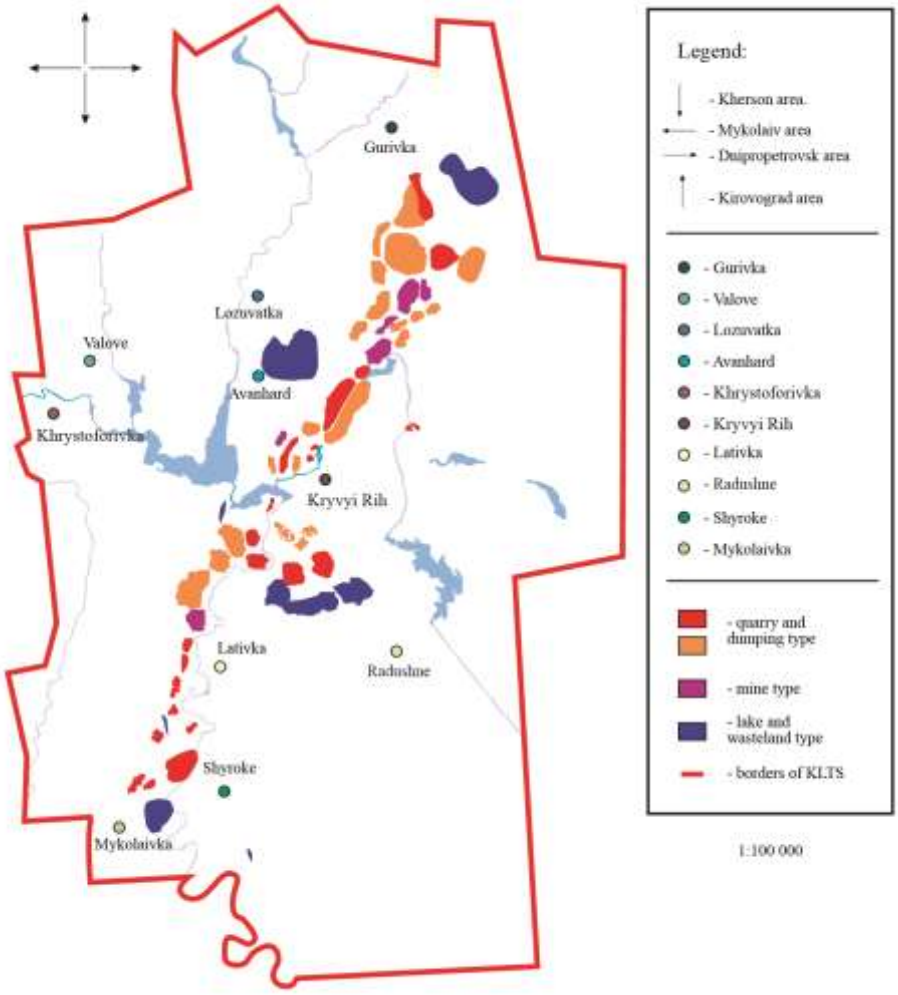

Fig.2 – The main structures of mining landscapes of Kryvyi Rih landscape technical system

• Phyto-recultivation of Kryvbas dump complexes showed that regulated forestry, agricultural, recreational landscapes enter into competitive relations with natural zonal and azonal development processes upon termination of agro-technical support and change rapidly as a result of intensification of soil-biotic processes. These changes (erosion, gravitational processes, reverse successions, formation of primitive soil, biota settlement) confirm that the geographical effects of zonality or azonality are several orders of magnitude higher than the potential of the anthropogenic factor [14].

One of the main factors in the ineffectiveness of reclamation measures is the lack of necessary funds, as a result of which large areas of disturbed land remain uncultivated to this day. The question arises about the development of alternative measures to optimize the functioning of mining landscapes and management of landscape-forming processes that develop within them.

Based on landscape research during 2015–2019, new approaches to optimizing processes and phenomena in mining landscapes, as well as measures to minimize the consequences of their development in order to rationally use mining landscapes have been proved.

The following points have been defined:

• taking into account the variety of adverse processes and phenomena, stages of their development for each mining landscape it is necessary to develop individual (optimal) micro-projects of rational use, restoration, destruction or protection;

• when developing measures for the optimization and functioning of mining landscapes, it is necessary to take into account the specifics of the development of adverse processes as leading landscape-forming factors;

• when developing measures to manage adverse processes and phenomena should take into account the speed of their development, which is instantaneous in relation to geological time, as well as the fact that these processes are factors in the development of dangerous catastrophic phenomena and emergencies.

Revitalization is a more important measure for optimizing mining landscapes.

The main tasks of revitalization are socialization of space; formation of elements of social infrastructure that regulate recreation and tourism; ensuring the development of production; improving the ecological condition of mining landscapes. The choice of the option of revitalization of mining landscapes depends on the complexity of their structure, the intensity of destructive processes and the amount of project funding.

Conclusions

The study of landscapes of zones of technogenesis in order to optimize their functioning and minimize the impact of processes developing within them is an important area of modern landscape science. Carrying out such research from the standpoint of anthropogenic landscape has a number of advantages, including understanding the anthropogenic landscape, especially mining as a landscape formed by the interaction of technology and nature, perception of the landscape as a holistic role and phenomena, in the development of which the leading role is played by landscape-forming processes and phenomena.

During the 1880s and 2019s, the landscape complexes of Kryvbas underwent significant changes. The biggest changes occurred as a result of iron ore mining and storage of industrial waste. In particular, the northern steppe landscapes, the Saksagan and Ingulets rivers were completely destroyed along the iron ore deposits of Kryvyi Rih structure. Instead, anthropogenic landscapes were formed and are developing, which today are leading in the landscape structure of Kryvbas.

When substantiating measures for optimization and management of adverse processes and phenomena in mining landscapes, it is necessary to take into account the specifics of their functioning as leading landscape-forming factors, as well as factors of dangerous situations. Appropriate and promising areas are the creation of a single system of anthropogenic protected areas (lithological, hydrological, phytological, cultural and historical) objects, the inclusion of mining landscapes in the ecological network, the creation of a regional integrated monitoring system. The proposed measures are aimed at minimizing the impact of the development of adverse processes and phenomena in areas of technogenesis on the environment.

Conflict of interest

The author state that there is no conflict of interest in the publication of this manuscript. In addition, the author fully adhered to ethical standards, including plagiarism, data falsification, and double publication.

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