UDC 622.882:622.884 DOI: https://doi.org/10.15407/geotm2021.159.096

THE PROCEDURE FOR SELECTING THE OPTIMAL DIRECTION OF USE OF DISTURBED AND TECHNOGENIC ENVIRONMENTS

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ПОРЯДОК ВИБОРУ ОПТИМАЛЬНОГО НАПРЯМКУ ВИКОРИСТАННЯ ПОРУШЕНИХ ТА ТЕХНОГЕННИХ СЕРЕДОВИЩ

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ПОРЯДОК ВЫБОРА ОПТИМАЛЬНОГО НАПРАВЛЕНИЯ ИСПОЛЬЗОВАНИЯ НАРУШЕННЫХ И ТЕХНОГЕННЫХ СРЕД

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Abstract. In the process of open-pit mining, excavations of various sizes are formed on the earth surface: from 1.5 to 8 kilometers long, from 0.4 to 1.5-2.0 km wide. At the same time, agricultural land is very often used for civil construction, as well as for the creation of industrial facilities. This leads to a reduction in land for food production. This problem is especially acute in countries with a rapidly growing population (for example, China) or with an intensively developed mining industry, where lands are significantly disturbed with the formation of technogenic and disturbed geological environments (Ukraine). In this regard, the direction of using the spaces of depleted quarries to create cities, industrial and economic, tourist, and recreational complexes is widely developing in the world.

The implemented and proposed in the world practice options for the use of such technogenic and disturbed environments were analyzed. It is shown that the worked-out spaces of mines and quarries can be used for the construction of hotels, residential complexes, cities, industrial enterprises of various industries, power plants, museums, sports complexes and parks.

Attention is focused on the presence of social, geomechanical, environmental and other factors, which are necessary to take into account when making a decision on the further use of a technogenic or disturbed environment. To take into account the influence of various factors through a comparison of existing indicators (the potential of the territory) with indicators of possible directions for the use of technogenic and disturbed environments is proposed. A phased analysis is proposed: indicative - to assess the safety of an object, analys of compliance of the object and the adjacent territory, area with the criteria that will determine the direction of its use, taxonomic analysis by the method of hierarchy analysis which evaluates the intensity of criteria, their weight, relative and absolute correction factors for each direction. This the most optimal direction is determines/

Keywords: use of disturbed territories, mining enterprises, criteria, territory potential, analysis, optimal direction.

Introduction. After the completion of the mineral deposit mining, quarries, excavation dumps and sludge accumulators are remain on the earth's surface. According to the projects, these facilities should be recultivated, but this has not happened in recent years. Thus, even after the closure, the mining company continues to have a negative impact on the environment.

The very closure of a mining enterprise (or a group of them) in the event that the enterprise was a city-forming one, leads to the emergence of a problematic and subsequently depressed region (district).

The Law of Ukraine "On Stimulating the Development of Regions" publishes a list of indicators for the identification of depressed areas (regions).

According to this law, a depressed territory is a region or its part (district, city of regional significance or several districts, cities of regional significance), the level of development of which according to the indicators defined by law is the lowest among the territories of the corresponding type.

There are depressed areas by areas of depression. Thus, depressed areas can include regions with social, economic or environmental negative conditions.

Depressed regions are characterized by the fact that with insufficient current socio-economic indicators, these regions belonged to the developed regions of the country in the past. As a rule, they have a fairly high level of production and technical potential, a significant part of industrial production in the structure of the economy, qualified personnel. But for various reasons (due to declining demand for basic products or declining competitiveness, depletion of minerals), such regions have lost their former economic importance. The duration and depth of the regional depression is determined by the composition of those industries in which the crisis has become the main cause of the spread of depression throughout the region's economy. On this basis, depressed regions can be divided into old-industrial, agro-industrial and mining. As a rule, the reason for the formation of depressed regions is the transformation of the country's economy during the transition phase.

Mining depressed regions usually occur in local excavating areas. The dominant problem of this group of depressed regions is the lack of opportunities to create alternative industries, the need to maintain the functioning of infrastructure, the organization of resettlement of the surplus population.

Depressed areas should be singled out on ecological grounds. As a rule, depressed ecological regions coincide in their territorial boundaries with depressed economic regions and old industrial areas. This is due to the fact that the lack of financial support for the economic development of such a region does not allow to allocate funds for environmental protection, the implementation of programs of environmental importance. In addition, the old industrial regions are characterized by a large number of operating and non-operating enterprises of mining, processing, metallurgy and chemical industries, which are the main source of environmental disturbance and pollution.

One of the main directions of development of such regions is the creation of new enterprises on the basis of disturbed mining and technogenic geological environments.

World experience in the use of man-made and mining-disrupted environments.

World experience in the use of technogenic and mining-disrupted environments

In China, where the main problem is not the presence of depressed regions, but the lack of agricultural land, seek to use rationally disturbed areas. This allows not to build up agricultural land.

An example of the use of disturbed environment in China is a 100 m deep granite quarry at the foot of Tianmenshan Mountain in Songjiang Province (Fig. 1).

Shimao Wonderland Intercontinental Hotel, designed by the British company Atkins. The main building is built into a 100-meter, steep quarry wall. Of the 19 floors of the hotel, two are located below the water level. Inside the quarry there is a swimming pool, equipped with sites for jumping and climbing. In addition, the complex includes an underwater restaurant overlooking the aquarium 10 meters deep, sports center, banquet hall, restaurants and bars, several conference rooms, hanging gardens, waterfall. Geothermal quarry heat is used for heating and electricity supply. Along the edge there are walking paths leading to the atrium, which is "inscribed" in the rock. The main concept was to integrate the hotel into the environment, not to fight it.

a)

b)

Figure 1 - The Depleted Granite Open-Cut Mine (a) and hotel built in it (b) [1]

In one of the depleted quarries (Lavender Pit Mine near Brisbane, Arizona), (fig.2 a), architect Matthew Fromboluti developed a project to create a residential complex called Above Below (fig. 2 b).

According to the architect's project, the old quarry should be covered with a roof with a large number (Fig. 2 d) of transparent elements for better natural lighting of the inner part of the underground city. Quarry ledges and their surface serve as walls for residential, office and infrastructure premises of the complex. Inside the quarry will also be located gardens, parks, kailyards, lake. This underground complex will receive electricity from solar panels and wind turbines installed above the ground (Fig. 2c).

This theoretical project proposes nesting a skyscraper inside the mine which will use its structure to support a dome covering the hole. The dome will act as a gigantic green roof, reclaiming the lost space for nature. The area beneath takes advantage of the unique conditions created by the dome to become a climate-controlled area for human use. Through use of many simple, passive systems, the entire complex is a sustainable, underground oasis in the desert, with the area above reclaimed for nature, and the space below a unique opportunity for human use (Fig.2).

In the city of Kajaran (Armenia), an eco-city has been designed at the site of the depleted quarry of the Zangezur copper-molybdenum plant (Fig. 3).

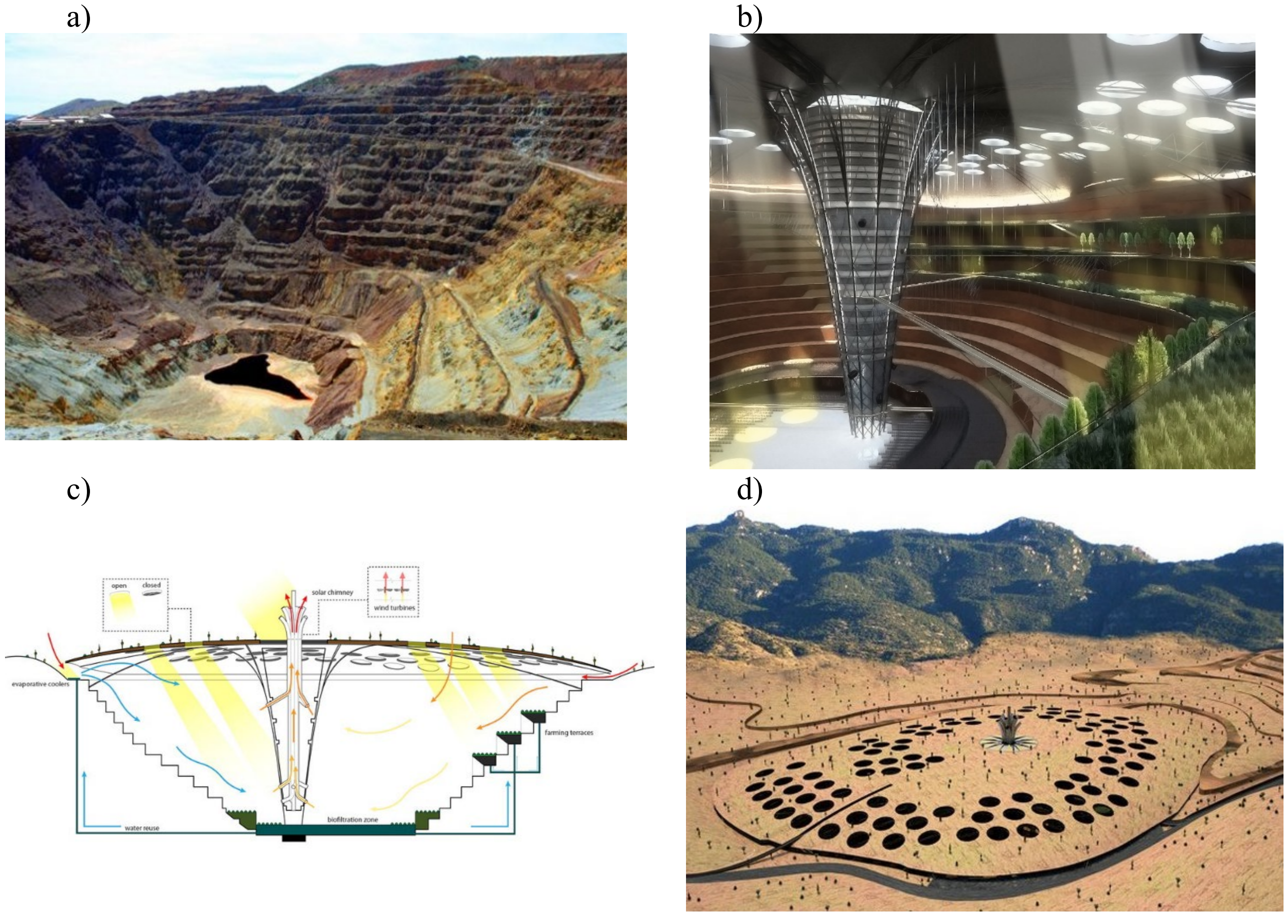

Figure 2 - Project of the residential complex Above Below [2]: a) the depleted quarry; b) the underground city; c) lighting and ventilation scheme; d) surface above the quarry

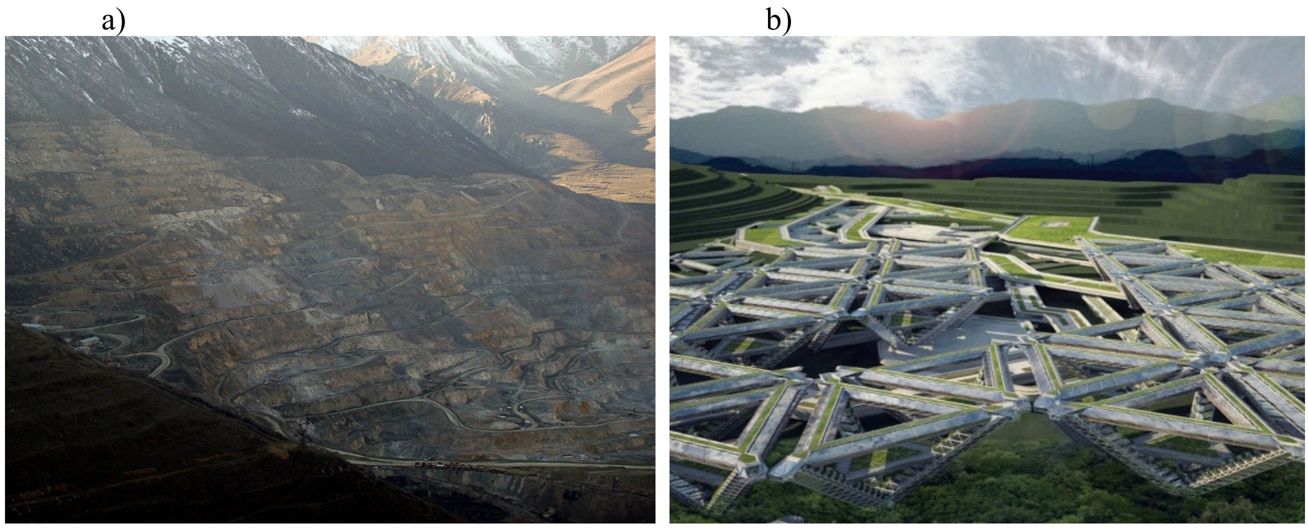

Figure 3 - The quarry of the Zangezur copper-molybdenum plant (a) and the eco-city project in it (b)

Similar projects have been created for other quarries in the world.

The staff of the IGTM NASU has developed a number of projects for the integrated use of environments disturbed by mining activities. Among them are the construction of a tourist and health-improving complex "Feodora" in the Kadykovsky quarry of the Balaklava mine administration [3], the creation of the Kozatska Slava complex during the recultivation of a failed crater near Zhovti Vody city [4], the creation of the village "Spring" and the TV tower "Youth" in Dnipro city, placement of a pumped-storage power plant in a quarry [5], construction of a mini-nuclear power plant in the Annovsky quarry [6].

In addition to quarries, mining disturbed environments include in mines.

In world practice, there are a fairly large number of examples of the use of mines after the completion of mining:

- The American biotechnology company Prairie Plant Systems, which is engaged in research in biopharmaceuticals and the agricultural sector, has placed its laboratories in one of the closed mines in Michigan. After the closure of the mine, all its internal infrastructure was preserved. The power of the preserved power supply system is enough for the uninterrupted operation of all components and elements of the laboratory. The climate system of the mine was almost ideally suited to maintain the desired temperature and humidity in the company's experimental fields;

- the C-Mine project was implemented in the Winterslag mine (Belgium) - lecture and concert halls, restaurants and cinemas operate on the territory. As well, part of the premises is leased by companies whose activities can be described by the term "creative economy". In the halls of the former mining enterprise, they develop mobile applications and games, create industrial design, and so on;

- The Rotherham Technology Park (Great Britain) opened in one of the abandoned mines. The launch of this project is one element of the plan to change the profile of the former mining region. Research offices of the world's leading corporations have opened in the technopark, including Boeing and Rolls Royce and a number of less famous companies. A wide range of technologies are being developed here - from military to medical;

- in Berkeley (West Virginia), in one of the closed mines, there is the most popular thematic museum among Americans dedicated to underground mining. The museum is located in a non-working mine, tourists can see all the possible surroundings and working conditions of the miners. Former miner Edsel Redden set up a fish farm at another abandoned mine in Berkeley, making use of the vast amount of water available at the site. Specialists from a local university found out that the water temperature is optimal for the life of trout and Arctic char, and also gave recommendations for water purification. Already a 1 year after the first launch of the fish, the number of farm workers numbered in the tens, and other entrepreneurs began to learn from the experience. The state authorities estimate the annual production of fish by the "mine method" at 45 thousand tons.

The issues of the use of man-made environments were also studied at the IGTM NASU. In article [7], when establishing the direction of the use of the technogenic environment, it was proposed to distinguish separately cleared and non-cleared objects. The main directions for the use of such territories are also given there.

Problems of development of disturbed and technogenic environments

Despite the attractiveness and the engineering originality of projects suggested within open-cut mining cities, it should be noted that there are some drawbacks in this sphere.

1. In order to obtain the final product of the valuable constituent from the mined mineral, the thousands or even tens of thousands of people are employed. At this, they are provided with housing in the settlements and the towns built for them, an appropriate infrastructure around the enterprise is also built. When the mining company is being closed, jobs are eliminated, people are deprived of their work and high earnings. Therefore, the main goal in developing the building project within the open-cut mine is neither in providing housings which are already built, nor in developing the entertainment areas, which are expedient to be built within the resort area, but in creating the project desirably requiring labor of high qualification in order to provide good employment for able population being dismissed.

2. During the development of steeply dipping deposits by an open method, mainly three objects are formed in the form of technogenic geological environments: a quarry, external dumps of open rocks and tailings (when enrichment is applied). Moreover, rock dumps and tailings, as a rule, occupy larger spaces than the quarry itself.

In addition, construction in the worked-out space of quarries has many features associated with the negative impact of the environment:

- deformation processes in the array;
- constant water inflow from aquifers of highly mineralized waters;
- uneven heating of the surface of a quarry, etc.

3. Moreover, from the geomechanical point of view, the open-cut mine of great depth and extent is a complex unbalanced system, in which there occurs various types of natural forces. These forces are manifested in the deformation processes within the array and develop in time with different rates. The stability of the open-pit sides and that of its benches are affected by the groundwater and the surface water as well as the direction of their flow.

4. Furthermore, when developing the project for a building construction or an object within the open-cut mine, one cannot neglect the fact of the microclimate forming within it: the absence of wind, uneven heating of open-pit sides by the sun, from which different temperatures are derived, uneven weathering due to the differences in the types of bare rocks in open-pit sides. The stable state of the sides and ledges of a quarry is influenced by underground and surface waters, the direction of their movement.

5. Important is such a natural factor to focus our attention on as groundwaters, which in abundance enter the open-cut mines. Their mineralization ranges from 30g/l to 90g/l. In most cases, they are different compositions and this difference is observed not only across the different deposits, but also throughout the aquifers within the open-cut mine. Thus, under conditions of the Kryvyi Rih iron ore deposits, there

occur radon waters, with the presence of radon gas in some mines and open-cut pits. Such types of waters could be utilized for medicinal purposes.

In this regard, it is necessary to take into account all available factors when deciding on the further use of a technogenic or disturbed environment.

Results

In general, the following areas of use of disturbed and technogenic environments can be distinguished: recreational; ecological; agricultural; forestry; water management; industrial; energetic.

These identify many options for the use of disturbed and technogenic environments. But not all of these options are specific to each individual object. For each of these areas there are the necessary conditions for their implementation (criteria).

Earlier, the criteria for choosing the direction of use of disturbed and technogenic environments were identified, which include geographical, engineering-geological, mining, technological, environmental, technical and economic [7].

Taking into account the idea of improving the socio-economic and environmental condition of the region of location of the object(s), it is necessary to take into account the existing potential of the territory.

First, it is suggested to choose possible directions of use (or recultivation) of the territory of the mining enterprise or its separate objects. For each of the directions it is needed to form a list of necessary resources (for example, approximate area, number of employees, water supply, etc.) and the most important criteria.

Such criteria include:

- general architectural - size in plan and depth, shape, stability of ledges, tiers, dams, natural and man-made objects nearby, etc .;
- infrastructure - the availability and condition of existing transport, energy, utilities, existing enterprises and their direction;
- resources - minerals, mining wastes that can be used, water, climate resources, the availability of able-bodied population;
- environmental - the state of pollution of the environment and the object itself (radiation pollution, pollution of soil, water and air resources);
- socio-economic - modern problems of the district (region), the cost of resources.

Next - to assess the potential of the territory (object) and its compliance with possible (selected) uses.

In the first stage, an indicative analysis is performed, which determines the condition and safety of the object.

In the second stage, the analysis of compliance of the object and the surrounding area, the area with the criteria that will determine the direction of its use.

The next step is taxonomic analysis. In this case, since there are many different criteria, it is proposed to perform this analysis by the method of analysis of hierarchies [8]. In this method, the weight is determined for each of the parameters.

The principle of the method is as follows: a comparison of the studied criteria in pairs in relation to their influence ("weight" or "intensity") on their common characteristics, and the results are entered into the matrix of paired comparisons, where ($A_1, A_2, \ldots, A_n$) the main factors.

If we denote the fraction of the factor A_i by w_i, t hen the element of the matrix $a_{ij} = (w_i) / W_j$, then, thus, in this embodiment of the method of pairwise comparisons, it is determined not by the magnitude of the differences in the values of factors. It is obvious that $a_{ij} = 1 / a_{ji}$. Therefore, the matrix of paired comparisons in this case is a positively defined, inversely symmetric matrix having a rank of 1.

Carrying out pairwise comparison of factors $A_1, A_2, \ldots, A_n$ the table of pairwise comparisons is filled. If $w_1, w_2, \ldots, w_n$ are unknown in advance, then pairwise comparisons of elements are made using subjective judgments, numerically evaluated on a scale, and then the problem of finding the component w is solved. In this formulation, the problem of solving the problem is to find the vector ($w_1, w_2, \ldots, w_n$). The definition of the vector w is as follows: for each criterion is determined by the "weight" of formula (1)

$$W_j' = \left(\prod a_{ij}\right)^{\frac{1}{n}}, \tag{1}$$

where W_j' – the weight of the criterion; a_{ij} - the importance of the criterion; n - is the number of criteria.

Then all a_i are normalized so that their sum is equal to 1. To do this, use formula (2)

$$\overline{W_j'} = \frac{W_j'}{\sum_{j=1}^{n} W_j''}, \tag{2}$$

as a result we obtain the desired vector w.

To conduct subjective pairwise comparisons of Thomas L. Saati [8], a scale of relative importance was developed (Table 1).

Table 1 - Scale of relative importance

Intensity of relative importance	Definition	Explanation
1	Equal importance	Equal contribution of the two species to the goal
2	Moderate advantage of one over the other	Experience and judgment give a slight advantage to one species over another
4	Significant or strong advantage	Experience and judgment give a strong advantage to one species over another
6	A significant advantage	One of the species is given such a strong advantage that it becomes almost significant
8	Very strong advantage	The obvious advantage of one species over another is confirmed most strongly
3,5,7	Intermediate decisions between two adjacent judgments	Used in a compromise case

On the basis of paired compare matrix (table 2).

Table 2 - Matrix of paired comparisons

	1	2	3	4	j	…	n	W_i'	$\overline{W_j'}$
1	a_{11}	a_{12}	a_{13}	a_{14}	a_{1j}		a_{1n}	W_1'	$\overline{W_1'}$
2	a_{21}	a_{22}	a_{23}	a_{24}	a_{2j}		a_{2n}	W_2'	$\overline{W_2'}$
3	a_{31}	a_{32}	a_{33}	a_{34}	a_{3j}		a_{3n}	W_3'	$\overline{W_3'}$
4	a_{41}	a_{42}	a_{43}	a_{44}	a_{4j}		a_{4n}	W_4'	$\overline{W_4'}$
j	a_{j1}	a_{j2}	a_{j3}	a_{j4}	a_{jj}		a_{jn}	W_j'	$\overline{W_j'}$
n	a_{n1}	a_{n2}	a_{n3}	a_{n4}	a_{n5}		a_{nn}	W_n'	$\overline{W_n'}$
								$\Sigma W_i'$	1,000

Based on the data of the matrix of paired comparisons, the "weight" or "intensity" of the impact of each analyzed criterion on the overall characteristics is determined.

At the next stage, the intensity of the criteria in the characteristics of each of the areas is expertly compared with a predetermined scale.

We take the intensity of the parameters available on the object as an average value, other coefficients may be greater or less, ie better or worse. The scale of intensity is as follows

$$1 \Leftarrow 2 \Leftarrow \overleftrightarrow{3} \Rightarrow 4 \Rightarrow 5,$$

where 1 - the parameters of the strap are much inferior to the parameters of the object; 2 - significant advantage of the object parameter over the direction parameter; 3 - direction parameters are identical to the parameters of the object; 4 - significant advantage of the direction parameter over the object parameter; 5 - very strong advantage of the direction parameter over the object parameter.

The results of the analysis are entered in table. 3.

Table 3 - Scale of intensity of parameters in the general characteristics (example)

Parameter, criterion	Direction 1	Direction 2	Direction …	Direction n	Object
Criterion 1	2	2	3	1	3
Criterion 2	3	3	4	5	3
Criterion 3	4	3	2	1	3
…..					3
Criterion n	5	5	4	2	3

Using the intensity indicators of parameter *I* and its "weight", the correction factors are calculated for each direction by multiplying the weight of criterion *W* by the intensity number *I*. Next, determine the relative correction factors as the arithmetic mean between the calculated coefficients of each direction.

The correction factor and the relative correction factor are also determined for the object. Absolute correction factors are defined as the ratio of the relative correction factor of each direction to the relative correction factor of the object.

After calculating the absolute correction factors, the most optimal option (direction) is determined.

Conclusions.

To prevent the formation of problematic and depressed areas and regions during the closure of mining enterprises, it is proposed to use their facilities to create new enterprises.

The use of quarries and mines, surfaces of dumps and sludge storages for the creation of industrial, economic, communal or entertainment complexes will reduce the man-made load and improve the environmental situation in the area (region), improve the socio-economic situation of the area (region) by creating new workers places, production of marketable products, and hence the payment of taxes to local budgets, will promote the development of infrastructure and more.

It is proposed to choose the direction of use of disturbed and technogenic geological environments in several stages. At the last stage, it is proposed to compare the selected options by the method of hierarchy analysis.

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Анотація. У процесі видобутку з корисними копалинами відкритим способом поверхні землі утворюються виїмки різних розмірів: довжиною від 1,5 до 8 кілометрів, шириною від 0,4 до 1,5 -2,0 км. У той самий час під будівництво, і навіть створення промислових об'єктів використовують землі часто сільськогосподарського призначення. Це призводить до скорочення земель для продовольства. Особливо гостро стоїть ця проблема у країнах із швидко зростаючою кількістю населення (наприклад, Китай) або з інтенсивно розвиненою гірничодобувною галуззю, де суттєво порушено землі з утворенням техногенних та порушених геологічних середовищ (Україна). У цьому світі широко розвивається напрям з використанню просторів відпрацьованих кар'єрів до створення у яких міст, промислово-господарських, туристичних, оздоровчих комплексів.

У статті проаналізовано реалізовані та запропоновані у світовій практиці варіанти використання таких техногенних та порушених середовищ. Показано, що відпрацьовані простори шахт та кар'єрів можуть використовуватись для будівництва в них готелів, житлових комплексів, міст, промислових підприємств різних галузей, електростанцій, музеїв, спортивних комплексів та парків.

Акцентовано увагу на наявності соціальних, геомеханічних, екологічних та ін. факторів, облік яких є необхідним при прийнятті рішення про подальше використання техногенного або порушеного середовища. Запропоновано облік впливу різних факторів проводити через порівняння існуючих показників (потенціал території) із показниками можливих напрямів використання техногенних та порушених середовищ. Запропоновано поетапний аналіз: індикативний – для оцінки безпеки об'єкта, аналіз відповідності об'єкту та прилеглої території, району критеріям, що визначають напрямок його використання, таксономічний аналіз методом аналізу ієрархій, при якому оцінюється інтенсивність критеріїв, їх вага, відносні та абсолютні поправочні коефіцієнти по кожному з напрямків. Таким чином визначається найбільш оптимальний варіант (напрямок).

Ключові слова: використання порушених територій, гірничодобувні підприємства, критерії, потенціал території, аналіз, оптимальний напрямок.

Аннотация. В процессе добычи полезных ископаемых открытым способом на поверхности земли образуются выемки различных размеров: длиной от 1,5 до 8 километров, шириной от 0,4 до 1,5 -2,0 км. В то же время под гражданское строительство, а также для создания промышленных объектов используют земли очень часто сельскохозяйственного назначения. Это приводит к сокращению земель для производства продовольствия. Особенно остро стоит эта проблема в странах с быстро растущим количеством населения (например, Китай) или с интенсивно развитой горнодобывающей отраслью, где существенно нарушены земли с образованием техногенных и нарушенных геологических сред (Украина). В этой связи в мире широко развивается направление по использованию пространств отработанных карьеров для создания в них городов, промышленно-хозяйственных, туристических, оздоровительных комплексов.

В статье проанализированы осуществленные и предлагаемые в мировой практике варианты использования таких техногенных и нарушенных сред. Показано, что отработанные пространства шахт и карьеров могут использоваться для строительства в них отелей, жилых комплексов, городов, промышленных предприятий разных отраслей, электростанций, музеев, спортивных комплексов и парков.

Акцентировано внимание на наличии социальных, геомеханических, экологических и пр. факторов, учет которых является необходимым при принятии решения о дальнейшем использовании техногенной или нарушенной среды. Предложено учет влияния различных факторов проводить через сравнение существующих показателей (потенциал территории) с показателями возможных направлений использования техногенных и нарушенных сред. Предложен поэтапный анализ: индикативный – для оценки безопасности объекта, анализ соответствия объекта и прилегающей территории, района критериям, определяющим направление его использования, таксономический анализ методом анализа иерархий, при котором оценивается интенсивность критериев, их вес, относительные и абсолютные поправочные коэффициенты по каждому из направлений. Таким образом определяется наиболее оптимальный вариант (направление).

Ключевые слова: использование нарушенных территорий, горнодобывающие предприятия, критерии, потенциал территории, анализ, оптимальное направление.

The manuscript was submitted 11.08.2021