Chapter 24
Character and Scale of Environmental Disturbances Resulting from Mining in the Kursk Magnetic Anomaly

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24.1 Introduction

In the early 21st century the geoecological situation in the region of the Kursk Magnetic Anomaly (KMA) reached a threatening state. According to the scale used by the Russia's Ministry on Emergency Situations, the KMA zone is currently classified as a fourth-ranked area of ecological disaster. It means that sustainable steps are necessary in order to improve the current environmental situation.

According to available statistics, more than 40% of lands in the KMA are disturbed at present. The quality of underground and surface waters near large-scale mining facilities is close to critical. The drinking water shortage amounts to 6,000 m^3/day. More than 1,300 km^2 (498 mi^2) of the KMA area are affected by irregularities in water balance. The zone of soil degradation in the KMA region exceeds 1,250 km^2 (478 mi^2). Soil erosion has also reached a significant scale (more than 30% of the total area of the KMA) resulting in the annual fall in fertility of up to 1 ton/ha. What is especially important is that the health of the able-bodied population is affected by the ecological situation brought on by the region's iron ore mining.

The region of the Kursk Magnetic Anomaly is 850 km (528 mi) long and 200 km (124 mi) wide; it is located in 9 administrative *rayons* (districts) of the Russian Federation. There are 18 existing and more than 200 explored iron ore deposits in the KMA. It contains 60% of Russia's iron ore reserves and 20% of the entire world. Exports are mostly to European countries (Czech Republic, Poland, and Slovakia); their combined total was 16 million tons. One million tons were sent to Romania in the first ten months of 2008, the same amount to Italy. Thus, the KMA zone can be considered as being fundamental to the Russian Federation' economy and security, especially in terms of minerals and raw materials.

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Taking into consideration the fact that Russia's economic policy emphasizes the mining industry playing a significant role in meeting the material needs of population, it is expected that the volume of extraction and processing of mineral raw materials will increase. At the same time there is the threat of further environmental degradation in the KMA region. Improving the ecological situation in the region could be realized by implementing urgent measures aimed at preventing furher environmental degradation. However, environmental protection actions do not improve the ecological situation automatically because of the lack of understanding of the complexities involved in the degradation of the environment.

Obviously, the development of approaches and methodology to assess the human-caused impacts in the areas of concentration of the mining complex facilities is becoming a major concern in Russia. The government is concerned about the ecological situations in areas where there are megaengineering complexes. Russian researchers, in particular those who are working in environmental and engineering spheres, are entrusted with developing a methodology that aims to decrease the human-caused impacts in areas of these large and complex operations.

24.2 The Theoretical Basis for a Complex Geoecological Assesment of the KMA

The iron ore industry stimulates economic development in Russia thanks to the operations of large mining complex in the European part of the country. These are definitely examples of megaengineering complexes.

The entire mining and smelting complex I discuss in this chapter is concentrated within the confines of the KMA region. It includes extraction facilities, concentration facilities (crushing-and-sorting plants and concentrating mills), and processing facilities. In addition, metallurgical lime, granulated and fine-dispersed chalk, sand for construction, moulding and glass production purposes, and suspensions for pellet processing before iron making are also produced in the region. Many of the local industrial plants also contribute to the environmental pollution in the KMA region.

The KMA mining complex is based on the largest and workable Lebedinskoye, Korobkovskoye, and Gostishchevskoye iron ore deposits in Russia. The Lebedinskoye deposit is located in the Starooskol'skiy *rayon* (district) of the Belgorodskaya *oblast'* (province). The extraction of ferruginous quartzites at the Lebedinskoye deposit is currently taking place at a high level. The Gubkin thermal power plant, the Oskol'skiy electrometallurgical integrated works, the Oskol'skiy cement plant, and the Lebedinskiy mining complex are also related to this deposit. The iron ore is extracted using opencast methods as the ore body occurs near the earth's surface (Fig. 24.1).

Such mining methods lead to the disturbance of surrounding lands, the inundation and deformation of rock layers, and radio-geochemical pollution of the air, soil, and water. There is also much dust pollution caused by the accumulation of heavy metals in the soils.

Fig. 24.1 The Lebedinskoye iron ore deposit

The Korobkovskoye deposit is situated in the Gubkinskiy *rayon* (district). This deposit forms a common ore field with the Lebedinskoye deposit. It was on this deposit that the underground mine «Gubkin» and the first integrated underground mining works «KMA-ruda» were constructed. This deposit was developed using underground mining methods. In terms of economic parameters, underground mining is less profitable than opencast methods. It should be noted that the prices for the production of the «KMA-ruda» exceed those of the Lebedinskiy mining complex by 22–25%. The development of the Korobkovskoye deposit entails operating in areas of subsurface voids, groundwater shortage, deformation of rocks, sagging, and cones of depression. The Gostishchevskoye iron ore deposit is situated in the Yakovlevskiy *rayon* (district). Beginning in 2010 this deposit will be developed using hydraulic borehole mining methods. This technique of extraction is done by first drilling a hole into the surface and injecting a working substance into the hold to force materials out. The working substance destroys the main iron ore body and crushes the iron ore into a pulp which is delivered to the surface through a tube. The method is cheaper than the traditional methods of extraction and does not cause ecological disasters. Nevertheless, the development in the Gostishchevskoye deposit contributes to the disturbance of underground hydrogeological conditions. Developing the existing and prospective iron deposits in KMA have major negative impacts on the environment. The nature of the damage depends on the techniques and methods used.

The Russian government and managers of industrial enterprises pay special attention to territories with unfavorable environmental conditions and support research into studies that examine the ecological situations in areas such as the KMA region.

The Russian Academy of Sciences (Institute of Geography), applied science centers (Scientific Research Institute of the KMA, Eco-Resource, Kursk-Geology, etc.), and environmentally-oriented private research companies (Russian innovative fuel-energy complex, industrial safety consulting groups, etc.) are among the leading Russia's institutions carrying out research in the region on the impact of the mining complex. The activity of these institutions is aimed at developing a system of methods and algorithms that measure the human-caused impacts. The methods considered can be divided into the two major categories: (1) those that assess the human-caused impacts on various components of natural landscapes (air, water, soil, biota, and parent rock, and (2) those that assess each component of the ecosystem affects the population.

The methods assessing human-caused influences are described in the scientific works of leading Russian researchers: S. A. Malyshev and M. M. Yakovchuk (2004), A. B. Miroshnikov (2001), N. V. Sorokovikona (1992), B. A. Simkin, B. T. Bebchuk, and A. V. Khokhryakov (1989). These studies yield significant scientific and practical results used in the course of solving of problems related to the maintenance of environmental safety while also studying the atmosphere, land, surface and subsurface waters. The scientific and practical studies by B. A. Ivanov (1989), and A. V. Khokhryakov (1988) are specifically devoted to solving the basic problems of environmental safety in territories deal with mining. They consider in detail the different forms of environmental disturbances as they are related to the pollution caused by mining. These methods are presented in the works of Russian scholars N. A. Solntsev (1984), M. A. Glazovskaya (1988), V. M. Kotlyakov, K. S. Losev, and I. A. Suetova (1995).

Many environmental problems are connected with the interaction of «population-facilities-nature». The theoretical and methodological bases of such interrelationships, the algorithm, and the typology and methods used in a complex assessment of each ecosystem component are considered in detail in the work by A. M. Grin and N. N. Klyuyev (1988), L. I. Mukhina and T. G. Runova (1980), and B. I. Kochurov (1997). Special attention in these works is paid to the geoecological analysis of geographical systems. Russian scientist V. I. Papichev (2005) developed a methodology for use in studying a complex engineering-ecological assessment that also measured the impacts of a mining complex on the environment. Another noted Russian researcher A. V. Khokhryakov (1988) suggested that the mining complex should be regarded as an integrated natural and human-related system.

In practice, there are various methods and approaches that one can use. However, in studies done to prevent environmental risk in areas and where the entire mining operation and smelting cycle are concentrated, a complex comprehensive analysis is most efficient and useful. Research into the human-caused impacts on mining territories represents a new step in the sphere of studying and analyzing mining's impact on the environment.

This study contributes to this on-going research in two ways: (1) the development of an algorithm that assesses the complex geoecological assessment at specific local administrative units and (2) the use of an algorithm to assess the impact of Russia's largest iron ore mining region on surrounding territory.

24.3 Methodology

As noted above, a wide range of research methodologies exist that one can use to focus on ecological situations. But, most of them do not have a complex character. The proposed methodology emphasizes the analysis of the interactions between all landscape components and the impacts of these on the population. The basic approach utilizes GIS (geographical information systems) in the analysis (Fig. 24.2).

A GIS analysis uses the following methods: comparative-geographical, statistical, cartographical, and geoinformation. The first stage involves selecting the *scale of analysis*. The most appropriate scale for this research is 1:200,000. This scale ensures a visibility of these assessments, matches the quality of initial information, and is suitable for the research at a level of such administrative units as the Starooskol'skiy, Gubkinskiy and Yakovlevskiy *rayons* (districts).

The *introduction of criteria* directly or indirectly relates to the geoecological and medical-ecological conditions of territories that are studied in the second stage. In order to assess the impact of mining on the territory and population, representative criteria and parameters are chosen and are classified using the 5-point scale adopted by the Russia's Ministry on Emergency Situations. The *choice of criteria and parameters* is determined by current geoecological and medical-ecological conditions of areas analyzed. Negative natural factors are emphasized, such as karst, suffosion, erosion, deflation, landslide processes, occurrence of gullies and rocks subject to washout. Air pollution, soil degradation, the pollution of surface and underground waters, and deforestation are also included. In addition, specific diseases associated with the population in the KMA region are considered (Nekrich, 2006). As mentioned above, the data characterizing the ecological situation are classified using the 5-points scale: satisfactory, stress-like, critical, crisis-like, and catastrophic (Table 24.1).

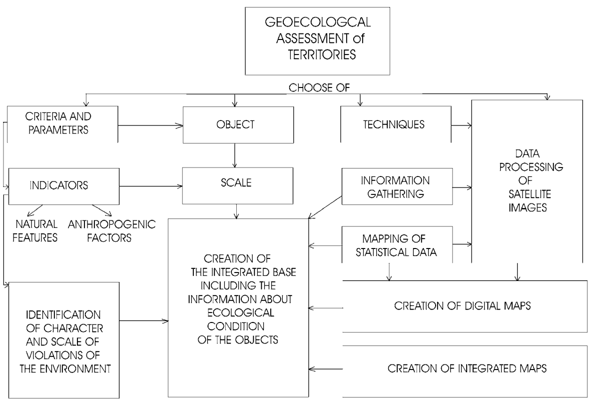

Fig. 24.2 The algorithm used to assess the complex geoecological assessment of areas at the level of administrative units

Table 24.1 Criteria and parameters used in the complex assessment of human-caused impacts on the areas of iron ore extraction

Criteria	Categories of ecological disaster areas according to the scale of Russia's ministry on emergency situations				
	Satisfactory	Stress-like	Critical	Crisis-like	Catastrophic
Natural features					
Karst and suffosion processes (occurrences per 100 km^2)	–	–	5–10	10–15	>15
Percentage of eroded lands (%)	< 20	20–40	40–60	60–80	>80
Deflation processes (mean annual amount of blown soils, ton/ha)	< 5	5–10	10–20	20–50	>50
Human-Caused Impacts					
1. Water pollution					
Wastewater amount (% of mean regional values)	<10	11–20	21–30	–	–
Water pollution					
(a) water pollution index	<1.0	1.0–3.9	4.0–6.0	6.1–10.0	more than 10.0
(b) indicator of chemical pollution:					
– for substances of the 1st–2nd degree of risk	<10	<20	21–35	36–80	80
– for substances of the 3rd–4th degree of risk	<10	<50	50–100	100–500	500
Changes of aquifer level (m)	< 0.5	0.5–1.0	1.1–2.0	2.1–5.0	> 5.0
2. Soil pollution					
Chemical pollution of soils with heavy metals (value of the aggregate index Zc),	< 16.0	16.1–24.0	24.1–33	33.1–128.0	> 128.0
Indicator of chemical pollution:					
– for substances of the 1st–2nd degree of risk	<1.0	0.1–2.0	2.1–3.0	3.1–5.0	>5.0
– for substances of the 3rd–4th degree of risk		1.1–5.0	5.1–10.0	10.1–20.0	> 20.0
3. Air pollution					
Pollution caused by enterprises of the mining complex (tenfold exceeding of norms for SO_2, CO, NO_x, CH_x, Pb, Cr, Zn)	in 1–2 times	2–5	5–10	10–50	50–100

Table 24.1 (continued)

Criteria	Categories of ecological disaster areas according to the scale of Russia's ministry on emergency situations				
	Satisfactory	Stress-like	Critical	Crisis-like	Catastrophic
Air pollution index	<5	6–15	16–50	51–100	more than 100
4. Deformation of rocks					
Deposit depletion (%)	<10	10–30	30–50	50–70	more than 70
5. Fragmentation of land cover					
Degree of projective cover (%)	<5	5–20	20–40	40–50	more than 50
Amount of woodland (%)	<10	10–25	25–50	50–80	more than 90
Medical-ecological features					
1. Medical-demographic rates					
Mortality:					
(a) total mortality	no increase	(a) and (b) cause-and-effect relation	(a) and (b) cause-and-effect relation	2.1–2.5	more than 2.5
(b) perinatal mortality				1.6–2.0	2.0
(c) infantile mortality (<1 year)		(c) <1.2	c) 1.3–1.5	1.6–2.0	2.0
(d) child mortality		(d) <1.2	d) 1.3–1.5	1.6–2.0	2.0
Life expectancy:					
(a) men					
– birth statistics	no increase	cause-and-effect relation	2.8	3.2	3.6
–up to 15 years old			3.9	3.4	4.0
– 35			2.0	2.5	3.0
– 65			1.8	2.0	2.3

Table 24.1 (continued)

Criteria	Categories of ecological disaster areas according to the scale of Russia's ministry on emergency situations				
	Satisfactory	Stress-like	Critical	Crisis-like	Catastrophic
(b) Women					
– birth statistics			2.0	2.6	3.5
– <15 years			2.0	2.5	2.9
– < 35			2.0	2.5	2.6
– up to 65			1.5	1.8	1.9
2. Occupational morbidity (for people working in the mining industry)					
Class and nosological appearance of ecologically conditioned diseases	no increase	cause-and-effect relation	2.1–2.5	2.6–3.5	> than 3.5
3. Medical-genetic and immunological indexes (increase)					
Congenital malformation rate	indexes are close to background value	up to 1.2	1.3–1.5	1.6–2.0	> than 2.0

A *satisfactory* situation in the region exists when the landscape features are not modified due to direct or indirect human-induced factors, that is, the state of the environment is not hazardous to the health. A *stress-like* situations are observed when insignificant spatial and temporal changes in landscapes occur, including changes affecting the resource-reproducing properties or the structure of the landscapes. Negative changes of some components of the landscapes lead to the degradation of an insignificant part of natural resources. *Critical* situations are associated with significant levels of environmental pollution, essential changes in landscapes features, a major threat to the natural resource base (including the gene pool), unique natural features in the region, and the health of the population. In these situations the human-caused impacts exceed the normal levelss. A *crisis-like* situation is characterized by significant changes in landscapes, the complete depletion of natural resources, and the deterioration of the health of the population. *Catastrophic* situations correspond to a very high degree with environmental degradation. The major attribute of this stage is the threat to life itself and a reduction of the gene pool. Table 24.1 lists some significant natural features of the KMS region and human-caused impacts on the environment and population. In general, this information allows one not only to assess the ecological situation, but also to identify the character and scale of environmental disturbances.

The third stage involves *the gathering of information*. Statistical data are derived from current publications of the State Committee on the Environment Conservation of the Belgorodskaya *oblast'* (province), the Committee on Land Resources and Land Management of the Belgorodskaya *oblast'* (province), the State Statistical Board of the Belgorodskaya *oblast'* (province), and Russia's Federal State Statistics Service (*Goskomstat*). Digital Globe results, provided by the Google Earth software are also used for the compilation of interactive maps. Field studies (sampling of water, soils, air, etc.) were additional and valuable sources of information.

The entire information about geoecological and medical-ecological conditions *is mapped* by using the ARC/INFO software, the program ArcView GIS (ESRI Inc.). The complex geoecological assessment of territories requires spatial data processing and the creation of integrated maps (land use, ecological situation, human-caused pressures, etc.).

The final stage of the algorithm involves *data processing and data extraction from the maps* which are compiled. In the course of this stage, the integrated base is created; it contains all initial quantitative and qualitative information and also provides for the input of new data. For example, the overlay of the land use map on the map of physical landscapes allows one to obtain information about human-caused impacts on the land itself as well as ecological problems.

24.4 Assessment of the Ecological Situation

The geoecological assessment consists of the following consecutive stages. The order is determined by the availability of information about the natural and economic state of the land, information about mining activities, and the methods used.

First, interpretations of satellite images and the processing of the statistical information about land use were performed. Linear features (watercourses, railways, and highways), natural lands (protected areas, pastures), arable lands, built-up areas, the objects of the mining complex were clearly identified in the images. These areas can be classified as spaces with different functions (agricultural, natural, mining, residential, etc.). All these groups or areas are rated in terms of their human impacts. This classification of the areas allows to assess the intensity of these impacts.

Because the resolution of the images is not sufficiently high, some objects are identified and included with other elements of landscapes. That is, indirect attributes revealing the presence or absence of objects are identified through the attributes of other objects or phenomena by directly interpreting their distinctive features (tones, colors, forms, sizes, locations, shadows, and specific patterns). The identification of indirect attributes also requires the processing of statistical and scientific textual information about the environmental condition and economic status of the territory.

The information allows us to prepare integrated maps. They contain thematic layers or cartographical images of present-day land use and natural-landscape differences in the territories. For example, the compilation of maps of environmental problems of areas is carried out through the integration of the maps of natural features, land use, human caused impacts, and negative problems (Fig. 24.3). These maps allow us to assess the lands unsuitable for agricultural use and help to identify the specific ecological features and conditions.

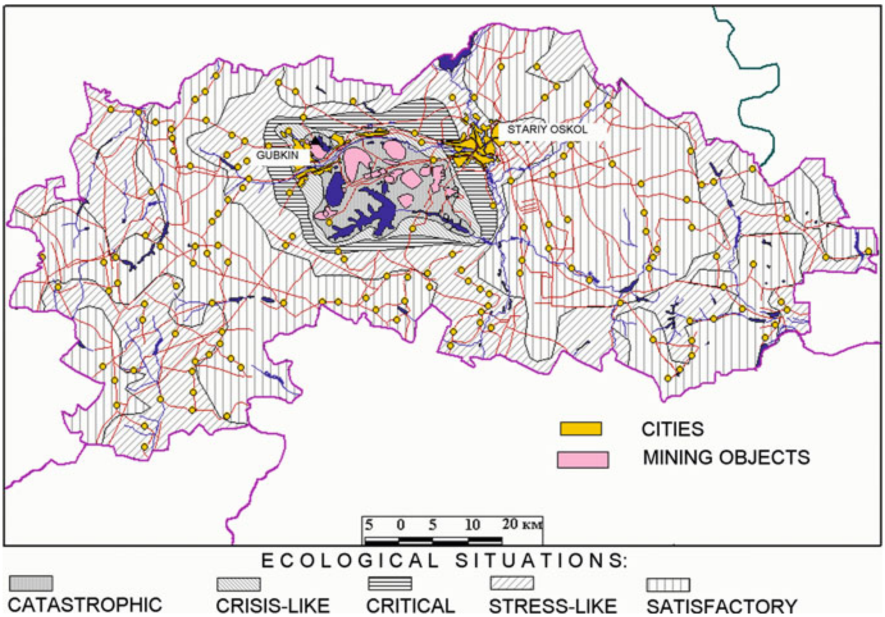

Fig. 24.3 The ecological situation in the Starooskol'skiy and Gubkinskiy *rayons* (districts)

The steps used in identifying the geoecological problems within the territories affected by mining activities and the determination of the spatial range of these problems can be accomplished through the digital cartographic syntheses of separate areas with various ecological problems. In practice, the compilation of maps displaying the ecological situations requires a consideration of significant (both natural and human-related) factors and regions where the environmental problems occur. Quantitative parameters also should be taken into account.

Combinations of environmental problems can be classified using the following ranks: satisfactory, stress-like, critical, crisis-like, and catastrophic. This ranking allows us to identify the parameters of the environmental disturbances shown in Table 24.1. The scales and intensities of the environmental disturbances and the determination of ecological problems caused by different mining methods (opencast, underground, and hydraulic borehole) are shown in Table 24.2.

The parameters specified in Table 24.1 are correlated with the data represented in Table 24.2. The correlations create the basis for the ecological maps of KMA areas show in Fig. 24.3.

24.5 Results

The areas of mining operations in the areas of the Lebedinskoye and Korobkovskoye and adjoining territories are associated with a “high” degree of human-caused impacts. The impacts on lands in the area of planned development of the Gostishchevskoye iron-ore deposit are usually classified as both “above average” and “low.” The lands with the “maximum” and “very high” degrees of impacts (6.7 and 10.3% of the *rayon* area respectively) refer to the sites of opencast and underground mining. The adjoining lands (more than 74% of the area) are involved in agricultural use are characterized as having a “high” degree of human-caused impacts. The lands with the “above average” degree of impacts (35.4%) are associated with projected mining areas.

The dominance of areas with the “high” degree of impacts are related to the intensive plowing of lands on slope surfaces. The areas of both the Lebedinskoye and Korobkovskoye deposits are characterized by a “high” degree of human-caused impacts (arable lands, disturbed lands, mining sites in the KMA complex, and transportation routes). The arable lands are located on slopes, terraces above the floodplain which are also subject to deflation as are sites near industrial complexes. Such arable sites results in soil degradation (erosion, chemical pollution) (Nekrich, 2007). Most lands within the area of the Gostishchevskoye deposit are characterized by “average” and “low” degrees of human impacts (cultivated hayfields, natural pastures and meadows, perennial plantations).

The ecological situation in the Starooskol’skiy and Gubkinskiy *rayons* (districts) can be classified as transition from stress-like (37%) to a satisfactory quality of the environment (27%). The areas of mining are in zones with catastrophic (15%) and crisis-like (9%) ecological situations.

Table 24.2 Assessment of the ecological situation in the areas of iron ore mining

Intensity of environmental disturbances	Combination of ecological situations leading to: Activating of negative environmental processes	Health hazard
Catastrophic	Rock dewatering, rock mass disturbance, formation of subsurface voids, rock deformation, landslides, mineral depletion, formation of gullies, occurrence of cones of depression, karst, suffosion, dewatering of soils, ground removal, humus decay, soil erosion, chemical pollution, changes of water level, projective cover fragmentation	Air pollution, bacterial pollution, industrial pollution, pollution by drilling and blasting operations, toxic pollution, chemical pollution
Crisis-like	Rock dewatering, occurrence of cones of depression, formation of gullies, karst, suffosion, dewatering of soils, ground removal, humus decay, soil erosion, changes of water level, partial projective cover fragmentation	Air pollution, industrial pollution, pollution by drilling and blasting operations, chemical pollution
Critical	Mineral depletion, formation of gullies, occurrence of cones of depression, karst, suffosion, dewatering of soils, ground removal, humus decay, soil erosion, chemical pollution, changes of water level, projective cover fragmentation	Industrial pollution, chemical pollution
Stress-like	Karst, piping, dewatering of soils, ground removal, humus decay, soil erosion, chemical pollution, changes of water level, projective cover fragmentation	Air pollution, chemical pollution
Satisfactory	Dewatering of soils, ground removal, humus decay, soil erosion, chemical pollution, changes of water level, projective cover fragmentation	air Pollution, water and soil pollution

The ecological situation in the Yakovlevskiy *rayon* (district) can also be classified as stress-like (39%) due to domination of arable lands in the structure of land use. The critical zone (24%) covers arable lands and territories which also include significant concentrations of settlements and transportation routes. The basic problems in this district are water quality degradation and air pollution.

24.6 Conclusions

The algorithm used to measure the complex geoecological assessment of territories is significant for others studying sites for mining development. The main objectives of this algorithm are to present the current geoecological situation and to prevent environmental risks. The GIS-based research carried out allows us to coordinate the works of experts from various environmental institutions and to assess objectively the scales of negative processes. In addition, the results presented could be useful to measure the stages of development aimed at environmental improvement. They could also contribute to solving environmental problems, that is, how to increase the volumes of iron ore extraction and raw materials processing while at the same time mitigating the contradictions between economic factors, the health of the population, and environmental conditions. The results also allow us to select the optimum mining technologies to develop the KMA region, to help improve the medical-demographic situation, and to favor investments aimed at the environment protection in the region. The information presented in the study can also be used to realize the objectives of federal target programs oriented to the implementation of environmentally safe technologies in the regions of mining activities.

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