References

1. Safronova O. S., Lamanova T. G., Sheremet N. V. The results of the study of natural regeneration of vegetation cover on overburden dumps in the Republic of Khakassia, which emerged in the 90-years of the twentieth century. *Ugol*. 2018. No. 7. pp. 68–77.
2. Kharionovsky A. A., Frank E. Ya. Validation of the technology of mine technical reclamation for the purpose of reforestation in the Krutokachinskiy ballast quarry. *Ugol*. 2018. No. 4. pp. 75–77.
3. Pesterev A. P., Vasilieva A. I., Safroneeva S. A., Sleptsova E. V. Alteration of the northern taiga ecosystems under open pit mining. *Gornyi Zhurnal*. 2019. No. 2. pp. 88–91. DOI: 10.17580/gzh.2019.02.18.
4. Krutskikh N. V. Assessment of nature transformation in the ining influence zone by earth remote sensing data. *Gornyi Zhurnal*. 2019. No. 3. pp. 88–93. DOI: 10.17580/gzh.2019.03.17.
5. Khairulina E. A., Kudryashova O. S., Novoselova L. V. Problems of potash tailings pile remediation. *Gornyi Zhurnal*. 2019. No. 5. pp. 90–94. DOI: 10.17580/gzh.2019.05.18.
6. Mesyats S. P., Novozhilova M. Yu., Rumyantseva N. S., Volkova E. Yu. Scientific substantiation of the natural ecosystems restoration disturbed during the development of georesources. *Gornyi Zhurnal*. 2019. No. 6. pp. 77–83. DOI: 10.17580/gzh.2019.06.11.
7. Shchadov I. M., Frank E. Ya. On the results and prospects of using ERS (Earth Remote PROBmG) resources when solving applied tasks of the coal mining industry in the global economic format. *Ugol*. 2018. No. 7. pp. 58–61.
8. Legostaeva Y. B., Ksenofontova M. I., Popov V. F. Geoecologic situation at site of drainage brine utilization during development of primary deposits in Yakutia. *Eurasian Mining*. 2019. No. 1. pp. 43–48. DOI: 10.17580/em.2019.01.11.
9. Strunk S., Houben B., Krudewig W. Controlling the Rhenish opencast mines during the transition of the energy industry. *World of Mining – Surface & Underground*. 2016. Vol. 68. No. 5. pp. 289–300.
10. Ohsowski B. M., Dunfield K., Klironomos J. N., Hart M. M. Plant response to biochar, compost, and mycorrhizal fungal amendments in post-mine sandpits. *Restoration Ecology*. 2018, Vol. 26. pp. 63–72.
11. Fernandes K., van der Heyde M., Bunce M., Dixon K., Harris R. J. DNA metabarcoding – new approach to fauna monitoring in mine site restoration. *Restoration Ecology*. 2018. Vol. 26(6). pp. 1098–1107.
12. Lanterman J., Goodell K. Bumble bee colony growth and reproduction on reclaimed surface coal mines. *Restoration Ecology*. 2018. Vol. 26(1). pp. 183–194.
13. Abdullah M. M., Feagin R. A., Musawi L., Whisenant S., Popescu S. The use of remote sensing to develop a site history for restoration planning in an arid landscape. *Restoration Ecology*. 2016. Vol. 24(1). pp. 91–99.
14. Eßer G., Janz S., Walther H. Promoting biodiversity in recultivating the rhenish lignite-mining area. *World of Mining – Surface and Underground*. 2017. Vol. 69(6). pp. 327–334.
15. Available at: http://www.google.com/earth/ (accessed: 10.03.2020).
16. Available at: http://gis-lab.info/qa/landsat-glovis.htm (accessed: 10.03.2020).

UDC 502:528.8

N. J. ADERO[1], *PhD Research Student, Mine Planning & Surveying*
C. DREBENSTEDT[1], *Professor, Doctor*
E. N. PROKOFEVA[2], *Associate Professor, Candidate of Engineering Sciences, eprokofyeva@hse.ru*
A. V. VOSTRIKOV[2], *Associate Professor, Candidate of Engineering Sciences*

[1] *Freiberg University of Mining and Technology, Freiberg, Germany*
[2] *National Research University Higher School of Economics, Moscow, Russia*

SPATIAL DATA AND TECHNOLOGIES FOR GEOMONITORING OF LAND USE UNDER ASPECT OF MINERAL RESOURCE SECTOR DEVELOPMENT

The main efforts of modern geoecology focus on various aspects of monitoring the state of the natural environment within the sphere of anthropogenic impacts on raw materials complexes and on determining the irreversible level of adverse impacts and consequences of natural disasters in the absence of effective tools and systems for early forecasting and detection of hazards and environmental risks (erosion, oil spills, oil and gas leaks and contamination of surface and groundwater, landslides, collapses, subsidence, mining, fire, among others). As a result, even with the highest methodological and technical level of modern research, there remains trivial conclusion on the need to protect nature. This leaves open the main question of effective methods of nature protection and the necessary changes in technologies and methods of data management.

The improvement of the methodological basis for the design of mining systems to achieve integrated development of subsoil is aimed at advancing the innovative energy and resource-saving geotechnologies, which ensure the required efficiency and safety of work, including early detection of potential hazards and risks. In this study, an integrated approach to the processing of remotely sensed data is being developed, which is envisaged to share the results of the measurements obtained in Russia and Kenya by various satellite-based technologies in both optical and radar bands.

Keywords: *mining industry, digital technologies, geoecology, geomonitoring, spatial data, geotechnology, subsoil use technologies, satellite images and aerial photographs, satellite data.*

DOI: *10.17580/em.2020.01.14*

Introduction

As is known, a comprehensive assessment of the level of environmental violations is based on visual and quantitative data, and dynamic modelling through an indicator of the severity of environmental situations, when a satisfactory situation, the performance characteristics of the natural potential of the territory is not violated, a conflict situation is characterized by low space and time changes in landscapes, including their areas and resources reproducing properties, that is, the ability to recover in the process of self-regulation or environmental measures, in a tense situation, there is a degradation of certain components of landscapes or natural resources, which in some cases leads to a deterioration of living conditions of the population. In turn, the critical situation is observed with more significant and poorly compensated environmental violations, the threat of depletion of natural resources, a steady increase in the number of diseases of the population due to the deterioration of living conditions, and the crisis environmental situation is already identified by very significant and almost non-compensable changes in the natural environment; the replacement of natural ecosystems with low-productive secondary systems; resource depletion and sharp deterioration of public health, requiring urgent measures. Finally, a catastrophic environmental situation means the irreversibility of changes in nature, the loss of natural resources, the threat to human life, the loss of the gene pool and unique natural objects. It can develop gradually, with increasing changes in nature as a result of multiple exceeds of the permissible limits of anthropogenic risks, or occur suddenly, in a major man-made accident or natural disaster of a destructive scale. The actual spatial localization of environmental problems and the overall assessment of their severity allows us to speak about the global scale of the developing environmental crisis – the solution of modern environmental problems requires joint efforts of all countries, members of the world community, the development of complex systems and tools for collecting and processing multi-format data to monitor the prerequisites of negative phenomena.

For example, in 1986, a joint scientific project between the USSR and Germany was implemented to organize satellite geomonitoring by means of multispectral video collection for the analysis of soil cover and lithosphere layer structure on the basis of photographic data of vegetation cover taking into account the dynamics of changes. Widespread use of satellite radar data began in 1991 with the launch of the ERS-1 satellite (European Space Agency) with a radar on board. The initial goal of launching this first civilian satellite radar of medium spatial resolution (20 m) was defined rather narrowly and was limited to maritime applications (monitoring of ice conditions, icebergs, shipping, currents, oil spills, etc.).

However, after the satellite has passed several full cycles of orbit repetition, it turned out that in addition to marine applications, this radar has a great potential for performing various tasks on land. The use of satellite images in conjunction with ground-based observations of natural-territorial complexes opens new opportunities for ecological research, allowing for environmental monitoring with the identification of its changes in time, to determine the nature of the pollution distribution under the influence of industrial objects on vast territories and map in different ecological situations between objects [1-9]. Combining technologies allows for gains over separate processing by increasing the amount of information received and the ability to obtain data.

Modern development strategies and geomonitoring tools

Remote sensing is also becoming increasingly important in mining and environmental research, thanks to a wide range of rapidly evolving technologies and techniques that generate big data in less time. Photogrammetry, GNSS, radar and a set of on-board scanning and monitoring sensors act as key systems, methods and tools. Mini, nano and microsatellites are among the modern Earth observation networks that are attracting increasing interest in the global community aimed at obtaining accurate spatial data to support integrated geospatial processes and sustainable solutions [10–15].

Advances in artificial intelligence and machine learning algorithms increase opportunities to study complex mining and environmental data and model scenarios to determine optimal options. In particular, this study is based on a model of Kenya ‘s recent case study on integrating geospatial modelling into systems dynamics. It examines and assesses the capabilities of mini and micro satellites to scale up and automate the results of optimal planning and monitoring of mining operations, subsoil use infrastructure and other spatial facilities.

Traditional geodetic and cartographic methods are too limited in spatial scale and temporal resolution to correspond to rapid spatial and temporal changes in the relationship between mining, the environment, and society. Therefore, new approaches and research innovations are needed that can provide high spatial and temporal resolution for geovisual and geomonitoring. For efficient and integrated monitoring of mining conditions, recommended new techniques should combine hybrid data from several sources, which are mainly derived from ground survey and remote sensing techniques. As global demand for minerals grows, so do global environmental concerns and risks associated with unsafe and unregulated mining. Recent trends indicate a rapid increase in mineral and metal consumption with increased industrialization. This was reflected in a significant 162% increase in iron and ferroalloy metal production between 2000 and 2016 (Reichl, Schatz & Zsak, 2018).

The subsoil is impacted adversely by the human activities carried out to meet the demands of civilization. Visualisation of precise and updated geodata on the environment is essential to making informed, inclusive, and timely decisions for enhanced safety. This study draws relevant examples from Kenya and Russia. The two countries represent different sociocultural, technological, economic, and demographic profiles. From Kenya, the paper presents a model for simulating environmental changes across the mineral belt of Taita Taveta as influenced by mining and other competing land-use sectors. Examples from Russia shed light on the challenges typical of the sociocultural, technological, economic, and demographic settings different from the mainly rural Kenyan situation.

Mining is a critical economic sector, but common in experience shows that unregulated mining activities conflict with, and adversely impact on, agriculture, water resources, ecology, and the social environment. Africa and Russia, both large and highly populated areas, share in this experience as well. The mining sector in Africa is young and rapidly growing, with a high proportion of artisanal miners who form part of the rapidly growing populations. Kenya’s coastal mineral belt of Taita Taveta is typical of the competing mining and non-mining drivers of environmental change in Africa, which interact in complex ways across space over time with divergent stakeholder interests [16–20].

Space images are the most important source of spatial information. Recently, however, aerial photography from

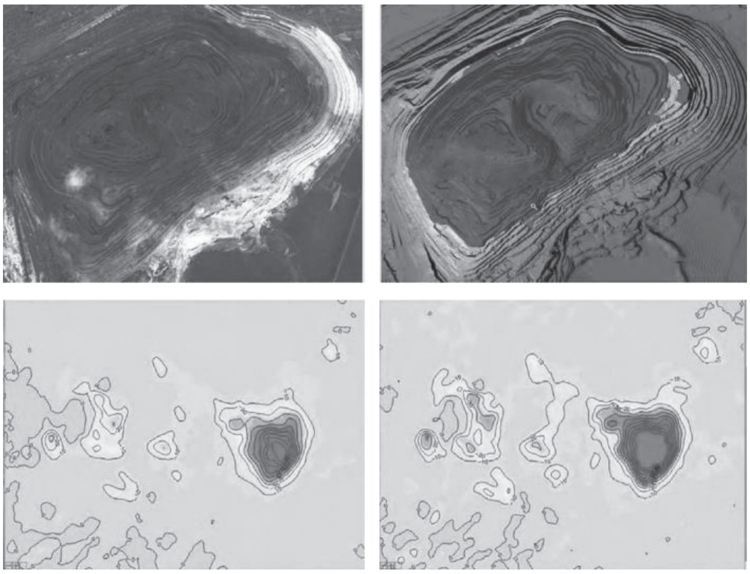

Fig. 1. Combining a satellite image and a digital model of a quarry. Development of subsidence processes in mining operations

unmanned aerial vehicles, aerial and ground laser scanning, mobile mapping systems and other methods of obtaining spatial data have been increasingly used. Earth observation satellites trace their history to Russia, following the pioneering launch of Sputnik 1 on October 4, 1957. Soon thereafter on January 31, 1958, NASA launched Explorer 1, in the United States. In recent years, earth observation and remote sensing satellites have been advancing in the number and power of mapping details for enhanced civilian applications. The satellites conveniently provide all-weather and wide coverage of geodata for decision support. There is also a rising number of miniature satellites. Doves by Planet Labs became the highest number of miniature earth observation satellites in 2019 (Planet Labs Inc., 2019).

The digital data revolution has been felt in Africa, too. The development priorities of the African Union's Agenda 2063 require quality data. The Africa Regional Data Cube (ARDC) has been supporting open data cube access to deliver a continental-scale platform and programme which democratises satellite data processing and analysis. ARDC has inspired the Open Data Cube (ODC) initiative in Africa for open-source technology and structured geospatial data, mainly from time-series satellite imagery. The Digital Earth Africa (DE Africa) initiative is working with the AfriGEO community to process openly accessible and freely available data to produce decision-ready products in support of Africa's data-driven development needs (Digital Earth Africa, 2019). The provision of Analysis Ready Data (ARD) under DE Africa removes the burden of pre-processing from users and reduces the demand placed on computing resources.

Development of satellite observation systems for subsoil infrastructure. Russian experience

Development of use and technologies of processing and analysis of space survey data is defined by a number of advantages as high speed of obtaining data after shooting (not more than a day), ensuring periodicity of shooting due to multiple grouping, large spatial coating, control of many objects on the basis of objective and multifaceted data, scale of shooting.

Mining industries require data from satellite navigation systems and space surveys, taking into account the specifics of technological process and infrastructure of coal mines, quarries of non-ferrous metals, gold, diamonds, extraction and transportation of oil and gas resources, logging, etc. Structural processing of big data and dynamic modelling ensures reduction of production costs for creation and improvement of geotechnologies, growth of industrial safety of mining infrastructure facilities, geoecological monitoring of environment condition, detection of landscapes caused by man-made and natural changes.

Figure 1 shows the results of combining a satellite image and a digital model of the quarry, as well as the dynamics of the development of subsidence processes for mining operations at the quarry.

The most difficult process of forming information technologies using remote monitoring methods is the process of decrypting space images. In order to obtain reliable information, it is necessary to have data of related ground observations recorded during remote monitoring. The permissible time deviation can be 2–3 years if during this period there were no emissions into the atmosphere of burn concentrations of gases or salvo discharges into natural water bodies of liquid wastes.

The essence of the related monitoring consists in the control of natural and man-made objects in the territories of mining complex activity made at an interval of 10–20 years. By processing and analyzing space surveys, comparing them with ground observations (Including panoramic photographs), it is also possible to identify with the help of a special program the disturbed territories, with the subsequent quantitative assessment of their area, comparing the obtained values of the area in the selected time interval, then determine the specific "increase" of the territory unresolved per unit of produced products (I million tonnes of ore or concentrate or metallurgical conversion product, etc.) [21–25].

A technique based on the integration of terrestrial observations and space scanning information has been used to detect the hidden defoliation processes of coniferous forests (different defoliation stages) associated with violation of the soil nutrition regime. Under conditions of air industrial contamination with acid-forming substances (sulphur compounds), the acidity and absorption capacity of soils change, that is, the natural mode of their nutrition is disturbed and, as a result, the defoliation process is developed.

This changes the reflective properties of the surface, which can be fixed by the scanner in the infrared range, determining the area of damage.

Features in the application of monitoring and results of spatial data analysis in Kenya

The Kenyan study used a GIS database of 53 mine locations spread across Taita Taveta County and confirmed the need for integrated dynamic models to enhance policy, planning and monitoring in the mining sector. Measuring approximately 17,000 km2 (KNBS, 2019), the region is rich in gemstones and industrial minerals.

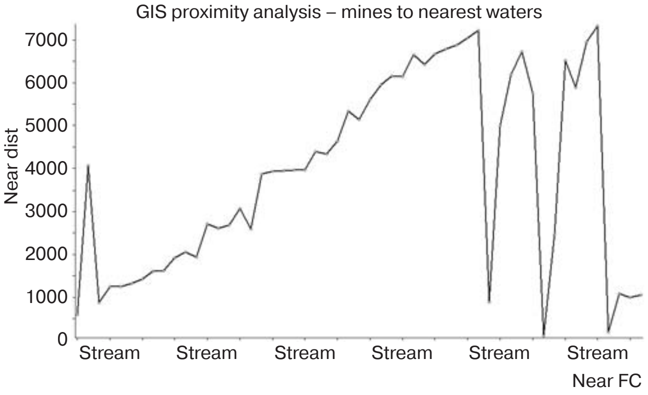

Fig. 2. GIS proximity analysis of how water bodies are close to the 53 mines studied in Taita Taveta

Demographics and the following five land-use sectors were identified as key components and important determinants or drivers of change in the study area: mining, forests, surface waters, agriculture, and the Tsavo national park taking up 60% of the spatial extent. Using a system dynamics model, time-series spatial metrics were integrated with attribute data on the sectors.

GIS data layers were created for the surface water bodies, agroecological zones, mining hotspots, key centres, transportation network, and critical zones. Sentinel 2 and PlanetScope satellite images were used to study the patterns of land-use changes with a particular focus on the mining hotspots.

Based on the principles of system dynamics, STELLA, a python-based dynamic simulation software application, was used to develop a stock and flow simulation model combining the following six model sectors: 1) updatable area under mining and exploration reserves; 2) updatable area under agriculture; 3) updatable area under surface water bodies; 4) updatable area forests; 5) updatable area under wildlife conservation zone/Tsavo National Park; 6) sector for simulating demographic changes and their influence on water demand and development spaces.

The following results have been extracted from the results obtained in this study. The mining activities in the area are mainly surface artisanal mining of gemstones and small-scale mining. The mapping and GIS spatial analysis of unregulated extractive activities along Voi River, the main river passing through the region's most populated urban center of Voi, established the risk posed by their close proximity to the river, mostly within 35 meters of the riverbed [26–30]. Laboratory tests further confirmed rapid changes in turbidity and Total Dissolved Solids (TDS) closer to the mining and quarrying hotspots.

Overall, 53% out of the mines mapped in this study were located less than 4 kilometers from adjacent water points, as shown in **Fig. 2**. In **Fig. 3**, the satellite imagery from Sentinel-2 on the area shows the pattern of land clearance and developments around active mines at 10 m spatial resolution.

In **Fig. 4**, scenario simulation from 1979 – 2029 shows simulated population growth (line-4) in Taita Taveta and how it causes increasing annual water demand (line-5). The simulated spatial extent of the mining space agrees closely with the active mining area (line-1 and line-2) as a confirmation of the reliability of the assumptions for simulation scenarios.

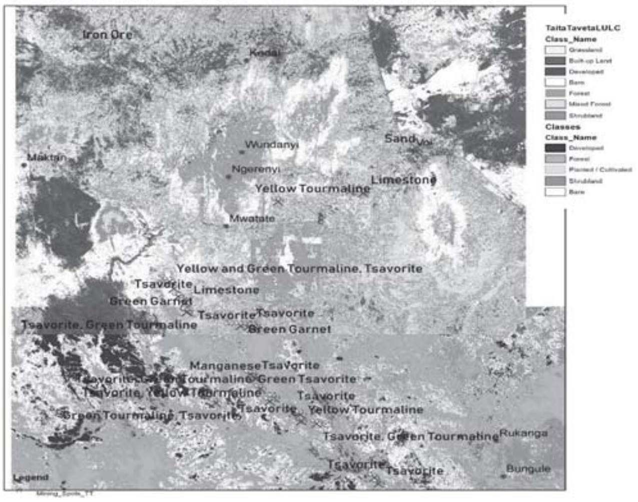

Fig. 3. Classified Sentinel 2 imagery on the study area, Taita Taveta, Kenya. Land clearance visible around active mines

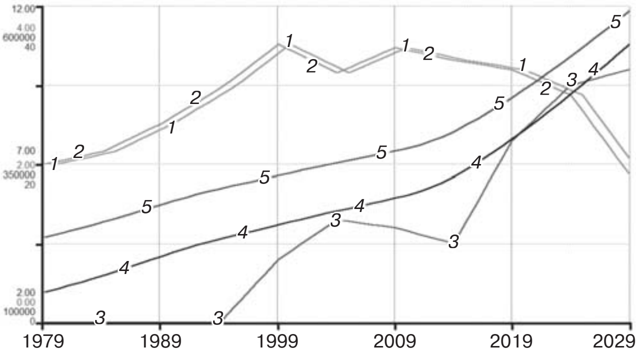

Fig. 4. Simulated changes in the share of mining space, population growth and water demand:

1 – simulated active mining area; *2* – active mining area; *3* – Reclamation; *4* – County population; *5* – Annual water demand

Reclamation targets can also be monitored through this model, and updates using spatial data are possible to inform policy, planning and management for sustainable mining and environment.

The model has a high level of adaptability, which allows to update spatial data of time series to build various effective solutions in the field of mining planning and technology selection. Model sectors can be updated by incorporating time series data at spatial scales of different land use and vegetation cover classes derived from multispectral and different time satellite imagery.

Conclusion

In order to monitor mineral development infrastructure and prevent emergency situations, timely monitoring of movements and deformations of the Earth 's surface and structures is necessary using the method of interferometric processing of a series of satellite radar images. This technology allows to determine displacements and deformations of the Earth ‘s surface and structures with accuracy to several millimeters. The use of satellite imagery for environmental monitoring allows full one-time coverage of the entire area of the production facility, and remote methods allow for environmental assessment not only within individual observation points, but also at any selected site. Digital relief models are successfully used to monitor earthworks, calculate the volume of dumps and develop erosion processes in meliorated quarries and dumps.

In the field of mining technologies, the idea of transforming into a technosphere the principles that ensured the ecological purity of the functioning of biological systems and the creation of mining environmental technologies based on them is promising. The emergence of biologically justified restrictions on the level of technological impact will give focus and specificity to research on the creation of real geotechnologies, the properties of which ensure unconditional implementation of these restrictions and create a technological basis for ensuring the environmental safety of mining of mineral resources in territories occupied by natural biota of the Earth [31–35]. The development of systems for the acquisition, processing and analysis of spatial data and technologies makes it possible to develop reliable models to support mining planning decisions and, in the future, to obtain even more accurate forecasts taking into account the prerequisites of negative phenomena and risk management strategies.

Acknowledgment

The publication was prepared within the framework of the Academic Fund Program at the National Research University Higher School of Economics (HSE) in 2020 – 2021 (grant № 20-04-033) and by the Russian Academic Excellence Project “5-100”.

References

1. The Development Strategy of Information Technology Industry in the Russian Federation for 2014–2020, and the Prospect for 2025. Available at: http://government.ru/docs/8024/ (accessed: 20.11.2019).
2. Yeralin Z. M., Goncharenko S. N. Models for solving key problems of strategic development of uranium mines. *GIAB*. 2019. No. 4. pp. 199–208.
3. Prokofeva E. N., Vostrikov A. V., Shapovalenko G. N., Alvarez A. The development of effective geomonitoring for mining area with industrial review. *Eurasian Mining*. 2017. No. 2. pp. 61–63. DOI: 10.17580/em.2017.02.15
4. All about mining. Extractive industry Available at: http://industry-portal24.ru (accessed: 5.11.2019).
5. Zotov L., Frolova N., Shum C. Gravity Changes over Russian River Basins from GRACE, in: Planetary Exploration and Science: Recent Results and Advances. Berlin: Birkhauser/Springer, 2015.
6. Aleskerov F. T., Karabekyan D., Ivanov A., Yakuba V. I. Individual manipulability of majoritarian rules for one-dimensional preferences. *Procedia Computer Science.* Vol. 139: 6th International Conference on Information Technology and Quantitative Management. Elsevier, 2018. pp. 212-220.
7. Vasin S., Gamidullaeva L., Shkarupeta E., Finogeev A., Palatkin I., Vasina T. Emerging trends and opportunities for industry 4.0 development in Russia. *European Research Studies Journal*. 2018.Vol. XXI, Iss. 3. pp. 63–76.
8. Tolstykh T., Shkarupeta E., Shishkin I., Dudareva O., Golub N. Evaluation of the digitalization potential of region’s economy. *Advances in Intelligent Systems and Computing.* 2018. Vol. 622. pp. 736–743.
9. Goncharenko S. N., Duong L. B., Petrov M. V., Stoyanova I. A. Modeling of parameters of innovation water-protection measures on the basis of industrial-technological indices of coal mining at Vietnam enterprises. *Gornyi Zhurnal*. 2014. No. 9. pp.143–146.
10. Gaydin A. M. From Geotechnology to geoesthetic. *Gornyi Zhurnal*. 2009. No. 4. pp. 72–76.
11. Ilin S. A., Kovalenko V. S., Pastikhin D. V The overcoming of the open cut mining initial disadvantages: experience and results. *Gornyi Zhurnal*. 2012. No. 4. pp. 25–32.
12. Ganitskiy V. I., Dayanits D. G., Vorobyev A. G., Eyrikh V. I. About development of innovation activity and its staffing in the mining industry. *Gornyi Zhurnal*. 2011. No. 12. pp.27–30.
13. Aleskerov F., Ivanov A., Karabekyan D., Yakuba V. Manipulability of Aggregation Procedures in Impartial Anonymous Culture. *Procedia Computer Science*. 2015. Vol. 55. pp. 1250–1257.
14. Vartanov A. Z., Petrov I. V., Kobyakov A. A., Romanov S. M., Fedash A. V. Ecological and economic aspects of the transition of the mining enterprises on the principles of best available technologies. *GIAB*. 2015. No. 1. pp. 511–521.
15. Goncharenko S. N., Kobyakov A. A., Petrov I. V., Stoyanova I. A. Economic-mathematical modeling of the distribution of the value of the cost of the preservation and restoration of the environment in the areas of mass closure of coal mines. Ecological and economic problems of the mining industry and development of fuel and energy complex of Russia : Preprint. Moscow : Gornaya kniga, 2012. pp. 20–25.
16. Adero N. J., Kiema J. B. K. Flow-based structural modelling and dynamic simulation of lake water levels. Book Chapter. Handbook of Research on Hydroinformatics: Technologies, Theories and Applications. 2010. pp. 316–331.
17. Hartlieb P., Grafe B., Shepel T., Malovyk A., Akbari B. Experimental study on artificially induced crack patterns and their consequences on mechanical excavation processes. *International Journal of Rock Mechanics and Mining Sciences*. 2017. Vol. 100. pp. 160–169.
18. Shepel T., Grafe B., Hartlieb P., Drebenstedt C., Malovyk A. Evaluation of cutting forces in granite treated with microwaves on the basis of multiple linear regression analysis. *International Journal of Rock Mechanics and Mining Sciences*. 2018. Vol. 107. pp. 69–74.
19. Abbaspour H., Drebenstedt C., Paricheh M., Ritter R. Optimum location and relocation plan of semi-mobile in-pit crushing and conveying systems in open-pit mines by transportation problem. *International Journal of Mining, Reclamation and Environment*. 2019. Vol. 33(5). pp. 297–317.
20. Kaplunov D. R., Ryl’nikova M. V., Radchenko D. N. Utilization of renewable energy sources in hard mineral mining. *Journal of Mining Science*. 2015. No. 1. pp. 111–117.
21. Temkin I., Deryabin S., Konov I.: Soft computing models in an intelligent open-pit mines transport control system. *Procedia Computer Science*. 2017. pp. 411–416.
22. Temkin I. O., Do Chi Thanh, Agabubaev A. T. Some algorithms of functioning analytical platform in the control system of ventilation methane abundant mine. *GIAB*.2018. No. S16. pp. 3–15.

23. Temkin I. O., Klebanov D. A., Deryabin S. A., Konov I. S. Method of determining the state of the haul road career in the management of the interaction between robotic elements of the mining transportation complex. *Mining journal*. 2018. No.1. pp. 78– 82.
24. Prokofeva E. N., Vostrikov A. V., Fernandez E., Borisov N. Navigation satellite systems as the audit foundation for mining companies. *Eurasian Mining*. 2017. No. 1. P. 30-32. DOI: 10.17580/em.2017.01.08
25. Satellite monitoring and geospatial solutions Available at: https://sovzond.ru/ (accessed: 21.11.2019).
26. Planet Labs Inc. Planet Imagery Product Specifications, August 2019. Available at: https://planet.com (accessed 30.08.2019).
27. Digital Earth Africa (2019). Open Data Cubes. Available at: https://www.digitalearthafrica.org/. (accessed: 15.11.2019).
28. 2019 Kenya National Housing and Population Census: Vol. I: Population by County and Sub-County. Kenya National Bureau of Statistics – KNBS. Nairobi, 2019.
29. Reich C., Schatz M., Zsak G. World Mining Data 2018. Vol. 33: Iron and Ferro Alloy Metals Non-ferrous Metals, Precious Metals, Industrial Minerals, Mineral Fuels. Vienna: Federal Ministry of Sustainability and Tourism, 2018.
30. Adero N. J. Redressing the nexus of human rights and mining in Kenya using geospatial models*. Book of Abstracts of the BHT 2018: Future Materials – Safe Resources Supply – Circular Economy and the 3*rd *Interdisciplinary Colloquium and PhD Conference on the Social Responsibility of Science and Scientists*. Freiberg, Germany, 6–7 June, 2018. pp. 12–13.
31. Trubetskoy K. N., Galchenko Yu. P. Geoecology of Subsoil Development and EcoGeotechnologies of Mineral Mining. Moscow: Nauchtekhlitizdat, 2015.
32. Rylnikova M. V., Galchenko Yu. P. Renewable Sources of Energy in Integrated Subsoil Development. Moscow : IPKON RAS, 2015.
33. Trubetskoy K. N., Galchenko Yu. P., Eremenko V. A. Fundamentals of converging mining technologies in integrated development of mineral resources of lithosphere. *IOP Conference Series: Earth and Environmental Science*. 2018. Vol. 134(1). 012064.
34. Rylnikova M., Ainbinder I., Radchenko D. Role of Safety Justification of Mining Development for the Regulatory Framework Formation and Mineral Resources Management. *E3S Web of Conferences*. 2018. Vol. 41. 01033. DOI: 10.1051/e3sconf/20184101033
35. Kolosov V., Medvedev A., Zotova M. Comparing the development of border regions with the use of GIS (the case of Russia). *Geographia Polonica*. 2018. Vol. 91, No. 1. pp. 47–61. EM

UDC 622.85

V. V. KHAUSTOV [1], *Doctor of Geologo-Mineralogical Sciences, Professor*
I. M. IGNATENKO [1], *Candidate of Engineering Sciences, Associate Professor, ignatenko_i@bsu.edu.ru*
A. V. SHLEENKO [2], *Candidate of Sciences, Associate Professor*
E. A. ERMOLOVICH [1], *Doctor of Engineering Sciences, Professor*

[1] *Belgorod State University, Belgorod, Russia*
[2] *Southwest State University, Kursk, Russia*

BIOCHEMICAL IMPACT OF THE TYRNYAUZ FIELD DEVELOPMENT ON THE BAKSAN RIVER

The influence of the Tyrnyauz tungsten-molybdenum plant on the water ecosystem of the Baksan River is investigated. The anomalies cased by mining activities in groundwater and surface waters, in suspended matter and in bottom sediments in long sections of the river valley are revealed. The relationship between the protein in bottom sediments and the concentrations of some heavy metals is determined and explained.

Keywords: *heavy metals, pollution, water ecosystem, bioindication, protein of bottom sediments.*
DOI: *10.17580/em.2020.01.15*

In recent decades, heavy metals as environmental pollutants are of increasing concern. Heavy metals are proved to be the main pollutants of the atmosphere, groundwater and surface water, soil cover, etc. Unlike organic pollutants decomposable in a varying degree, heavy metals are incapable to disintegrate but only re-spread among different components of water ecosystems—water, suspended solids, bottom sediments and biota, and, therefore, they should be considered as constantly present in ecosystems [1]. Increasing concentrations of heavy metals in various natural objects is detrimental to the living world, therefore, identifying sources of pollution, their distribution, developing methods to combat pollution seems to be a very urgent task both in general and for specific regions where these processes have their own specifics.

In this regard, the topic of choosing the most informative indicators in assessing the extent of technogenesis is also relevant. There is a need to study the geochemical conditions of migration of pollutants and their role in the functioning