

Environmental Safety in Mining and Processing of Mineral Raw Materials under the Conditions of Rational Nature Management as Exemplified by the Kursk Magnetic Anomaly Region

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Abstract

Objectives: This study represents the analysis of technogenic and biosphere conceptions from the perspectives of the environmental problems of mining and reprocessing of mineral raw materials in Russia and other countries. **Methods:** The fundamental conceptual complex approach has been identified to solve the ecological problems of mining and processing of minerals taking into account the conditions of rational nature management using the example of the Kursk Magnetic Anomaly (KMA). **Findings:** Based on the developed concept it has been suggested that a Single Regional Environmental Protection Center should be established that would formulate and implement the complex approach to solve the regional problems making it possible to identify the conditions for the well-balanced methods of fulfilling the environmental engineering tasks of various profiles and to facilitate economic and social development of the promising mineral producing regions of the country, particularly, the region of the KMA. **Applications/Improvements:** The study suggests the examples of the innovative solutions to solve the problems of rehabilitation and support of the environment in the KMA region.

Keywords: Concept of Development, Conditions of Rational Subsurface Resources Management, Complex Program, Geotechnologies, Kursk Magnetic Anomaly, Natural Mineral Raw Materials, Single Regional Environmental Protection Center

1. Introduction

Growing rates of production and consumption of different types of products that have intensified over the last 100 years are associated with the enhanced mining operations and extraction of commercial minerals as well as with the technogenous impacts on the environment that lead to

the destruction of the mechanisms of natural stabilization (especially in the areas of large mineral deposit fields).

E. Kozlovskiy (Minister of Geology of the USSR in 1975-1989) in his published works (2014-2016) admonishes anxiously and suggests the things as follows¹⁻². "The rock mass extracted from the interior parts of the earth is approximating the figure of 100 billion tons per year

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already, and it is subject to intensive oxidation by atmospheric oxygen. Combustible mineral resources account for circa 1/5 of this amount. When fuels and organic materials are oxidized and burned or used in the technological processes such compounds as CO₂, H₂O, SO₂, NO₂ are formed inevitably as well as other volatile and mineral combustion products that can cause climate change, acid rains and can pollute atmosphere and nature in general. Under these conditions there comes the problem of survival and viability and as a consequence, the problem of rational use of natural resources”¹.

“...First and foremost, the concept of national security of Russia has to be amended in line with the new conditions of social development and with a view to meet the needs of the country for strategic mineral raw materials and for the products of their reprocessing. The modern system of principles of social reforms has to be developed focused on securing the dignified living standards of Russian citizens”. The author notes that “...This predetermines the concept of the new law “On Subsurface Resources”. The development of this law should be based on such major principles as ensuring economic security of the country, maintaining the capabilities to reproduce resources and satisfy the vital needs of the population in conformity with the recognized world standards. The focus on future generations should become the main message of the law”².

V.V. Adushkin academician of the Russian Academy of Science (RAS) highlights the increased significance of explosive works in energy physics of seismic processes. A number of studies developed by the Institute of Geosphere Dynamics of RAS prove that while on a worldwide scale the development of the explosive technologies cannot surpass the energy of natural earthquakes, in some cases at regional level the contribution made by the effects of explosive technologies in the overall flows of seismic energy is several orders of magnitude higher than the level of the energy released by natural earthquakes. In particular, this is exactly the situation that occurred in the territory of European Russia in KMA region that is characterized by relatively low seismicity³.

In order to prevent ecological catastrophes in the areas of mineral mining operations, the technogenic processes are, as a rule, supervised and controlled; however, the dynamics of the natural processes associated with mining is seldom paid its due attention, inasmuch as in the course of elaborating the models for economic development of the regions that are rich in mineral raw materials the authors of these models still adhere to the

technogenic conception that neglects the emerging natural processes.

To ensure further development of the economy and the creation of favorable living environment on Earth taking into account the urgent problems of technogenic pollution and global ecological violations the priorities should be set clearly for both technogenic and biosphere conceptions of development.

The study demonstrates that any extrapolation of the future within the framework of technogenic development conception inevitably shows its limitations as compared to the biosphere concept that gives an answer to the question about the biotic sustainability of the environment.

Further, the authors of this study will try to suggest the model of development for the mineral deposit area of Kursk Magnetic Anomaly (KMA) within the context of the biosphere concept whose principle idea is that the threshold of the stable state of the environment should never be exceeded. This approach is supposed to ensure the possibility to improve the living standards of people in the KMA region, to ensure the opportunity for sustainable progress of the society and of the state.

2. Concept Headings

Over the last ten years the raw-material orientation of the world economy in general has been stipulating the intensification of mining operations.

For several recent decades the extraction of mineral resources has been developing extensively not only in the land areas but also in shelf zones; however, the existing technology of mineral resource extraction is inevitably associated with technogenic pollution and global ecological detrimental impacts on the environment.

To solve the problem of ensuring environmental safety in general, it is necessary to select the concept for further development and to search for the ways of mining and reprocessing mineral raw materials avoiding any disturbances to the ecosystem. Today, notwithstanding the variety of opinions, hypotheses and models, only two concepts of development really compete with each other, given the emerging ecological problems of the world community as a whole.

According to the first concept that is conventionally called resource-based or technogenic, the mankind can solve all ecological problems and ensure ecological safety

using technical means, i.e. by improving the economy based on the new technologies setting no limits to the amounts of utilized resources or to economic and population growth rates.

There are different versions of this theory that start from the complete denial of any ecological danger and the declaration of the unlimited opportunities for development and finish with the appeals to transit to sustainable development that is understood as the satisfaction of the needs of present and future generations of people. Within the framework of this concept the environmental problems are often represented as temporary phenomena caused by the “imbalanced use of technologies” and as those that would be overcome in either near or more distant future. Thus, there is an attempt to combine safeguarding of the environment with economic growth and with natural growth of population. It is exactly within the framework of this concept that the modern principles of environmental protection activities have been established. Protection is understood as a system of local pollution preventing facilities and as the development of the indicators of environmental quality based on the narrow range of indices together with the implementation of resource-saving technologies.

However, this is in direct contradiction to the observed and documented global changes in the natural environment that are associated with mineral mining and extraction operations.

The technogenic conception does not possess any elaborated theoretical foundations. It just represents the propagation of available human experience and its extrapolation to near and distant future. The models that are developed within the framework of this concept preset random initial conditions in ecological context with some certain assumptions as regards future development. Similar assumptions are also used for other resulting parameters such as resources, food, population, regional specifics, etc. However, even these models predict either early or distant dead end of development, its physical limits.

The second concept can be conventionally called the biosphere concept. As early as in the first quarter of the 20th century there appeared the ideas about the role of “living matter” in the formation of our planet, about the role of biochemical cycles in this process and, finally, about the significance of man as geological power. However, the concept was realized theoretically only as late as in the last quarter of the 20th century; first, as Gaia hypothesis

within the frames of which the basic principle of biotic regulations has been formulated; thereat, the mechanism used by biota to regulate the environment and to ensure its sustainability for the purposes of its own development has not been discovered by that time. Only over the last decade of the century the mechanism of biotic regulation and environmental sustainability has been fully defined and described in Russia.

Theoretical concept of biosphere represents an empirical generalization of all accumulated experimental materials founded on the known laws of physics and biology. It gives an answer to the question of how the sustainability of life is ensured given the assumption of the biotic stability of the environment. The theory defines that stability represents the ability of biota to compensate external perturbations due to the effects of the negative reverse connections that are agitated by these disturbances and also the ability to return the environment back to the state which is either stable or dynamically balanced.

External disturbances initiate the agitation of the biota itself, and the effects that compensate the disturbances can only be produced up to some certain threshold level. When this threshold is exceeded, biota loses the ability to stabilize the environment and then local and global changes occur. Biota in its over-the-threshold state starts searching for the environment even faster than the anthropogenic impacts that come over the threshold occur; and thus the processes of losing environmental stability also become faster.

Presently, the sum of empirical data testifies of the fact that the mechanism of stabilization has been violated by the activities of man that lead to the increased concentrations of greenhouse and other gases in the atmosphere, to the changes in carbon and nitrogen cycle, to colossal transformations of the Earth's surface on the continents. Based on the theory of biotic regulation and sustainability it has been established that the crossover of the biota disturbance threshold occurred in the beginning of the 20th century. The problem is now reduced to the question whether this crossover resulted in irreversible changes of biota or can its regulatory capability be rehabilitated in full.

While within the framework of the first concept the solutions to ecological issues imply the evaluation of the degree of environmental pollution, the development of norms and regulations to control the admissible levels of pollution of different media, the installation of cleaning facilities and the introduction of resource-saving

technologies, the second concept attempts to identify the area of sustainability of any ecosystem that would make it possible to find the admissible value of disturbance, the maximal load on the ecosystem. Such threshold has already been established for the biosphere (global ecosystem) in general based on the data on the changes of the global carbon cycle. It has already been proven by the results of the investigations of the ratio of consumption of pure prime product by the organisms of different sizes.

However, the issue of determination of sustainability thresholds in concrete ecosystems has not been solved completely as yet. The major reason for global ecological violations and for the ecological crisis that threatens the very existence of the mankind is represented by the danger of disturbing the stabilizing biotic equilibrium of the environment. Consequently, on global and regional scales the major task now is to preserve the natural biotic equilibrium at the relevant level required for the purpose, i.e. the solutions to the modern ecological problems and the establishment of ecological safety should not be reduced just to cleaning the environment from the controllable pollutants or to low-waste technologies but they should also aim to save the resources⁴.

All these things are of current importance at the local level as well, especially in the most congested areas, i.e. primarily in the locations of densely populated industrial centers; however, on the scales of the whole planet this will not be enough.

3. Method

To investigate the problems of environmental safety in mineral mining and reprocessing the complex and systemic methods of generalization, comparison, observation, induction, deduction and synergy have been applied. The use of these methods of investigation made it possible to evaluate the effects of the resource-based (technogenic) and biosphere concepts of development on solving the ecological problems in the world community as a whole.

4. Results

Similar to other mining, metallurgical, mining and chemical regions, in KMA region the trend of the declining medical and demographical indicators has been observed since 1986^{5,6}. This testifies of the low efficiency of the methods of environmental protection (EP).

The authors of this study have already addressed their suggestions to the Committee on Environmental Protection and Natural Resource Management of the State Duma, to the Ministry of Natural Resources and Environment of the Russian Federation. These suggestions have been received well by the State Duma.

The results of the investigations show that to solve the environmental problems in the KMA the following activities have to be undertaken in the nearest future:

- The concept of the law “On Subsurface Resources” and the concept of national security of Russia have to be revised in accordance with the new conditions of social development and taking into account the objective of meeting the needs of the country for strategic mineral raw materials and for the products of their reprocessing;
- The complex regional system of geo-ecological and geodynamic security has to be implemented;
- The step-by-step transition to the combined open-cut and subsurface mining of ferruginous quartzite should be envisaged;
- The system should be implemented to ensure efficient isolation of the water-bearing formations from the technogenous waters of tailing dumps, sludge reservoirs, storage areas of solid and liquid industrial wastes at the existing opencast and underground mines (LGOK, CGOK, MGOK and other mining and metallurgical enterprises);
- Modern cleaning facilities should be installed at all wastewater sources;
- A system of dams should be built to create the gathering ponds for the surface water followed by cleaning of the nearest river beds and well springs in the area of gigantic cone of depression;
- The issues should be resolved concerning the transportation and storage of the dumps of overburden rocks in the opencast mined-out areas of LGOK, CGOK, MGOK and tailings in the underground pits upon their extensive reprocessing to recover useful and to dispose of the toxic elements⁴.
- The detrimental components of mining and metallurgical gas cleaning systems should be reclaimed and disposed of;
- The systems for dust and gas suppression, for seismic and Explosive Shock (ES) protection should be developed²;
- The automated geo-ecological and radio ecological systems should be applied to control dust and gas

pollution, seismic and ES effects in the process of Drilling and Blasting Operations (DBO).

One of the most important problems is the issue of developing principally new resource-saving, safe and environmentally friendly technologies for mining and reprocessing of mineral raw materials of KMA that would envisage complex utilization of deposits, selective mining of minerals, dumping of detrimental chemical and radioactive production wastes, etc.⁴.

For more than ten years Scientific Research Center Eco-resources of the KMA Regional office and ANPO “Independent Institute of Examination and Certification” have been working in cooperation with a whole number of other organizations on the complex of the problems associated with the protection of human life and environment. They possess innovative technical solutions to the ecological problems that occur in the course of mining operations.

Below the authors provide the descriptions of some of these solutions that have been developed and tested at the authority of the abovementioned organizations and that can solve the problems of one of the most troubled regions through the implementation of the new techniques and technologies. These solutions primarily suggest the development of ecologically clean equipment and technologies for mining and reprocessing of mineral raw materials and also the implementation of the innovative methods of re-cultivation and farming agricultural plants on the areas that have been pretreated and cleaned by mobile technological complexes⁸⁻¹¹.

Mobile technological complex for intensive reprocessing of technogenic wastes of mining and metallurgical companies also makes it possible to recover simultaneously metals and fine quartz sands for construction industry and for manufacturing different types of construction mixtures including those on polymeric basis.

Additional features of the mobile complex are represented by the opportunities to use it for the purposes of re-cultivation of the contaminated areas of the deposit fields.

The costs for building one module type mobile complex for intensive reprocessing of natural and technogenous fields designed by Scientific Research Center Ecoresources are two or three times lower than the costs for manufacturing its foreign counterparts and the pay-back period makes no longer than 6-12 months.

The construction and operation costs of this complex under the conditions of Mikhaylovskiy, Lebedinskiy or Stoylenskiy dressing plants could be returned within the

period of 6-12 months (this will depend on the efficiency of a particular field, on the intensity and on component recovery rates) due to the extraction of gold from the tailings of the dressing plants, not to mention uranium and other rare-earth by-products.

The efficiency of the re-cultivation improves considerably in cases when at the final stage special kinds of vegetation are planted to accumulate hard metals. The methods of phytoremediation make it possible to eliminate different types of pollution (toxic matters, radionuclide) simultaneously, improving the fertility of the reclaimed soils. The costs for the re-cultivation are repaid due to the possibility to use wastes as construction materials.

In order to reduce the disease rates among the population of the KMA region the methods of industrial toxic water treatment should be developed and implemented. The health of the population can be improved considerably by applying the electrochemical water treatment method developed by Russian scientists in the 70s of the 20th century. The technologies to apply this method have already been developed not only for the purposes of potable water treatment for towns and settlements, but also for individual water treatment, for sterilization of animal farm wastes, for medical purposes (including therapy of oncologic and other serious diseases) and for health improvement in general.

Today it is very important to determine and to identify the geographical locations of active tectonic faults in the region taking into account their effects on the health of the population. These locations have to be regarded during design and construction of settlements and industrial enterprises.

Innovative technologies for raw material reprocessing, for re-cultivation, for assessing the unfavorable conditions of the natural, industrial and living environments, as well as agricultural technologies for growing and reprocessing, for evaluating the safety of food products cannot be developed without the laboratory assessments of the technological parameters of the manufacturing processes and detrimental factors of natural, industrial and living environments. These functions should be coordinated by regional authorities and also by an independent environmental protection center that would specialize in the rehabilitation of biotic equilibrium in the region and the relevant activities should be performed by governmental and independent laboratory centers, such as, for example, ANPO “Independent Institute of Examination and Certification”.

The costs for the implementation of the complex environmental safety program that would also cover the opportunities for manufacturing safe agricultural food products and take into account the health conditions of the population in the regions of intensive mining operations can be paid back from the revenues of the produced raw materials. For instance, the costs for medical laboratory tests, for diagnostic and curing equipment will not be higher than USD 10-20 thousand depending on the selected methods; and one unit of diagnostic equipment will not exceed USD 10 thousand. Application of such methods and devices will make it possible to perform monitoring of oncologic, cardio-vascular and gastrointestinal diseases at the early stages to identify the potential patients and those who already suffer. To prevent occupational and oncologic diseases in particular the electro-activated water, anolyte and catholyte should be used. The costs for medical devices will be paid back within three up to five months due to the fact that the occupational diseases will be diagnosed and cured at early stages by applying modern highly informative and inexpensive kinesiology, osteopathic and manual methods of diagnostics and treatment thus reducing the time required for periodic health examinations of large groups of employees and also reducing the time required for selecting the medicines for the patients at the stage of drug treatment.

In ecologically unfavorable regions of mining and processing operations another important problem is represented by the necessity to monitor detrimental natural and industrial factors under laboratory conditions.

Using the example of the KMA the authors have described just several of all possible innovative solutions that would help improve ecological and economic situation and that can be applied in any ecologically troubled region of the country. However, in the region of the KMA these activities are hampered, inasmuch as there is no any single independent ecological center that would be in position to coordinate the activities of the experts of different profiles and could objectively evaluate the nature and the scale of the detrimental processes that could develop the program for environmental improvements and predetermine the conditions for the balanced approach to solving the problems associated with the increased output and more intensive reprocessing of mineral raw materials under the conditions

of the reconciled contradictions between the factors of resource-related and food safety, to prevent the destruction of the unique fertile soils and also to improve health and demographic characteristics of the population.

The principal functions of the center should cover the aspects as follows:

- Generalization of the results of the investigations that have been carried out in the territory of the KMA within the framework of the biosphere concept, for instance, in Starooskolskiy - Gubkinskiy area over the historically long period identifying the regularities and the reasons for the processes of degradation of the environment in time and space;
- Development of the short- and long-term concept to reconcile the contradictions between natural and technogenic factors of the region;
- Development and implementation of the program aimed at step-by-step rehabilitation of the basic elements of natural environment (including agricultural land) up to the level when the systems are capable of rehabilitating themselves;
- Implementation of complex social program studying the capabilities to produce safe agricultural products for food industry and also covering the healthcare issues in the regions of intensive mining operations;
- Coordination of the activities of different experts taking into account the results of the developed programs.

5. Discussion

In his days V.I. Vernadsky one of his works called "Biosphere" wrote: "The visage of the planet, the biosphere, is drastically chemically changed by man consciously and, predominantly, unconsciously. Now we witness the new evolutionary change of the biosphere." From these perspectives the issues of the environmental protection have been studied recently by V.K. Kushnerenko, I.I. Kosinova, E.S. Demidenko, E.A. Dergacheva, P.P. Sivashchenko, O.V. Luchinikov and many others.

The destruction of the natural biota occurs proportionally or even supra-proportionally to the growth of energy consumption rates because man uses energy only to reconstruct or to destruct the environment. However, even under hypothetical transition to zero-waste technologies, to the full prevention of the pollution and to the use of absolutely clean energy sources the environment will lose sustainability still because of the continuing destruction of natural biota.

The biosphere concept of development should be selected as the fundamental concept of environmental safety due to several reasons.

If mining and extraction of raw materials and energy consumption follows the technogenic conception, then the introduction the biosphere concept will facilitate the resolution of the ecological problems and will ensure the prevention of the catastrophe, although, it can entail some certain necessary expenses. And vice versa, if the resources are produced and consumed following the biosphere concept then the shift to the anthropogenic conception will result in inevitable catastrophe.

Anthropogenic conception does not possess any elaborated theory but is founded on the experiments carried out with models and the latter are usually based on quite random and admittedly incomplete assumptions. The biosphere concept does possess the well-developed theory based on the laws of physics and biology, and it makes maximal use of the data on observations. It comprehensively covers the environmental protection activities that originate from the anthropogenic conception encompassing the private aspects, the tasks of creating the cleaning systems, the resource saving technologies and the normative regulation of environmental pollution. This concept formulates the laws of biosphere development that set certain limits and requirements to man.

If the biotic equilibrium returns back to its before-threshold conditions then there will emerge wider opportunities for the progress of the mankind but only in case if this disturbance threshold of natural equilibrium of biota is never exceeded again!

Based on the above there follows the definition below: geo-ecological safety is the stable state of the environment that ensures the possibility to improve the standards of living of the people, that ensures protection from both natural and technogenic catastrophes, gives opportunities for sustainable progress of the society and of the state.

The word "opportunity" is used in this context because the living standards and the sustainability of the progress of the society and state are ensured not only by the stability of the environment but also by social and economic systems in each particular state.

It has to be noticed that the intact territory of Russia that accounts for more than 1/7 of the globally preserved natural land makes a great contribution to the stabilization of the environment of the Earth. However, this amount of the intact biota in the undisturbed territory of land is not enough for its global stabilization. Therefore,

the ecological crisis is getting ever more serious and the whole mankind, including the population of Russia is now placed under the conditions of ever increasing ecological danger.

The intensified rates of mineral mining and extraction over the last decade and the consequences of the imperfect approaches that have been applied for many years to the processes of mining and reprocessing of raw materials in this country stipulate the necessity to revise the approaches to the problems of ecological safety and to implement step-by-step transition to the concept of biosphere.

Involving the combined natural and technogenous fields into commercial processing is a large task of the economy of Russia, and this task is inevitably becoming more urgent. Russia makes its definite and considerable contribution into the development of this violent ecological crisis that is fast developing all over the world.

The technology of mining mineral resources (both natural and those recovered from the production wastes of chemical, coal, mining and metallurgy, oil industries) is inextricably associated with technogenic pollutions and with the destruction of land and environment.

The regions where natural and technogenous fields are located may be densely populated and also can possess the reserves of arable lands that may be unique in terms of black humus contents or feature well-developed agricultural sector.

The large-scale geo-ecological changes associated with mineral mining operations are observed in the strategically important areas of the central industrial region, for instance in the Kursk Magnetic Anomaly, in the Northwest region, in the Urals, in West Siberia, in the Far East and at the mines of the neighboring countries. The unfavorable environmental situation is observed in the fields of the Moscow region, in the Kuznetsk and Rostov coal deposit fields and also in the Far East, in Yakutia and in other regions.

Environmental violations result in the deterioration of agriculture, in poorer health of the population, in growing death rates and lower birth rates; they also affect negatively the overall social climate in the regions of intensive mining operations.

Intensive mining of natural and technogenous fields needs a serious scientific approach that would apply complex solutions not only to economic and technical problems of mining operations but also to the problems of occupational safety, healthcare and social

comfort of the population who live in the areas of the deposit fields. This is exactly the way to consider the environmental problems associated with mining and affecting flora and fauna in the vicinity of the deposit field.

The example of KMA is of special interest as this region represents the most powerful iron ore deposit in the world that has been mined for very long period.

KMA includes Belgorod, Novooskolskiy, Starooskolskiy and Kursk-Orlovskiy iron ore deposit regions. The territory of the KMA expands from south-east to north-west for over 600 km its width being 150-250 km. Total area of the basin makes 120 thousand square kilometers.

The environmental problems that have accumulated here over the decades are in need of the most modern and innovative solutions that would make it possible, under the existing conditions, to solve the issues of occupational safety of miners as well as the problems of agriculture and public healthcare¹¹⁻¹³.

6. Conclusion

This study analyses the principal ecological approaches to the solutions of the problems of economic development in the congested raw material mining regions using the example of the KMA.

The examples prove convincingly that there are inexpensive ways for introducing complex solutions to environmental safety practices applying modern and innovative methods.

Creation of regional single environmental protection centers that would formulate and implement the complex approach to the solution of regional problems is a very important area of the economy that would make it possible to determine and to realize the conditions for the well-balanced methods to fulfill the tasks of different profiles, such as, for instance, social and economic, geoecological and geodynamic safety, and thus to facilitate general economic and social development of the promising resource producing regions of the country and the KMA region in particular.

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