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THE ROLE OF FORECASTING IN THE MANAGEMENT OF ENVIRONMENTAL ENGINEERING ISSUES AT ENTERPRISES OF THE MINERALS SECTOR IN THE CONTEXT OF NEW CHALLENGES AND THREATS

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Abstract

The paper outlines the principal threats and challenges that are facing the minerals sector of Russia and the world, including the EU carbon tax, ban on imports of certain products in different countries of the world (for instance, on asbestos-containing products and high-sulphur and high-ash coals), shortage of land in mining countries, and/or changes in land planning regulations. These threats and challenges are considered in their relationship with environmental safety issues at mines and in mining areas. Related environmental engineering tasks are examined. The role of forecasting in the accomplishment of these tasks and in environmental risk reduction is highlighted. The author proposes a systemic eco-technological approach to effective comprehensive forecasting of mining area's environment quality.

Keywords: **f**orecasting, environmental risk, threats and challenges, environmental engineering tasks, minerals sector enterprises

I. Introduction

Environmental safety issues in mining business are currently very important. Mining operations produce a substantial adverse impact on all components of the environment. In Russia, their contribution to total wastes amounts to 90%[1]. [1]. In other countries, these figures vary in a broad range. Thus, in the European Union mineral companies account for around 65% of total wastes [7], while in the US this proportion amounts to 50% [8]. Environmental safety is a particularly important problem for old industrial[2] areas, where human impacts have reached a critical value[3]. The list of these regions includes some areas in the Russian Federation (for instance, the Middle Urals, including Sverdlovsk Oblast).

Today, the enterprises of the minerals sector face a broad variety of qualitatively different environmental engineering tasks, threats, and challenges[4].

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[1] Data were obtained by mechanical counting using information from Rosstat, the federal state statistics service [1]

[2] Old industrial region is an area with outdated and technologically backward industry [2]

[3] The author defines critical value as maximum permissible burden, an indicator of the effect produced by one or several pollutants on the environment which, if exceeded, may impact the environment adversely [3]

[4] Challenge is a set of circumstances that are not necessarily hazardous but implying a compulsory response if they have arisen.

Threat is the most specific and immediate form of hazard in the economic sphere, presenting a set of adverse conditions and factors that are likely to impair economic security [4]

What follows is a description of some of the existing threats and challenges facing the minerals sector and related environmental engineering tasks.

Challenge. Introduction of carbon tax.

EU member countries are introducing a carbon tax on suppliers of high carbon footprint commodities to EU. This tax is imposed, first of all, on companies producing and exporting cement, electricity, fertilizers, iron and steel, and aluminum. In fact, producers of these commodities would have to buy a special certificate that would enable them to sell carbon-intensive products. The tax is aimed at reducing greenhouse gas emissions [5].

Threat.

In connection with the introduction of this kind of tax, Russian exporters of such goods to the EU are facing a threat of losing competition on the European market to producers of similar goods who have introduced low-carbon "green"[5] technologies, with a consequential repartitioning of the market.

Environmental engineering tasks.

This threat may have an essential economic effect on carbon-intensive product exporters and force mining companies to take appropriate actions to decrease greenhouse gas emissions, diversify business, introduce "green" technologies, and modernize production facilities.

Greenhouse gas emissions could be reduced through both low-cost interventions (for example, by improving thermal insulation of buildings, installing heat meters and thermostats, upgrading heating network insulation, introducing smart heating, ventilation and air-conditioning control systems, stopping gas leakages, etc.) [9] and more costly measures such as off-schedule modernization or production shutdown (for example, closure of coal-fired power stations) and introduction of "green" power generation technologies, including new nuclear, wind, solar and hydroelectric power stations. The latter is exactly what Enel is undertaking [10]: this Italian company has sold its coal-fired power stations in Russia and is setting up new non-polluting wind power stations.

Challenge. Ban on import and use of certain products.

Currently, EU countries, USA, Canada and many other countries do not allow the use and import of asbestos-containing products and high-sulphur (more than 1 %) and high-ash (over 16%) coals. This is done, first of all, for the purpose of reducing human-induced burden on the environment and human health.

Asbestos-containing products are banned for import to EU countries and USA since asbestos dust can provoke such dangerous diseases as asbestosis and occupational dust bronchitis [11]. The use of high-ash and high-sulphur coals is forbidden because of their considerable effect on ambient air and human health. These types of coal are forbidden for import not only in the above countries but also in China [12]

Threats.

A ban on import of certain products may result in decreasing sales or even closure of whole production facilities in general.

Environmental engineering tasks.

Bans on import of products presenting environmental and human health hazard may, on the one hand, produce a positive effect on the environment of the regions that used to import such goods but also cause considerable ecological problems for the enterprises and areas where these products were mined and refined. Major mining enterprises and refineries often operate a continuous process designed for a certain level of daily output. With the mining output decreasing, the effect on the environment does not decrease proportionately, staying on the same level for some sources or sometimes even increasing. Thus, for instance, such influencing factors as volumes of effluents to nearby reservoirs and water streams or dusts from waste storage and

5 There is no common definition of the term «green technologies». In EU, green technologies are understood as best available techniques [41]

mining sites do not decrease but may even increase as the enterprise starts experiencing a shortage of usable funds and, hence, is having to reduce expenditure on environmental protection.

The solutions to these problems could be:

1. Business diversification, i.e. pursuing new, more eco-friendly lines of business (for example, the Uralasbest company in the city of Asbest, Sverdlovsk Oblast, Russia launched a thermal insulation production facility)
2. Modernization (for example, introduction of technologies for additional treatment of coal to reduce its ash and sulphur content, as was done by the coal mining enterprises in Australia to ensure its sales on China's market, which in 2015 imposed a ban on imports of coals that do not meet environmental criteria. [12]

Challenge. Shortage of land in Russia, EU countries, USA and other mining countries and/or changes in land planning regulations.

Threats. Shortage of land entails the need to develop new, more compact waste dumping technologies. It is important to note that such technologies are not always environmentally safe. An example of technological solution of this kind is increased waste dump height. However, the higher the dump height, the more dust it generates.

Besides, sites for mining wastes may be allocated at some distance from the mineral mines, thus complicating the company's mining logistics, increasing expenses on waste rock transportation and making it necessary to develop complex approaches to their transportation.

Another threat arising out of the shortage of land is the probability of increased social tensions in areas where new dumping sites are supposed to be allocated. Vivid examples of social tensions associated with this threat are local protests in the Russian Federation during the construction of Tominsky GOK, a mining project in Chelyabinsk Oblast [13], and Dakota Access Pipeline protests in the USA [14].

One of the solutions to the above threats is introduction of new waste recycling technologies, which could help reduce volumes of waste and, accordingly, reduce areas of land needed for locating dumping sites.

These threats and challenges create significant risks for enterprises in the minerals sector, including environmental, economic, social, demographic, technological, technical, etc.

An important role in the resolution of the above problems and environmental risk reduction belongs to forecasting.

Forecasting is widely used in characterizing environmental and economic processes and tackling various environmental engineering and related problems, and it is described in detail in research literature and textbooks, and in regulatory documents.

In our opinion, all approaches to forecasting the quality of the environment in various industries can be conventionally divided into the following: regulatory; graphic, statistical and physico-mathematical.

The regulatory approach is closely connected with standardization [15-16] and calculation of prognostic concentrations of pollutants at specific points in ambient air, water, and soil. This approach is employed by supervising agencies for exercising environmental quality control at enterprises and sites, and it enables them to force businesses to implement certain requirements of the legislation of the Russian Federation.

Formally, this standardization-based approach [18] could be described as follows:

$$L = f(a);\ 0 < a < m,\ \ m = f(e) \qquad (1)$$

where L is a prognostic value that is a multiple of MAC at a specific point in the atmosphere, hydrosphere, or soil; m is the concentration of a pollutant in the atmosphere, hydrosphere, or soil; e is a group of indicators that determine the concentration of the pollutant in the atmosphere, hydrosphere, or soil.

This approach is currently mandatory for use at any industrial enterprise. A limitation to the use of this approach is the invariance of the production process parameters. If output is changed, it becomes necessary to re-compute the quality forecasts for air, water, and soil.

The main disadvantage of the approach is that it enables one to take into account only a limited number of factors which do not allow for the specifics of the mining complex.

Graphic approach.

We understand the graphic approach as environment quality forecasting based on specialized maps with essential information marked on them.

Formally, this approach to forecasting may be represented as follows:

L=*f* (a,b,c…) (2)

where L is the values of the indicators on the map, a,b,c are the factors on which L is dependent.

An example of this approach is ref. [17], in which the photogrammetric method was used for evaluating and forecasting ambient air quality. In this study, the researchers analyzed the structural elements of a stack plume (including average linear dimension, plume displacement, plume volume, outline to area ratio, and plume contour asymmetry). Using available data, this approach is employed for research-based planning of industrial enterprises and residential areas and development of protected and recreational areas around mining facilities. In our opinion, this method enables all processes to be assessed in dynamics in relation to any project or area. The doubtless advantages of the method are visual representation and forecasting of pollutant distribution in air. Its disadvantage is that it cannot be used in relation to facilities being designed, and for forecasting soil pollution. The applicability of this method to forecasting water body pollution requires additional studies. In ref. [19], a similar approach is suggested for forecasting the occurrence of dangerous natural processes. To this end, the authors propose to develop forecast maps (plans) showing the location of sites that have not yet been identified as such but are potentially dangerous in terms of rock burst.

Statistical approach.

The statistical approach includes such methods as trend analysis, correlation-regression analysis and some others.

The trend and correlation-regression analysis methods may be formally represented as follows:

$$\bar{y}_x = f(x)$$

where $\bar{y}_x$ is the arithmetic (conditional) mean of all possible values of parameter Y which corresponds to the value X=x.

Trend analysis is used for the forecasting purposes in [20-25] to tackle the following tasks: assessing the influence of meteorological parameters on technogenic pollution with carcinogenic chemical substances; forecasting oil prices; planning operations in current economic contexts; and forecasting the demographic situation.

The correlation-regression method is used in [26-32] for solving the following problems: forecasting an appropriate dose of the coagulant needed for the treatment of industrial effluents discharged into a river; selecting a method for protecting the environment against pollution in asbestos mining; performing research into possibilities of reducing the depletion of the planet's water resources; forecasting coke production macroeconomics under uncertainty; addressing the issue of sustainable social and economic development of an area; forecasting agricultural output; forecasting gas-well flooding start and end times; forecasting market demand for mining machinery and equipment in the long term.

The essential limitation of the trend analysis method is that it allows one to take into account only one factor that influences a specific process, while in the correlation-regression method it is impossible to account for all related factors at once.

Physico-mathematical modeling methods, including neural networks, fuzzy sets and numerical methods, are widely used for tackling various environmental engineering and related tasks, such as in [32-36] for selecting a relevant water-treatment reagent, forecasting agricultural crop yields, rationalizing factors that influence complex decision-making in safe colliery design; substantiating factors that influence the forecasting of dangerous natural processes, for modeling the processes of geofiltration and hydrogeomigration. We believe that these methods are very important today; however, their use requires considerable knowledge in the field of mathematical modeling and mathematical statistics and application of specialized software, which, in our opinion, does not allow them to be used by companies for efficient forecasting of this or that situation.

Today forecasting methods find various applications in the minerals sector, including technological, technical, organizational, economic, health and safety, safe mining and environmental engineering tasks. However, many of the authors do not give proper attention to the forecasting of environment quality, especially at official level. Current issues that are resolved by forecasting methods are largely narrow-focused and aimed at isolated environmental engineering tasks, including those in the minerals sector.

It is important to note that, in the domestic and international literature, the forecasting methods are practically never used for addressing complex environmental safety issues of mining enterprises in a comprehensive way. Besides, the forecasting methods used do not account adequately for factors characteristic of enterprises in the minerals sector, such as mineral species, method of concentration, ore grade, mining method and other technological factors.

In our opinion, effective comprehensive forecasting of environment quality in mining areas should employ a systemic eco-technological approach that would allow for a whole range of qualitatively different factors, including technical, technological, economic, demographic, logistical, geological, hydro-geological, climatic and ecological ones. All these factors should be considered in a systemic way, with appropriate weight coefficients given to each of them. Also, different factors in differing conditions may allow the use of different methods of forecasting. Thus, in cases where essential baseline information is lacking, it should be possible to use expert judgment-based forecasting [37, 38]; if a significant amount of information is available over a long period of time, then trend analysis forecasting could be employed; whereas a final prognostic forecast would require the use of a multifactorial method of correlation-regression analysis and/or neural networks and fuzzy sets. The latter make it possible to consider several factors at once, take into account the seasonal component, and feature machine learning capabilities.

The above-mentioned systemic eco-technological approach, if used for forecasting the quality of the environment, should be versatile to allow comprehensive, efficient and prompt forecasting of environment quality to be performed by enterprises in the minerals sector employing various mining and refining technologies under various mining, geological, climatic and environmental engineering conditions. In so doing, the executive management of an enterprise should be enabled to make decisions efficiently concerning control of the nature-technology system under uncertainty.

In general terms, the systemic eco-technological approach proposed in this paper could be represented as follows:

$$S = f(a, b, c);$$

where S is a systemic indicator characterizing the environmental situation for an enterprise or an area, based on which the management of this enterprise or area could make relevant management decisions; a, b, c represent a set of qualitatively different factors, including technical, technological, ecological, demographic, geological, hydro-geological, etc., translated into a dimensionless form by the method of qualitatively different indicators [38, 39, 40]. The values of these factors are obtained by means of various forecasting techniques (judgmental, statistical, probabilistic, etc.) and presented in numerical and graphic forms with the use of GIS.

Thus, based on the foregoing, we can conclude that at the present stage of its development, the mining science should enable comprehensive forecasting of possible threats and challenges faced by an enterprise and their consequences from the point of view of ensuring environmental and economic security and interrelation with ecological factors. To this end, it is necessary to develop an algorithm for the application of available forecasting methods. Furthermore, in relation to the above-stated problems these methods may be used both separately and collectively depending on the objective in view. Thus, for instance, initial data could be processed, depending on their amount and quality, by different forecasting methods (for example, it makes sense to use the expert-judgment based method for dealing with weakly structured or insufficient data); long time series data with no essential influence of other factors could be subjected to trend analysis, while data influenced by a number of factors at once may need to be considered by the correlation-regression analysis method. Once initial data have been processed, a high-level forecast may be produced using fuzzy sets and/or neural networks, which enable one to take into account the seasonal component and uncertainties, and possess machine learning capabilities.

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