Industrial and environmental safety in the extractive natural resource management for the needs of agriculture

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Abstract. The development of agriculture, primarily crop production, is determined by the availability of the necessary amount of phosphorus-containing fertilizers. In order to meet the needs of agriculture in phosphorus mineral fertilizers, extractive nature management is carried out in a number of regions of the world through the extraction and processing of apatite and phosphorite ores. At the same time, it is important to ensure the minimum permissible impact on the environment and natural water systems. For these purposes, methodological approaches are proposed, through which it is possible to monitor the state of objects and processes of mining production and take timely measures to ensure industrial and environmental safety. The author proposes a structure for complex research and monitoring of objects and processes in extractive nature management, based on the integration of interdisciplinary research related to the earth's surface.

1. Introduction

Studies of the special commission of the European Union have revealed significant increase in the world's population, with a forecast to 7.8 bln people, which will have a fundamentally significant impact on the problem of providing the population with food [1, 2]. Food is supplied by agricultural farms by more than 90%, primarily by crop production. The necessary increase in agricultural production can be achieved by increasing the yield of land. The latter is largely determined by the introduction of mineral fertilizers into the soil, primarily, phosphorus-containing ones [3, 4, 5].

According to the EUC report [1], the upper part of the earth's crust contains $4 \times 10^{15}$ tons of phosphorus-containing mineral raw materials, but technologically, with the availability of modern technologies and equipment, $2 \times 10^{8}$ tons of reserves are available for industrial development. At the same time, the report notes significantly less amount of economically and geopolitically available reserves. At the same time, to the date, for the normal life support of all mankind, it is necessary to use about $3 \times 10^6$ tons per year [2-6].

In order to meet the needs of agriculture in phosphorus mineral fertilizers, extractive nature management is carried out in a number of regions of the world, through the extraction and processing of apatite and phosphorite ores [4, 5, 7, 8]. At the same time, it is important to ensure the minimum permissible impact on the environment and water systems.

The purpose of this study is to substantiate methodological approaches to ensure industrial and environmental safety in the extractive natural resource management for the needs of agriculture.
2. Methods

Mining production is a set of natural-technical objects and processes (figure 1) in combination with the mining workings, mining machinery and equipment necessary for its implementation. One of the main requirements is along with the main goal of mineral extraction to ensure safe and environmentally acceptable mining environmental management [4].

The main technical objects of mining nature management are industrial buildings, underground workings, an open pit, dumps, and a tailings dump. The technical objects are integrated and interconnected with the surrounding (host) natural systems, as a result of which the main processes are formed during the mining use of natural resources: water whirlpool in nature, mutual (from natural water bodies into mine workings and vice versa) infiltration of water, technological whirlpool, dusting (emission of small particles and gases into the atmosphere).

The mining of natural resources forms huge volumes of mining waste, which are stored in dumps, as well as in the reservoirs of liquid waste from mineral processing plants - tailings [9]. It is the mining wastes, belonging to the category of especially hazardous objects, which require special attention when ensuring the industrial and environmental safety of extractive nature management [9-16].

For industrial and environmental safety purposes, this study uses interdisciplinary methods and approaches integrated into a multilevel monitoring system [17-21].

3. Results

Studies have revealed that the tailings dumps of mining enterprises extracting phosphorus mineral raw materials are located in ravines or in the hollows of streams (small rivers) [16, 17]. Over a long period of mining natural resource use, tailings dumps have increased, occupy larger and larger areas, and have acquired significant volumes.

For example, on the Kola Peninsula the intensive extractive management of natural resources for 90 years has formed large tailing dumps with a total area of over 45 million m$^2$, in which more than 1 billion m$^3$ of waste with a total weight of over 2.5 billion tons has been accumulated by today.
According to the data [18], three tailing dumps of Apatit JSC have accumulated over 1 billion tons of waste, with a total volume of almost 500 million m$^3$; Kola MMC JSC - about 500 million tons (over 220 million m$^3$); OLCON JSC - slightly less than 500 million tons (210 million m$^3$); Kovdorsky GOK JSC - about 370 million tons (160 million m$^3$). At that, 3/4 of the waste volume belongs to the phosphorus mining.

Violation of filtration and functionality and loss of stability of the tailings dams lead to an emergency situation, which results in significant socio-economic damage to the population, civil and industrial buildings, roads, engineering and technical communications, etc. The accident entails financial losses (lost profits due to the shutdown of the enterprise), additional costs (repair and restoration work on dams, roads, power lines, devices and mechanisms, etc.; elimination of the consequences of the accident; restoration of the surrounding natural systems), as well as fines for environmental pollution and environmental damage [12-17].

Therefore, in order to ensure industrial and environmental safety, a structure for integrated research and monitoring of objects and processes in extractive natural resource management has been developed (figure 2).

**Figure 2.** Structure of complex studies and monitoring of objects and processes in mining nature management.

4. Discussion

The main problem of monitoring and diagnosing the state of tailing dumps of extractive nature management enterprises is that the origin of dangerous filtration and deformation processes occurs in the subsurface weakened and inhomogeneous soil zones of the dams, and, at the initial stage, is hidden from visual and ground-based instrumental observations. The occurrences of such processes can be recorded at an early stage only with the use of studies of different scales and at different levels, which allow, among other things, to control both individual components and the entire tailings storage facility as a whole, as well as the associated natural and technical systems [18-22].

Therefore, the developed structure of integrated research and monitoring of objects and processes in extractive natural resources management (see figure 2) integrates, on the one hand, necessary modern methods of continuous monitoring and diagnostics of tailing dumps as open dynamic natural-
technical systems, and is focused, on the other hand, on the rapid detection at early stages of geoindicators of loss of strength and stability, and a decrease in the reliability of the waste storage as a whole.

The proposed methodological approaches to ensuring industrial and environmental safety in extractive nature management are based on the integration of interdisciplinary observations at various levels related to the earth's surface (see figure 2): remote level (GPS geodesy, optical, spectral and radar images of spacecraft); above-surface level (aerial photography of various types using UAVs); surface level (geodetic surveys and measurements, laser and radar surface scanning); subsurface level (hydrological measurements, seismic tomography, GPR scanning) [17-21]. This makes it possible to solve multi-scale monitoring tasks: from soil grains (millimeters) to a tailing dump as a whole (tens of square kilometers). An important addition to the integration of multi-level observations is the computer level: the use of digital processing technologies, the construction of 3D models and hydrogeomechanical modeling [23].

5. Conclusion

The needs of agriculture in mineral phosphorus fertilizers obtained as a result of mining natural resource management have been analyzed. It has been revealed that for the normal life support of all mankind, $3 \times 10^6$ tons of phosphorus fertilizers are needed per year. It is shown that mining production is a set of natural and technical objects and processes that have a significant impact on the environment and water systems.

Special attention is paid to mining wastes which covers an area of up to 45 million $m^2$ and exceed the volume of 1 billion $m^3$. It is the waste that poses the greatest hazard, and therefore, in order to ensure the industrial and environmental safety of these facilities, a structure for comprehensive research and monitoring of their condition in extractive environmental management has been developed.

The structure of research and monitoring of objects and processes in extractive natural resource management integrates, on the one hand, the necessary modern methods of continuous monitoring and diagnostics of waste storage facilities as open dynamic natural-technical systems, and is focused, on the other hand, on the rapid detection at early stages of geoindicators of loss of strength and stability of dams, and reduction in the reliability of the structure as a whole.

Methodological approaches to ensuring industrial and environmental safety in extractive natural resource management have been proposed, which are based on the integration of interdisciplinary observations at various levels related to the earth's surface: remote (satellite), above-surface (aerial photography), surface (ground) and subsurface (underground) levels. This allows solving multi-scale monitoring tasks: from soil grains (millimeters) to the object as a whole (kilometers). An important addition is the use of digital processing technologies, the construction of 3D models and hydrogeomechanical modeling of objects and processes.

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