

# *Ecological Substantiation of System for Managing Toxic Mining Waste in Primorye*

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**Abstract**—It is shown that natural-mining systems were formed as a result of economic activity in the last century of the mining enterprise of the Primorye Territory Khrustalnensky mining and processing plant (now closed). It is proved that the intensive development of mineral deposits in the last century contributed to the accumulation of toxic waste in large quantities stored in the tailing dump, which led to large-scale man-made contamination of the ecosystem and the emergence of ecologically caused diseases in the population of miner settlements. The methods of ecological rehabilitation of the tailing dump surface have been developed, the novelty of which has been confirmed by the Patents of the Russian Federation (2013, 2015, 2017).

**Keywords**—toxic waste management system; technological solution; tailing dump; environment; mining and environmental monitoring; reclamation

## I. INTRODUCTION

The formation and accumulation of mining waste is an integral part of the life processes of society. Currently, in the Far Eastern Federal District (FEFD) about 100 million m<sup>3</sup> of such waste located in the territories of mining areas are generated annually, more than 40 million m<sup>3</sup> of which is in the Primorye Territory.

As a result of the storage of waste in tailing dumps containing toxic waste, often in the immediate vicinity of settlements, environmental pollution occurs. This circumstance predetermines the need for such development of waste management systems which will be aimed primarily at reducing their negative impact on the environment.

On the other hand, for most of the settlements located on the territory of mining areas, due to the small number of the population living in them and the limited amount of own funds

allocated for waste disposal, the search for cooperation options and specialization in the field of waste management is becoming increasingly important.

Thus, the development of an environmental assessment of the development of toxic waste management systems in mining areas, taking into account the environmental consequences and consistency of the interests of the population, the state and entrepreneurs to prevent pollution of the environment, is a relevant scientific task. In this regard, the goal of the work is to provide environmental justification for the provisions of the toxic waste management system for mineral processing, to ensure rational economic decisions in environmental management based on the environmental assessment mechanism and the choice of waste management options for the mining region.

The idea of the work is the need to create a rational system of management of waste mining areas, contributing to the improvement of the environment when making economic decisions in environmental management.

## II. MATERIALS AND METHODS

The research material is the waste of tin-ore raw materials accumulated in the last century, stored in tailing dumps within the influence of natural-mining systems in the Primorsky Krai of the Kavalersky district. The subject of study - the economic and environmental processes that occur in the treatment systems of mining waste area of the study.

The methodological basis of the study was the teaching of academician V.I. Vernadsky on the biosphere and noosphere [1] and the provisions of the theory of man-made biogeocenoses by B. P. Kolesnikov and L. V. Motorina [3, 4].

In the process of researching the problems, generally accepted methods and approaches were used.

### III. RESULTS AND DISCUSSION

In studies of scientists from different regions of Russia [2, 7–12], a waste management system is a set of measures for collecting, transporting, recycling, recycling or disposing of them, as well as monitoring these processes.

Analysis, synthesis and systematization of literary data suggest that the waste management system includes the use of a complex of various methods of waste processing, focused on regional and sectoral applications (Komachkova et al. [5], Krupskaya [6], Chertes et al. [10-11] and others.). A review of the literature on this problem shows that the problem of the household waste management system is fully covered. Unfortunately, there is almost no information on mining waste.

Our research has shown that the intensive development of mineral deposits in the past century has contributed to the accumulation of toxic mineral processing waste in large quantities stored in a tailing dump. So, only in Primorsky Krai more than 40 million m<sup>3</sup> is accumulated annually (fig. 1). As a result of the economic activity of the mining enterprise “Khrustalnensky mining and processing plant” (MPP) in the last century natural-mining systems were formed here. This led to large-scale technogenic pollution of the ecosphere and the emergence of environmental-related diseases in the population of mining villages.

Years of experience in researching the storage and storage of waste products from tin ore raw materials have led to the conclusion that, under the influence of technogenesis, they undergo processes of weathering and transformation into new forms that migrate with groundwater and air flows. Studying the environmental consequences of the negative impact of tailings on the ecosphere proved that their term is unlimited. It is not by chance that after more than 20 years after the bankruptcy of the mining complex “Khrustalnensky MPP”, man-made objects (including waste, tailings) remain the main sources of pollution of biosphere components.

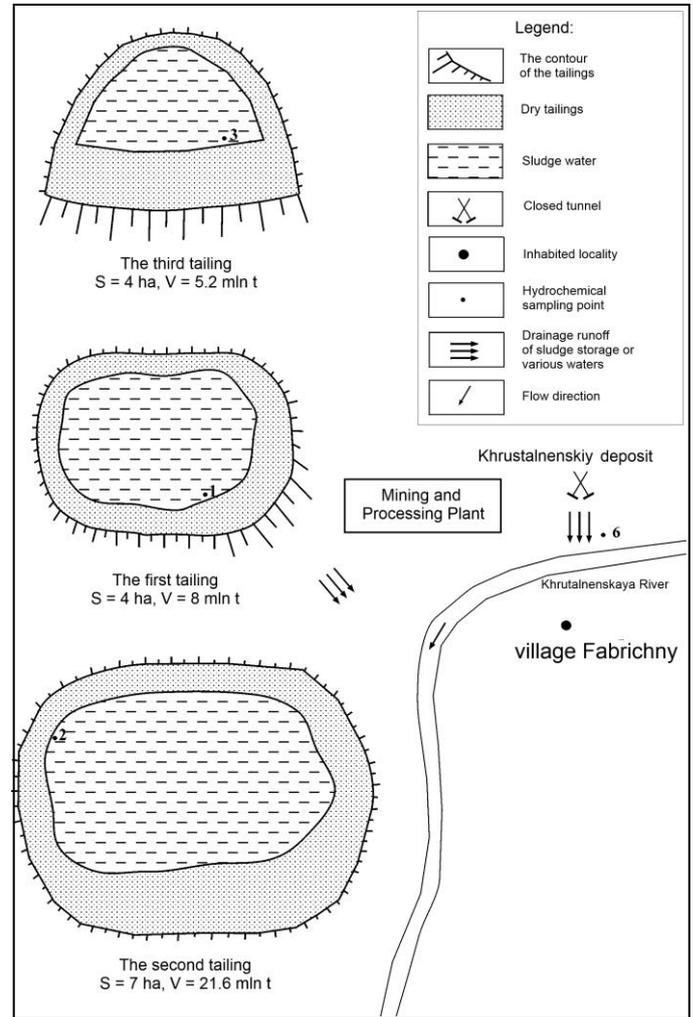


Fig. 1. The layout of the tailings of the first factory in Fabrichny (Kavalerovskiy district)

In this regard, the general direction of preventing the further transformation of environmental components within the influence of the natural-mining technogenic system is the development and application of fundamentally new technological solutions aimed at creating a waste management system, reducing and eliminating environmental damage accumulated in the last century (mineral processing waste, raw materials) by the former mining enterprise “Khrustalnensky MPP”.

It is known that the basis of waste management is their disposal and disposal. At the end of 2017, in the Kavalerovskiy district of the Primorye Territory, the share of recycled, neutralized waste in the total volume of waste generated in the process of production and consumption was too small (0.003%).

As part of the justification of the toxic waste management system stored in the tailing dumps, in the Primorye Territory, the following areas are needed: development of a concept for a waste management system for mineral processing, the main objectives of which are:

1) development of principles for ensuring environmental safety of damage to waste processing of mineral raw materials accumulated in the past century by the activities of a closed mining enterprise, and principles of mining and environmental monitoring of changes in the components of the biosphere within the influence of mining systems;

2) development of methods aimed at minimizing the impact of toxic waste on the environment and maximizing their involvement in economic circulation;

3) attracting investments in the development of the waste management industry in the Kavalеровsky district of the Primorye Territory;

To achieve these goals, you need an integrated and systematic solution of the following tasks:

1) developing the waste management system, taking into account the territorial location of settlements and the availability of transport links and its seasonality;

2) reducing the volume of waste streams through the development of technologies for processing secondary raw materials, organizing their utilization and recultivation of the surface of the tailing dump;

3) improving the mechanisms of interaction between government bodies, local governments of municipalities of the autonomous region and organizations in the field of waste management;

4) increasing the ecological culture of the population and training in the safe handling of waste;

5) developing a program for the environmental rehabilitation of the mining area of the study area (that is, environmental damage - accumulated waste mineral processing of the past economic activities of mining enterprises).

The program assumes: 1) the establishment of priority goals and objectives for the Administration of the Primorye Territory of the Kavalеровsky District and individual executive authorities of the Primorye Territory, the consolidation of these goals and objectives in the Program for the Socio-Economic Development of the Primorye Territory for the medium term; 2) development of a system of indicators and target indicators of the ecological state of the environment; 3) the creation of an information system for the interaction of public authorities of the Primorye Territory in order to inform the population about the environmental situation in the study area; 4) creation of an information system for mountain-ecological monitoring (development of its principles) and prediction of indicators and target indicators of the state of the ecosphere.

Conducted research in the studied area (within the influence of the closed mining enterprise "Khrustalnensky MPP") allowed us, based on the proposed principles of disposal, recycling and processing, to give the following definition to the concept of waste management systems accumulated in tailings as a result of its past economic activities. This is a set of measures for recycling, recycling or their disposal, based on the principles of environmental safety

and mining and environmental monitoring of these processes and changes in environmental objects, as well as the implementation of the forecast of the environmental situation. In our opinion, the development of measures should be carried out in accordance with the principles of maximum use of resources of natural ecosystems of the studied area, man-made and external systems (forest and mining complexes, their waste), taking into account an integrated approach, system analysis and phasing.

The results of the study allowed to propose new technologies aimed at eliminating the accumulated environmental damage to past economic activities of the mining and mining industry using biological potential.

In this regard, experimental studies were conducted in the greenhouse of the Far Eastern Research Institute of Forestry, the purpose of which was to study the possibility of using phototrophic bacteria (PTB) in solving the issue of recultivating disturbed lands by a tailing dump containing toxic waste. The experiment was carried out in eleven-fold containers: with the introduction of phototrophic bacteria onto the surface of toxic waste collected from the tailing dump (legume-cereal grass mixture (clover, fescue, and larch) were used for sowing seeds). Waste mineral processing was taken from the tailing dump containing toxic wastes. PTB irrigation was performed after seeding of plants at the rate of 1.5 liters of phototrophic bacteria per 1 m<sup>2</sup>. The optimal dose (1.5 liters of PTB per 1 m<sup>2</sup>) was selected empirically based sanitary and environmental characteristics of the substrate and to achieve high productivity phytocenosis generated on the surface of the tailings waste. In control SFRs not used.

Accounting of the harvest was carried out by mowing in the earing phase of cereals. The proposed method is effective because it allows you to increase the productivity of the cultural phytocenosis and at the same time improve the sanitary and environmental properties of the substrate (toxic waste from the processing of tin ore raw materials) due to changes in the desired directions of PTB formulations.

The solution of the problem of reducing the negative impact of toxic waste on ecosystems is due to a new technical result consisting in a highly effective activity of a bioactivator (PTB) and is implemented by the interaction of PTB with a substrate (toxic waste). Phototrophic bacteria improves the water-physical properties of the substrate and, not having the ability to organotrophic nutrition, extracellularly emit a variety of vitamins, nucleotides, amino acids and ATP, thereby attracting other microorganisms, with which they receive the necessary for their nutrition low-molecular organic compounds. And this is one of the features and usefulness of PTB in the elimination of toxic and harmful compounds for organisms. The best results (by biomass) were obtained in the variant with the introduction of PTB (the yield was 23,400 kg/ha).

Figures 2 and 3 show the results of an experiment set up in a greenhouse with the introduction of PTB in containers containing toxic waste and sowing legume-grass mixture.



Fig. 2. Control (toxic waste) is missing. PTB is not made



Fig. 3. The results of the experiment in shoots greenhouse with the use of PTB

As follows from the experimental data, the version with the introduction of PTB contains a sufficient amount of energetic substances in the form of organic matter and nutrients due to the activity of phototrophic bacteria, which contributes to the biological processing of the substrate under study. In addition, heavy metals are bound by carbon of organic matter and immobilization of the main amount of heavy metals to non-hazardous limits. In variants without introducing PTB (control), seedlings did not appear (mold was found).

Thus, the proposed method provides a successful solution to the problem of reducing the negative impact of toxic waste from the processing of tin ore stockpiled in a tailing dump on environmental objects and improving the efficiency of reclamation through the use of PTB.

The beneficial effect of PTB on the formation of soil structure, as well as the growth and development of plants (legume-grass mixture), has been revealed.

The positive results obtained in the greenhouse made it possible to conduct an experiment under production conditions in the autumn of 2018. The legume-grass mixture was sown on the surface of the former mining enterprise tailings (on an area of 0.25 hectares).

Figure 4 shows an option under production conditions, where seeds of legume-grass mixture and larch seeds are sown on the surface of a tailing dump containing toxic waste) and produced based on 1 m<sup>2</sup> of irrigation in the amount of 1.5 liters of phototrophic bacteria.



Fig. 4. Experimental results under production conditions using the PTB (at the tailing dump of the former Khrustalnsky MPP)

The research was carried out as follows: first, the disc harrow was loosened at the tailing site, containing toxic waste to a depth of 5-10 cm, then sowing legume-grass mixture and larch at seed rates of 25 and 15 kg, respectively, with 98% seed germination, after which watering PTB is carried out in the amount of 1.5 liters per 1 m<sup>2</sup> of the recultivated area

On the basis of the conducted research, the possibility of using the PTB in solving the problem of eliminating the accumulated environmental damage of the past economic activity of the tin industry in the Far Eastern Federal District has been proved.

The positive results of experimental studies in the greenhouse and production conditions (experiments with the sowing of legume-grass mixture and larch) suggest the possibility of recultivation in the technogenic formations of the former mining enterprise "Khrustalnsky MPP" using PTB. An application for an invention has been filed and a Patent of the Russian Federation has been received (2015, fig. 5). In 2019, in the spring it is supposed to conduct a production inspection of the reclaimed area.

The ways of ecological rehabilitation of the surface of tailings containing toxic waste, consisting in the rational use of natural resources, including mineral resources, have been outlined. Three stages of the Program implementation were

proposed: Stage 1: “Assessment of the extent of accumulated environmental damage (2016–2019)”; Stage 2 “Assessment of the results of the implementation of priority projects, creating conditions for replication of tested technologies (2020 - 2022)”; Stage 3 “Large-scale liquidation of accumulated environmental damage on the basis of developed and tested technologies (2023-2025)”.

methods aimed at minimizing the impact of toxic waste on the environment and their maximum involvement in economic circulation. The authors of the article proposed a technological solution for the reclamation of the surface of tailings, the novelty of which was confirmed by patents of the Russian Federation (2013, 2015, 2017). The ways of ecological rehabilitation, consisting in the rational use of natural, including mineral and raw material resources, have been outlined. Three stages of program implementation have been proposed: Stage 1: “Assessment of the extent of accumulated environmental damage; Stage 2: Evaluation of the results of the implementation of priority projects, the creation of conditions for replication of tested technologies; Stage 3: “Large-scale liquidation of accumulated environmental damage on the basis of developed and tested technologies.



Fig. 5. Patent of the Russian Federation on the method of reclamation of the surface of a tailing dump containing toxic waste using phototrophic bacteria

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The ecological substantiation of the provisions of the toxic waste management system for the processing of mineral raw materials, ensuring the adoption of rational economic decisions in environmental management based on the environmental assessment mechanism and the choice of treatment options for area mining are given. The authors have proved the need to create a concept for the implementation of this problem, including the principles of ensuring the environmental safety of mineral processing waste accumulated in the past century by the mining enterprise, and the principles of mining and environmental monitoring of changes in the biosphere components within the influence of mining systems, as well as the program of environmental rehabilitation of the mining territory. An important aspect is the development of

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