Features of technological water pollution during the development of the tin-ore raw materials in the borders of the tailings dam “Dalnegorsky GOK”

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Abstract. The article presents a long-term study of the features of technogenic water pollution within the influence of technogenic systems (tailings dams containing toxic heavy metal compounds). In this regard, the purpose of the work was to study the specifics of water pollution during the development of tin ore raw materials at the mining enterprise “Dalnegorsky GOKZ” of the Primorsky region to ensure its environmental safety. Based on the goal, the following tasks are formulated: (1) analysis, synthesis, and systematization of literature data on the problem; (2) assessment of the impact of waste stored in tailings on water and other environmental objects; (3) development of proposals for ensuring environmental safety of technogenic pollution. Research has established that the high toxicity of waste processing of tin ore raw materials stored in tailing dams located near mining villages, contributed to intensive pollution not only of the air basin, soil, vegetation (MPC excess was from 2 to 34 times), but also surface and groundwater (excess background readings were 5-9 times). On the basis of the conducted research, proposals were made to ensure the environmental safety of technogenic pollution.

1. Introduction

In the past century, tin sulfide and polymetallic deposits were mastered in the Far Eastern Federal District (FEFD). As a result of the economic activities of the mining tin-mining enterprises during this period, a large amount of mineral processing waste has been accumulated and stored in the tailings dump. Analysis of the existing information and our own results led to the conclusion that the floodplains of many valleys occupied by dumps, tailings dams, septic tanks, etc., have been almost completely changed, over more than a century of mineral resources development in Primorsky region [5, 6, 8 and others]. It is known that the quality of water in modern conditions is formed mainly under the influence of man-made factors, as evidenced by studies of a number of scientists [4 and others]. The satisfactory condition of the waters is maintained only in the upper reaches of the rivers, sharply deteriorating below the mining village or the mining complex. Surface waters reflect in general terms the chemical composition of the ores of the deposits being mined, for example, the draining mining areas of the south of the FEFD [4-6, 8, and others].

According to the data of various authors [7 and others], soils and bottom sediments take up to 70% of the total man-made loads. The use of highly toxic reagents is a characteristic feature of the
technology in the processing of mineral raw materials in a mining enterprise. It is known that industrial wastewater discharged into water bodies contains a large amount of pollutants. There is intense pollution of the atmosphere, biosphere, lithosphere, and especially the hydrosphere. In connection, the purpose of the work was to study the specifics of water pollution during the development of tin ore raw materials at the mining enterprise “Dalnegorsky GOK” of the Primorsky region to ensure its environmental safety. The research had the following tasks: (1) analysis, synthesis, and systematization of literature data on the named problem; (2) assessment of the impact of waste stored in tailings on water and other environmental objects; (3) development of proposals for ensuring environmental safety of technogenic pollution.

2. Objects and Methods
Long-term studies at the mining enterprises of the Far-Eastern Federal District have been conducted from the beginning of the 1990s to the present. The teaching of academician V. I. Vernadsky on the biosphere and the noosphere served as the methodological basis [2] and the main provisions set forth in the Program and methodology for the study of man-made biogeocenoses [9]. Modern instrumental and traditional physico-chemical, chemical, and biological methods and modeling methods used in the research process. The object of the study was the natural mining industrial man-made systems within the influence of the tailings dam of the “Dalnegorsky GOK” of the Primorsky region (waste, tailings dams, man-made soils, biota, surface and groundwater).

The subject of the research is the distribution and accumulation of compounds of toxic chemical elements in environmental objects and the improvement of the system of post-treatment of industrial waste water in the process of tin production.

3. Results and Discussions
Analysis, synthesis, and systematization of literature data suggests that waste processing of tin-ore mineral production is one of the main sources of pollution of the hydrosphere, atmosphere, lithosphere, and biosphere [1, 6, 7]. To date, large volumes have been accumulated. A huge amount of various pollutants, including heavy metal compounds, arsenic and cyanides contained in industrial wastewater, has a negative impact on the ecosphere. Therefore, when released into reservoirs, they violate the processes occurring there and significantly affect the biological equilibrium, which leads to a change in both its physical and biological components. Waters become unsuitable for household needs. Unfortunately, the problem of biological treatment and purification of industrial wastewater in the form of pulp with the use of higher water vegetation has not been practically studied in the Far Eastern Federal District, including in the Khabarovsk and Primorsky regions. Water bodies and bottom sediments in them are informative when analyzing the ecological and geochemical environment within the influence of man-made systems. Our research has established that the high toxicity of waste processing of tin ore raw materials stored in tailings dams located near mining villages, contributed to the intensive pollution of not only the air basin, soil, vegetation (MPC excess was up to 34 times), but also surface and groundwater, as well as bottom sediments. The condition of surface waters draining tin ore areas is due to the chemical composition of the ore of the deposit being mined and waste. Unorganized discharge from the territory of the production sites of the object under study makes a large contribution to the pollution of surface waters. They found an excess of the MPC (more than 4-7 times) of the fishery water use in surface run-off on suspended substances, oil products, full biochemical oxygen consumption (BOC_full) and heavy metals compounds. Surface watercourses and groundwater are intensively polluted within the influence of tailings dams of closed mining enterprises with toxic chemical compounds: zinc, copper, lead, iron, nickel, cobalt, manganese, arsenic compounds whose content exceeds background values from 1.6 to 20 times or more. (fig.) (such as: the Khrustalnensky GOK of the Kavalerovsky district of the Primorsky region; the Solnechny GOK of the Solnechny district of the Khabarovsk region). The results of our research
show that in the settlements located near the mineral deposits being explored there is a high level of pollution of water sources.

Figure 1. Migration of Zn compounds in the aquatic environment.

Figure 2. Migration of Pb compounds in the aquatic environment.
Figure 3. Migration of As compounds in the aquatic environment.

Figure 4. Migration of Fe compounds in the aquatic environment.
Works by Far Eastern researchers [1, 7, and others] indicate that the content of heavy metal compounds in reservoirs within the influence of tailings is much higher than background, for example, Sn is almost 40 times, and from 15 to 40 times of Mn, Cu, Pb, Zn; and the length of the scattering flux extends from 1.5 to several tens and even hundreds of kilometers [3 and others]. A significant amount of heavy metal compounds (copper, zinc, nickel, etc.) of the wells found by us in drinking water in the study area is associated with the mining and industrial component. The results of the study indicate that the excess, for example, for lead is 2.6 times, and it is more than 20 times for arsenic. The pollution of the ecosphere as a whole and the disruption of the background indicators of the study area are facilitated by the occurring hypergenic and technogenic processes in the waste stored in the tailings dam, due to the mechanism of sulfide oxidation and hydrolysis. The formation of aggressive highly concentrated microporous solutions containing compounds of toxic elements that are carried outside the production area is the result of these processes. Compounds include: Cu, Zn, Pb, Cd, As, Fe, Mn, Co, and As.

Knowledge of the revealed patterns in the formation of the technogenic system and the processes taking place in it allows us to develop a set of measures aimed at reducing its negative impact on environmental objects and human health. Ecological and social security for all living things, including humans, should be ensured in the region in the near future, which can be done by improving the technology of cleaning and after-treatment of industrial wastewater, carrying out the reclamation of the surface of tailings with the use of the potential of biological systems (novelty ways confirmed by Patents of the Russian Federation (2013, 2014, 2015, 2017).

4. Conclusions
According to the set of indicators, the environmental situation in the study area is assessed as critical, catastrophic, and to a lesser extent satisfactory. Water bodies and bottom sediments in them are informative when analyzing the ecological and geochemical environment within the influence of man-made systems. Our research has established that the high toxicity of waste processing of tin ore raw materials stored in the tailings dams located near the mining villages, contributed to the intensive pollution of not only the air basin, soil, vegetation (MPC excess is up to 34 times), but also surface and groundwater (excess of background indicators was 5-7 times). On the basis of the conducted research, proposals were made to ensure the environmental safety of technogenic pollution.
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