Disposal of open-pit and wastewaters of Evraz Kgok

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Abstract

The effectiveness of water management in mining companies is largely controlled by mining, geological, natural and man-made conditions of the area. The use of dewatering and thickening of tailings of wet magnetic separation with installation of the process water circuits, and a reduction of wastewater discharge and seepage losses will be critical for ensuring the ecological efficiency of water balance management, which makes it possible to efficiently utilize the groundwater resources in the area for the establishment of water supply systems.

Keywords: water management, wet magnetic separation tails, thickening.

Rationale for study

The mining industry is a major contributory factor to the persistent environmental devastation and can have substantial geochemical effects on natural waters of the mining site and adjacent areas. Safety and environmental control of mining activityare largely dependent on the adopted water supply and wastewater disposal schemes. Minimizing the quantity of contaminated quarry wastewater inflow into the natural environment is a priority task for managing the water balance at a mining site. The order is to reduce industrial load on the environment and to maintain the ecological and resource potential of the territory.

According to the national waste management standards in the mining industry, special attention should be paid to the safety of tailings dams, tailings dewatering and thickening, dry storage of condensed wastes and minimization of the amount of discharge into natural water bodies (wastewater treatment with quality control) (GOST R 55100-2012).

EVRAZ KGOK (Kachkanar Mining and Processing Enterprise) is the largest mining company in Russia and the only company producing low-grade vanadium-titanium magnetite iron ores. The enterprise's annual output is approximately 55 million tons of iron ore (EVRAZ KGOK 2018; Vlokh 2016).

The high production efficiency of EVRAZ KGOK and low-grade sources of titaniferousmagnetite iron ore generally require beneficiation. As a result of the use of large amounts of water, which generates substantial volumes of wastewater and tailings. In 2014-2016, the annual level of water use at EVRAZ KGOK amounted to 32.6-40.8 million m^3. About 50% of this volume has been discharged to the watercourses of with plant effluents (State Report 2017).

In addition to wastewater discharge, environment contamination from this site can be attributed to beneficiation tailings produced from wet magnetic separation. Beneficiation tailings in the volume of about 45 million tons are discharged tothe tailings disposal site with an area of about 12 km^2 (Deryagina 2013). The disposal site is an aggradational tailings pond located on the slope of the Vyya River valley and Rogalevka River, its right-hand tributary.

The large proportion of all wastewater produced by the plant is accounted for by quarry wastewater and operational effluents pumped into the tailings pond, which stores tailings from magnetic beneficiation. About 3% (15.0 million m^3/year) of this volume is discharged through the foundation of tailings dams, directly seeping to the watercourses in the adjacent areas.

The chemical composition of natural waters depends on the geological environment of the area. The geology of the area is dominated by various metamorphic and igneous rocks overlain by a thin layer of loose

Quaternary deposits. The confinement to the ore depositis the mina factor controlling the natural hydrochemical background of the area and results in the high iron, titanium, vanadium, chromium, manganese, cobalt, copper, zinc, and molybdenum content of natural waters (Ushakova, 2012). The absence of readily soluble rocks in the geological section leads to low TDScontent of natural waters. The total amount of annualwater inflows to open-pit areas is 7-8 million m^3. The development of the deposit, promotes the transition of some of the chemical elements contained in the rocks into soluble forms. The compounds are discharged into surface water and groundwater with effluents and result inwater contamination.

A substantial factor that causes changes in the chemical composition of natural waters is the use of blasting agents in mining operations. As a result, a high content of nitrogen compounds is recorded in wastewater and natural waters. Nitrogen compounds are nitrite, nitrate, and ammonium ions. The presence of ammonium ions (ammonium nitrogen) inopen-pit drainagewater is due to dissolution and leaching of ammonium nitrate during recharging of water-producing wells. Nitrite (nitrite nitrogen) contamination of drainage water is associated with absorption of nitrogen oxides during blasting, their subsequent percolation with atmospheric precipitates and release into drainage (open-pit) waters. The input of nitrate ions into drainage (open-pit) waters is associated both with the dissolution of ammonium nitrate in water-producing wells and leaching of absorbed nitrogen oxides with atmospheric precipitates. The amount of nitrogen compounds released into the drainage (open-pit) watersaccounts for 3–4% of the total amount of nitrogen contained in blasting agents (Khokhryakov 2016). As a result, the concentrations of nitrogen compounds in surface water and groundwater substantially exceed the maximum admissible concentration (MAC), which results in the contamination of water bodies by the discharge of drainage waters.

Elevated concentrations of nitrogen compounds in watercourses would adversely affect the quality of water supplied to settlements via infiltration water intakes. Such water intakes are recharged by groundwater, the reserves of which are formed by river water. In particular, the development plan for the Ust-Vyyaaquifer using infiltration water intake is prepared to ensure water supply to the town of Lesnoi located some 25 km downstream of the wastewater discharge point of EVRAZ KGOK. The proposed waste dump expansion will lead to the increase in concentrations of nitrogen compounds in the river water and groundwater if the cone of depression keeps expanding during water intake.

The results of monitoring observations conducted by ENI PGNIU since 2008 on the Vyya River, the main water stream receiving mine wastewater discharge, the river waters in the control section is 3.0 km downstream of the wastewater discharge point are fresh and ultra-fresh (174–333 mg/dm^3), of calcium-bicarbonate and calcium-sulfate type. The concentration of nitrate ions in the river waters exceeds MAC for drinking and amenity water use (45.0 mg/dm^3). Over the observation period, the concentrations of nitrate ions in the river waters varied within 29.5-130.6 mg/dm^3 and did not exceed the MACs in certain periods downstream of the wastewater discharge point (Blinov 2016).

The contents of nitrite ions and ammonium ions do not exceed the MACs for drinking and amenity water use.

The concentrations of elements in groundwater in the vicinity of the tailings sitecommonly exceed the hygienic standards of total iron (up to 11.7 MACs) and manganese (up to 3 MACs). In individual wells are characterized by one-time maximum admissible concentrations for nitrate ion (up to 1.5-1.7 MACs) and vanadium (up to 2.6 MACs). The contents of other detectable components are substantially lower than the MAC values specified for drinking and amenity water use.

In view of the forthcoming large-scale projects to increase the productivity of EVRAZ KGOK, it is necessary to use environmentally and economically more efficient waste and quarry water management plans to reduce the industrial environmental. Load through installation of closed water

systems, the application of dehydration technologies and thickening of tailings of wet magnetic separation, minimization of wastewater discharge to water courses, and reduction of fresh water consumption to replenish the circulating water supply system.

Justification of the environmental efficiency of the proposed open-pit and wastewater management plan

The reconstruction of EVRAZ KGOK's the tailings facilities to ensure safe tailings storage is associated with the abandonment of the existing tailings dam and enhanced production efficiency of the enterprise. Taking into account the relatively small linear dimensions of the project area and the existing limitations, the main technical requirement for the design of a new tailings site is the thickening of tailings slurries.

Hydrocyclone thickenershave been used for thickening and efficient disposal of tailings in the tailing dam since the 1960s. The efficient disposal of tailings is achieved through the separation of tailings slurries, based onthe particle size range and the pulp density of the slurry. Hydrocyclone thickeners were first used in Russia at the Achisai Polymetallic Plant for dam construction. Subsequently, hydrocyclone thickeners were appliedat some tailings sites of the Almalyk, Afrikand, Mirgalimsai, Kamtaga, Khaidarkan and other beneficiation plants.

Cyclone thickeners were first used abroad for building tailings dams in the USA in the 1950s. Currently, this technology is widely used in Canada, Africa, Chile, Brazil, and South Africa. The construction of new and reconstruction of existing beneficiation plants always envision installation of the process water circuit. At the same time, the maximum use of processwater was attained via thickening of tailings slurries (up to 30–70% solids) and recyclingthe clarified water back to the beneficiation process.

The environmental efficiency of the studiedopen-pit and wastewater management plan during the reconstruction of EVRAZ KGOK's tailings sitecan be achieved by elimination of the possible influence of seepage water within a new portion of the site on the water intake within the Ust-Vyyaaquifer located some 25 km downstream. The technical solutions for tailings facility reconstruction developed by MEKHANOBR ENGINEERING (St. Petersburg) envision engineering activitiesto ensure trapping of seepage water and effluents from the new and existing tailings dams.

The environmental effectiveness of the open-pit and wastewater management plan will depend onan equivalent maximization of the use of process water and a reduction of the wastewater volume discharged. This is achieved via tailings thickening and recycling the clarified water back to the process. This technology provides thickening of the initial tailings slurry of the enrichment plant from 7-11 to 75% in solids content using flocculants, which corresponds to current world best practice. The use of this technology will result in a more than 4-fold decrease in the tailings dam area (up to 10.5 million tons/year), a reduction of the volume ofthe pumpedslurries thus reducing energy costs for pumping.

The volume of wastewater pumped to the tailings dam as part of wet magnetic separation tailings is decreased by 40 times (to 12.19 million m^3/year). This is lower than the volume of the observed seepage losses through the foundation of the embankment dams. The water content in the thickened tailings at 75% solids is 0.33 m^3 per 1 ton of solids, which is approximately equal to the pore volume of the dumped tailings. Small amounts of water may seep through the dumped tailings and enter the drainage system and then the process water circuit. In accordance with the developed flow diagram, the water seeping from the existing tailings storage is also collected and pumped back to the process water circuit. Reducing the volume of a liquid component in the dumped tailings and removal of seepage water will cause the pressure drop on tailings dams. Thus preventing emergency situations and, as a result, contamination of the adjacent areas.

The use of the dewatering and thickening of wet magnetic separation tailings technology, the creation of water recycling systems and minimization of the discharge of wastewater seepage losses will ensure the environmental efficiency of the plant's water

balance management. The implementation of these actions is important to reduce theindustrial load on the environment, to prevent contamination of natural waters by nitrogen compounds, and to more effectively use the groundwater resources for establishment of a water supply system.

Conclusions

The analysis of existing natural, industrial, and geological conditions in the operation area of EVRAZ KGOK confirmed the maximum ecological efficiency of the proposed water balance management plan.

Overall reduction of the technogenic influence on the ecosystems in adjacent areas is achieved through the application of tailings thickening and dewatering systems, the maximum use of recycled process water, and reduction of the volume of discharged wastewater.

The proposed actions will decrease the probability of contamination of natural waters and provide the opportunity for the augmentation of groundwater resources of the area. The water quality allows to organize safe domestic and drinking water supply by attracting surface water to infiltration water intakes of settlements.

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