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Water Rock Interaction [WRI 14]

New opportunities for effective tailing storage operation (JSC "ALROSA", Russia)

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Abstract

This paper reports on a new technological scheme of recycling water removal and water level decrease at the tailing impoundments of a processing plant. To isolate recycle waters from tailing storage it is proposed to use permafrost. The processing water, with a salinity of 15 g/L, will be mixed with drainage brines from the quarry, with a salinity of 370 g/L, and then will be disposed into permafrost. The scheme realization will allow decreasing the water area outlines of the tailing storage and the waterworks to be effectively operated and its availability to be provided.

Keywords: recycling water, water salinity, water temperature, permafrost, tailing storage, Udachnaya kimberlite pipe.

1. Introduction

The largest diamond deposit in Russia, hosted in the Udachnaya kimberlite pipe (Fig.1), is located in western Yakutia, 20 km away from the polar circle (66°25′ N, 112°19′ E). The deposit is exploited as an open pit, which depth currently reaches 640 m.

Fresh water with salinity 100-250 mg/L is used in the technological cycle of kimberlite ore-processing. Besides, the local water recycling is involved in the ore flotation cycle. The pulp is discharged into tailing impoundments, from which the recycling water returns into the technological process.

The Udachny Mining and Processing Division of "ALROSA" annually stores in its tailing storage over 10 million tons of pulps. The kimberlite ore-processing annually consumes up to $50 \cdot 10^6$ m^3 of recycling water. The flotation process, as well as the presence of easily dissolved salts in kimberlites contributes to accumulation of sulfates and chlorides in recycling water and pH values increase to 8.0. As a result, the

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pulp discharged into the impoundment has salinity 14-15 g/L. The water composition is primarily sulfate-chloride magnesium-calcium. Chloride and bromide exceed the maximum concentration limit some ten- and hundred-fold, respectively.

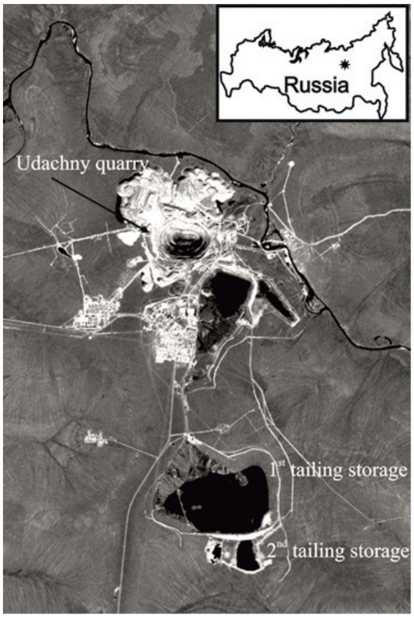

Fig.1. The Udachny diamond deposit (from Google).

Currently, the size of tailing storage and water level within the contour of impoundment reached the critical design point. The excess of processing solutions could be discharged into the nearby River Sytykan after a significant dilution. For instance, a dilution of $1 \cdot 10^5$ m^3 recycling water would requires about $85 \cdot 10^6$ m^3 of fresh water. However, the water volume of the Sytykan water reservoir – the nearest source of water supply - is only $23.1 \cdot 10^6$ m^3.

In this paper the new technological scheme improving water management in mining and processing is proposed.

2. Research results

It has been found out that the water-surface area of the 1st tailing storage (Fig. 2) was about 4 km^2, and maximum depth of the water reservoir was 12 m. In summer time the chemical composition of recycling water in the 1st tailing storage is chloride magnesium-calcium, with salinity 14.5-15.4 g/L. Water stratification was not observed. In fact, the countinous discharge of pulp into the impoundment causes intensive water mixing that avoids temperature gradient in the 1st tailing storage. The water temperature varies from 16 to 12 °C.

The 2nd tailing storage is located at the lower hypsometric level, and it accumulates clarified recycling water (Fig. 2). Water gets there filtered through a drain rock-fill dam. The water-surface area of the 2nd tailing storage was about 0.6 km^2, and maximum depth of water reservoir was 12 m. The chemical composition of water is chloride calcium-magnesium with dominant calcium.

At depth, an increase of water salinity and content of main ions was observed. A gradual increase of water salinity from 3.9 to 16.4 g/L has been recorded within the depth interval 1-5 m. Such stratification

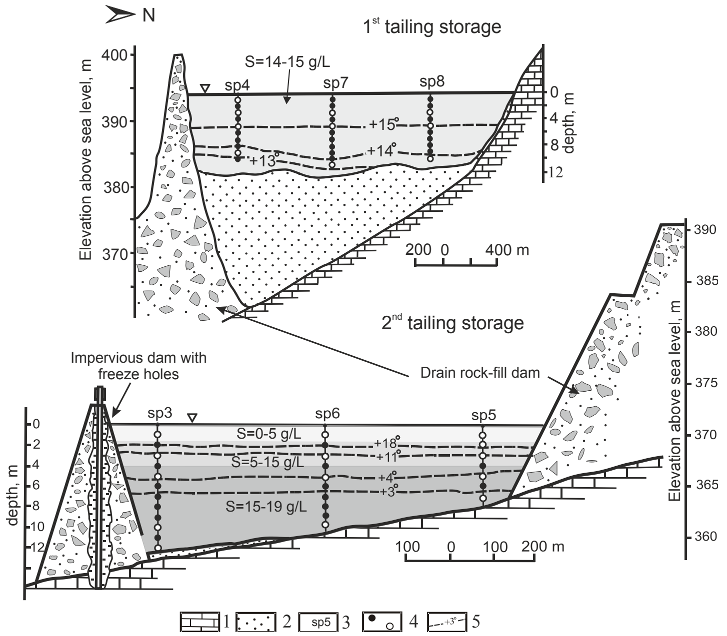

Fig. 2. Cross-sections of the tailing-storages: 1 - terrigenous-carbonate rocks in the reservoir floor, 2 – fine-dispersed sediments, 3 – sampling points, 4 – sampling points of water (empty circles) and temperature measuring (full circles), 5 – isotherm. S = salinity.

is due to inputs of snow melt and rain, as well as the absence of convective water mixing. Within the depth interval 5-12 m water salinity was estimated at 17.3-18.3 g/L, which is the consequence of a constant saline water supply from the 1st tailing storage into the 2nd tailing storage. At depth of 4 m an abrupt decrease of water temperature from 19.5 to 5.1 °C was recorded. Within the depth interval 4-10 m the water temperature gradually lowered, and at the bottom it was 2.0 °C.

3. Discussion and recommendations

The long-term experience of Udachnaya mining and waste water management indicates that reliable and environmental safety storage of drainage brines could be achieved using the permafrost in Lower Cambrian fractured terrigenous-carbonate rocks [1, 2]. Since 1985, over $15 \cdot 10^6$ m^3 of drainage waters have been disposed underground. The brines with salinity of 370 g/L are currently discharged into disposal wells without excessive pressure at the well head. The wells are equipped with filter column at 200-280 m depth.

To isolate recycle waters at tailing storage it is proposed to use the frozen rocks as well. Such a choice is supported by the following considerations: (1) the frozen sedimentary rocks contain collectors with high filtration and storage capacity; (2) a long-term disposal of drainage brines from the quarry into wells caused melting of ground ice in the permafrost and a significant increase of filtration properties of rocks; (3) the disposal system including pumping stations, water pipe duct, injection and observation wells has been properly operating for many years.

According to the proposed technological scheme the water with salinity of 15 g/L will be transported from the 1st tailing storage to wells. At the same time, it is necessary either to construct the water intake in the tailing storage, or to use the floating conduit intake. Then recycling water will be mixed with drainage brines from the quarry in the metallic tank and further will be disposed of into permafrost.

The freezing temperature is a critical parameter that characterizes the state of physical-chemical system – either the natural or technogenous solutions. The temperature lowering in the field of negative values causes decrease of velocity reactions and solubility of most compounds, increase of gas solubility and concentration of non-dissociated ion pairs, formation of individual and mixed crystalline hydrates. The drainage brines require significant cooling and freeze at lower temperature than binary water-salt systems (such as NaCl, $MgCl_2$, $CaCl_2$) or seawater. Saline waters accumulated in the tailing storage also freeze at negative temperature.

According the data of the Permafrost Institute SB RAS, the mean annual rock temperature at depths of 200-280 m does not exceed -3 ºC. The experimentally obtained data was applied by the authors to compute the extreme salinity of mixed water disposed into permafrost, corresponding to the freezing temperature: $S = -0.1266T^2 - 13.048T + 11.888$; where S = water salinity, g/L; and T = freezing temperature, ºC [3].

With the temperature of water-rock system equal to -3 ºC, the disposed waters will freeze at salinity of 50 g/L. Consequently, the increase of salinity of mixed solutions even to 60 g/L will ensure permanency of their absorption in wells.

Following the principle of mixing solutions to gain salinity of mixed water of 60 g/L it is necessary to mix the recycling water from tailing storage (S=15 g/L) and the drainage brines (S=350 g/L) at ratio 8:1. Therefore, to reduce the water level in the 1st tailing storage with surface water it is sufficient to mix and further dispose into wells $4 \cdot 10^6$ m^3 of recycling water and $5 \cdot 10^5$ m^3 of drainage brines from the quarry. This leads to a significant decrease of the water area outlines of the tailing storage.

The simulation carried out using the software complex HydrGeo [4] proves that during the water disposal in the permafrost the interaction of technogenous water with host rocks leads to a physical-chemical equilibrium of the water-rock system and eliminates undersaturation of solutions with respect to rock-forming minerals, i.e. calcite, dolomite and gypsum. This implies that there will be no precipitation or plugging in near-well zones.

Thus, for mixing purposes water from the 1st tailing storage can be pumped at any depth, whereas water from the 2nd tailing storage should be taken within the depth interval 6-12 m.

Proposed project would be realized within the Yakutian diamond-bearing province for the first time.

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