Analysis and technology to reduce the impact of tailings on the ecology of local water bodies

R T Brzhanov¹, L I Sofronova², S A Abramova²

¹Department of Building, Caspian State University of Technology and Engineering named after Sh. Esenov, 32 Microdistrict, Aktau 130003, Republic of Kazakhstan
²Department of Mining, Construction and Life Safety, Kokshetau State University named after Sh.Ualikhanova, Abay street 76, Kokshetau 020000, Republic of Kazakhstan

E-mail: brzhanov@mail.ru

Abstract. An integral part of the technological chain in the processing of uranium ores is a tailing dump designed for organizational disposal and long-term storage of tailings. There are up to 170 production and monitoring wells around the tailings for comprehensive monitoring of the impact of the tailings on groundwater. Wastewater is discharged from the industrial site into the Aksu riverbed after preliminary complex biological treatment at the sanitary treatment facilities. This article provides an analysis of pollutants from the processing of uranium ores. Studies have found that arsenic, molybdenum, uranium, and radium are the main pollutants that affect surface and groundwater. Under the influence of precipitation, the oxidation of ore minerals, many radioactive and chemical elements transform into more mobile forms and enter the environment. The main accumulator of radionuclides is bottom sediments. It is this component of the aquatic ecosystem that determines the mechanism and rate of redistribution of radionuclides. The analysis of water samples from the tailing dump itself and from surface water bodies in the area of the GMZ industrial site in the direction of thalwegs was carried out.

1. Introduction

Ecological condition of local water bodies. The tail pulp of uranium and copper-molybdenum production, which is currently stored on card No. 2, is dumped into the tailing pond of the MMP (mining and metallurgical plant). The ratio of the solid and liquid parts (S:L) in the combined tail pulp is 1: 5.7. The total volume of pulp supplied to the tailing dump in 2010 was 4.33 million m³, including 4.06 million m³ of the liquid phase (water).

The solid part of the tail pulp is deposited, forming tail sediments (beach), and the liquid phase, settling, forms a pond. The area of the pond on card No. 2 is 191 hectares.

The chemical composition of pond water is largely determined by the chemical composition of the processed ores and the solubility of their constituent substances.

Studies have found that the main pollutants that affect surface and groundwater are arsenic, molybdenum, uranium and radium [1-3]. The content of these pollutants in the pond water of the tailings is given in table 1 [4,5].
Table 1. Content of pollutants in the pond water of the tailing ponds.

| Substances       | MPC    | Chart 1       | Chart 2       | Evaporative Chart |
|------------------|--------|---------------|---------------|-------------------|
| Uranus (mg/l)    | 0,25   | 0,04-0,06     | 0,04-0,06     | 0,05-0,10         |
| Radium (Bq/l)    | 0,5    | 0,59-1,70     | 1,11-2,92     | 0,67-0,74         |
| Molybdenum (mg/l)| 0,25   | 29,0-44,5     | 45,5-51,0     | 58,5-69,3         |
| Arsenic (mg/l)   | 0,05   | 8,6-13,0      | 16,2-18,4     | 32,4-49,2         |

The present table shows that the main pollutants are radium, molybdenum and arsenic, the actual content of which exceeds the MPC (maximum permissible concentrations) by tens of times.

2. Analytical solution of the problem

Open reservoirs, as an integral part of the regional ecosystem, serve as a kind of condenser of natural and artificial radionuclides and need to regulate radiation and chemical contaminants, to assess the genetic damage to aquatic organisms from environmental mutagens.

Under the influence of atmospheric precipitation, oxidation of ore minerals, many radioactive and chemical elements transform into more mobile forms and enter the environment. The main depot of radionuclides are bottom sediments. It is this component of the aquatic ecosystem that determines the mechanism and rate of redistribution of radionuclides [6-8].

We carried out the analysis of water samples from the tailing dump itself and from surface water bodies in the area of the MMP (mining and metallurgical plant) industrial site in the direction of the Manybay and Sulukamys talwegs. The maximum values of pollutants in these water bodies and streams are shown in table 2.

To assess the degree of pollution of water bodies, the maximum permissible concentrations of pollutants in drinking water MPC (maximum permissible concentrations) were used, which are: arsenic - 0.05 mg/kg, molybdenum - 0.25 mg/kg, sulfate ion - 500 mg/kg; radionuclides: uranium (238) - 0.25 mg/kg, radium - 0.5 Bq/kg. [9,10].

The water composition in the thalweg of the Manybay direction is mainly sulfate-chloride, which is typical for the reservoirs of Northern Kazakhstan, and in terms of pH it corresponds to the class of neutral and slightly alkaline waters (Table 2).

Table 2. The chemical composition of surface water reservoirs.

| No in sequence | Sampling Point Location | $\Sigma$A$\alpha$, Bq/l | U, mg/l | Ra, Bq/l | Mo, mg/l | As, mg/l |
|----------------|-------------------------|------------------------|---------|----------|----------|----------|
| 1              | 200 m to the east from card 2 | 4,9                    | 0,19    | 0,13     | 13,57    | 1,47     |
| 2              | 400 m to the east from card 2 | 11,3                   | 0,08    | 0,18     | 0,90     | 0,23     |
| 3              | 500 m to north-east from t.2 | 4,0                    | 0,11    | 0,27     | 8,82     | 1,49     |
| 4              | Quarry pond             | 3,5                    | 0,11    | 0,22     | <0,1     | 0,08     |
| 8              | Sulukamys lake, south    | 0,5                    | <0,04   | 0,10     | 2,49     | 1,35     |
| 9              | Sulukamys lake, north-west | 2,6                   | 0,17    | 0,09     | 1,92     | 0,98     |
| 10             | Quarry on the bald peak  | 0,5                    | <0,04   | 0,13     | 0,12     | <0,02    |
| 11             | 400 m to the north from the dam | 21,6                   | 0,44    | 0,48     | 8,38     | 2,10     |
| 12             | Quarry to the north of FPS (Fire Pump Station) | 0,06                | 0,09    | 0,09     | 0,11     | 0,15     |
| 13             | Former w-type water drainage | 2,6                   | 0,15    | 0,19     | 0,30     | 0,06     |
| 14             | 100 m to the west from MMP | 7,4                   | 0,36    | 0,21     | 2,3      | 0,48     |
| 15             | Around the railway weights MMP | 134                  | 5,1     | 0,13     | 6,05     | 0,41     |
In reservoirs and watercourses of the Manybay direction, the maximum values of harmful substances were [11,12]:

- for uranium - 1.2 mg / l, or 0.67 MPC (maximum permissible concentrations) (for reservoirs for household purposes, MPC = 1.8 mg / l);
- for arsenic - 2.27 mg / l, or 45.4 MPC (maximum permissible concentrations) (for water bodies for household purposes, MPC = 0.05 mg / l);
- for molybdenum - 1.91 mg / l, or 7.6 MPC (maximum permissible concentrations) (for reservoirs for household purposes, MPC = 0.25 mg / l).

3. Purpose and objectives of research

Thalweg reservoirs of the Sulukamys direction are mainly represented by sulfate and chloride-sulfate waters and belong to the class of neutral and slightly alkaline.

The maximum content of pollutants in the water of the thalweg reservoirs of the Sulukamys direction was: for arsenic - 41.8 mg / l (856 MPC); for molybdenum - 49.0 mg / l (196 MPC) [13].

The decrease in the concentration of toxic substances in surface water bodies occurs due to the interception of filtration water from tailing dump cards by drainage systems and pumping stations. In addition, there is a process of leaching polluting substances (U, As, and Mo) from the surface by flood and rainwater and their removal into the most lowered relief forms [14].

Elevated concentrations of uranium in water were observed in the area of the railway waste dump. So, in the area of mine drainage, the uranium content was 0.54 mg / l, and in the reservoir adjacent to the rock dump on the north side, it reached 4.95 mg / l, which is likely due to leaching of this element from the rocks of the dump. In the same reservoir, an increased molybdenum content of up to 24 MPC (maximum permissible concentrations) was established [15].

In recent years, the concentration of pollutants in the pond water of card 1 and the evaporation card has increased markedly, which is associated with a decrease in water volume due to evaporation. Analyzing the overall results of the observations, the following can be noted:

- the concentrations of the main pollutants, except for uranium, are much higher in the reservoirs of Sulukamys talvega than Manibaysky. This is due to the fact that prior to the installation of the drainage system, the water filtered from the tailing dump was distributed mainly along the Sulukamys Thalweg;
- against the background of large scatter of values, associated mainly with various degrees of evaporation of water bodies, it is difficult to establish the dependence of the change (decrease) in the content of pollutants over time. The reservoirs of the Sulukamys Thalweg, drying out several times completely in dry years, and then filling in spring, are nevertheless constantly characterized by high concentrations of pollutants;
- of all the reservoirs of the Manybay Thalweg, elevated concentrations of pollutants, except for uranium, are noted only in three or four, located closest to the tailing pond. Further down the thalweg in all water bodies are the equally low concentrations of pollutants, except for uranium, the content of which is slightly increased here - up to 0.6-0.7 mg / kg, which is associated with the previously discharged mine water.

Also, for the radiological examination of open reservoirs in the territory of the former uranium mining enterprises and settlements, 6 reservoirs were selected. Of these, 4 are located on the territory of uranium mining enterprises (the Kutunguz river, the exhausted quarry of the Shantobe settlement, reservoirs located near the MMP (mining and metallurgical plant) tailing pond). Two reservoirs were chosen for comparison, which are located outside the tailing ponds: the Aksu river, a pond near the village of Aksu [16].

The main watercourse of the region - the Aksu River - flows more than 10 km south of the tailing pond site and, taking into account the direction of the groundwater flow (northeast), is outside the tailings impact zone.

In the exhausted quarry and standing pond near the tailing dump (N1-point), the specific activity of $^{226}$Ra is high and is 205 and 236 Bq / kg, respectively. In the Aksu river and the pond near the village
of Aksu, the concentration of $^{226}$Ra is insignificant and amounts to 14 Bq / kg and 35 Bq / kg and 35 Bq / kg, respectively.

The specific activity of $^{232}$Th in the exhausted quarry, when compared with other water bodies, is slightly higher and amounts to 112 Bq / kg.

Data on the content of radionuclides and the total alpha -, beta - activity in bottom sediments are presented in table 3.

**Table 3.** The content of radionuclides and total alpha, beta activity in bottom sediments (layer 0-15 cm) of dry mass, 2010-2011.

| Sampling point | The specific activity of radionuclides Bq / kg | The total alpha activity Bq / kg | Total beta activity, Bq / kg |
|----------------|----------------------------------------------|--------------------------------|----------------------------|
|                | $^{40}$K $^{137}$Cs $^{226}$Ra $^{232}$Th    |                                |                            |
| 1              | 2 3 4 5 6 7                                    |                                |                            |
| Kutunguz River N1-Point | 257±79 10±7 65±23 56±14 5775 | 2955 |
| Kutunguz River N2-Point | 327±93 9±7 61±15 51±11 2218 | 1550 |
| Kutunguz River N3-Point | 303±83 8±5 10±10 40±9 2808 | 1145 |
| Exhausted quarry, of Shantobe settlement | 339±16 40±5 205±10 112±50 5625 | 2580 |

4. **Research methodology**

According to the data of the MMP (mining and metallurgical plant) Stepnogorsk Mining and Chemical Combine LLP in the water of the upper part of the Kutunguz river before the discharge of mining water, the specific activity of $^{238}$U (uranium) is 0.27 Bq/l, and 500 meters after the discharge 3.8 Bq/l.

The results of our research indicate that the concentration of uranium in water after discharge into the Kutunguz River does not decrease, but remains high [17].

So, at points No. 1, 2, 3 of the Kutunguz river, the specific activity of natural uranium is 14.3 Bq / l, 10.7 Bq / l, 15.6 Bq / l, respectively, the data are shown in table 4.

**Table 4.** The research results of samples of open water.

| Sampling point | Natural uranium concentration Bq / l | Total alpha activity, Bq / l | Total beta activity, Bq / l |
|----------------|-------------------------------------|----------------------------|-----------------------------|
| River Kutunguz 500 m to discharge | 0.27 | - | - |
| Kutunguz River 500 m after discharge (SES (sanitary-epidemiological station) MMP data) | 3.8 | | |
| Kutunguz River N1-Point | 14.3 | 7.6 | 1.03 |
| Kutunguz River N2-Point | 10.7 | 8.7 | 1.10 |
| Kutunguz River N3-Point | 15.6 | 12.04 | 0.91 |
According to the data obtained, it can be assumed that a significant contribution to the pollution of the river with radioactive substances comes from the water coming from mine No. 11.

In an exhausted quarry, where the specific activity of natural uranium in water is 4.3 Bq / l, water is used to irrigate gardens [18].

The total alpha is the activity of all water samples and the total beta is the activity of samples of standing reservoirs near the tailing pond exceeds the standard values for drinking water (for alpha - 0.1 Bq / l, for beta - 1.0 Bq / l, uranium 238-3.1 Bq / l), although the water of open reservoirs is not standardized by radiation indicators [19].

In general, a comparative analysis of the radionuclide contamination of water bodies showed that water bodies near uranium mining enterprises and the tailing pond are contaminated with radionuclides [20].

To intercept the waters filtered through the dams and under the dams, a protective drainage system has been built from the north and east sides of the tailing pond (along the slope of the relief). The system consists of three drainage pumping stations and closed drainage of ceramic pipes with a length of 5850 m, which serves to collect and bypass drainage water to pumping stations. To collect and transfer surface water to pumping stations from territories directly adjacent to the dry slope of dams, a surface drainage system has been built. To prevent dusting of drying beaches, the project provides for the maintenance of the washed solid phase of the pulp under flooding or in a moist state.

5. Conclusions

Based on the materials of engineering-geological, hydrogeological, and design and survey works, it was found that the boundary of groundwater pollution with an underground drain 1 km wide that existed before the drainage system was put into operation does not go beyond the SPZ (sanitary protection zone) and does not reach the tracts Manybay and Sulukamys. The area of groundwater pollution by the filtrate of the liquid phase of the tailings, caused by the surface runoff of melt and rainwater, was identified in the northeastern direction at a distance of 100-700 m from the bund wall of tailing, its main polluting components are sulfates, molybdenum, arsenic, and fluorine. Currently, due to the existing drainage system, the water filtered from the tailing pond is contaminated by the substances contained in the tail pulp. In this connection, further expansion of the halo of pollution is stopped.

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