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Technical Article

Evaluating the Environmental Effects of Uranium Production at the Kara-Balty Mining Complex

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Abstract. A γ-radiation dose rate is defined for the Kara-Balty Industrial Complex**,** which is located in the Kyrgyz Republic (formerly part of the Soviet Republic). The increased γ-radiation doses are being monitored at tailings areas and at the industrial platform. The γ-radiation dose rate does not exceed background values in the designated protective (buffer) areas or in the inhabited zones nearby.

We studied the concentration, isotopic composition and spatial distribution of uranium and the concentration and spatial distribution of ^{226}Ra, sulfate and nitrates in the ground water of the region. The central area of intensive ground water contamination by uranium lies within the eastern part of the village of Alexeevka and the western part of the town of Kara-Balty, but neither the concentrations of uranium nor ^{226}Ra exceed the legal limits. The locations where sulfate and nitrate exceed the legal limits and the sources of contamination are defined too.

Key words: Ground water, Kara-Balty, Kyrgyz Republic, nitrate, sulfate, uranium.

Introduction

Environmental aspects of uranium production include radiation and elevated levels of radioactive isotopes, heavy metals, sulfates, nitrates and other contaminants. Studying the basic components and processes that caused the environmental contamination is key to understanding the problems. We investigated the indicated factors and the processes that took place in the industrial plants of the Kara-Balty Mining Complex (KMC) and adjacent land, including inhabited areas. The total area covered by our investigations was about 100 km^2. These included the tailing areas, the industrial platform (which includes the Hydro-Metallurgical plant (HMP) for deriving uranium from mineral raw materials), auxiliary plants, the designated protective zone (a buffer area), and somewhat further away, the inhabited town of Kara-Balty and some nearby villages.

We attempted to define the temporal and spatial variations in contamination in this area. To accomplish this, we had to establish natural background concentrations and the sensitivity limits for our analysis of certain key indicators. It is important to note that simply looking at the total content of uranium in waters without determining what is natural and what is technogenic ignores an important component. The concentration of uranium in natural waters varies over orders of magnitude in the absence of uranium extraction plants. The environmental effect of uranium production should be based only on the technogenic uranium. As such a method has not yet been proposed, we attempted to do this based the natural separation of uranium-234 and uranium-238 (Cherdyntsev and Chalov 1977; Chalov 1998). The essence of this approach is that the uranium of the hydrosphere has a higher activity of ^{234}U in comparison with ^{238}U than does the uranium in minerals. The wastewater of the technological processes is derived from the mineral forms and so does not display such a surplus. So by the magnitude of the ratio of activities $^{234}U/^{238}U=\gamma\geq1$, we can distinguish natural waters from seepage from tailings.

The Kara-Balty Mining Complex

The KMC industrial complex is located in the western part of the Chui valley, south of the town Kara-Balty in the Kyrgyz Republic. It is located 800-865 m above sea level on the northern slope of the Kyrgyz mountain range and contiguous to the plain terrain of the Chui depression. Hydrogeologically, the site is characterized by Quaternary deposit ground water (Tutukin 1971), a highly permeable unsaturated zone, and a very thin (0.7-1.0 m) cover of loam (Grigorenko 1979). This readily allows drainage solutions from the tailings to reach the local ground water.

The HMP located in this area commenced operations in 1955. The liquid and solid wastes from the HMP were placed in a tailings area, which occupies about 240 he. The technological processes of the HMP are described in Khabirov and Vorobiov (1993). The generated solid and liquid wastes were transported and deposited as a slurry atop a layer of loam, a drainage layer (gravel), loam, polyethylene film, sand and gravel cover.

Methods

To measure the isotopic distribution of α-radiating isotopes, various modifications of ionization α-spectrometers (Chalov 1975; Vasiliev 1998) were utilized; this allowed us to analyze preparations over a large area despite low levels of radioactivity. The output of uranium and chemical operations was monitored with the help of ^{232}U. The concentration of heavy metals (except for uranium) in natural waters, drainage solutions and soils was analyzed by emission spectral analysis using an installation with two-jet plasmatron (Jeenbaiev and Engelsht 1983; Engelsht et al. 1976), which has provided a sharp response and satisfactory reproducibility of results. The γ-surveys, where necessary, were performed in 2π-geometry (with a screened detector).

The phenomenon of natural fractionation of ^{234}U and ^{238}U (Cherdyntsev and Chalov 1977) was investigated in ground water samples so that the sources and the relative contributions of technogenic uranium could be determined (Chalov et al. 1991).

Results

The experimental results are presented in the form of isoline maps (Figures 1 to 6). Figure 1 illustrates the distribution of the dose rate (D) of exterior γ-radiation in μR/hour. As one would expect, the values are highest for the tailings and the industrial plot. The range of values observed reflects the presence or absence of a shielding cover provided by non-radioactive material. For most of the tailings area, D varies between 400-800 μR/hour. However, some sections of the tailings show only 200 μR/hour. The highest values of D, about 1.5 μR/hour, were found in the northern area.

The industrial plot was characterized mainly by low values of D (16-25 μR/hour). However at some isolated locations where radioactive metal scrap accumulated, solutions and pulp spilled from pipelines, radioactive ore fell from railroad cars on reloading stations etc., D reached values of 360-5440 μR/hour (Vasiliev et al. 1997).

The dose rate of γ-radiation on all the other studied areas does not exceed 30 μR/hour, and for most areas outside of the sanitary-protective zone, including the town of Kara-Balty, it is less than 20 μR/hour.

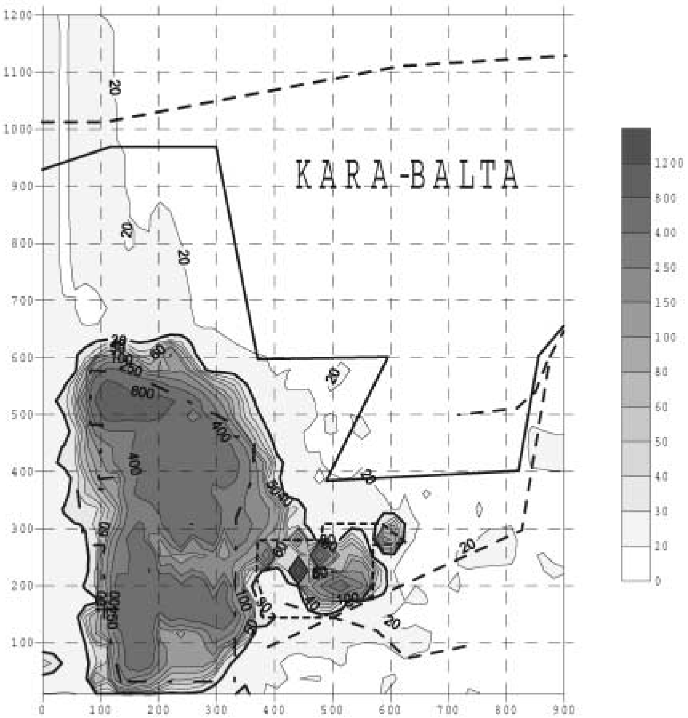
Figures 2 and 3 illustrate the spatial distribution of total uranium and the $^{234}U/^{238}U$ (γ) as a result of ground water migration from the tailings. The concentration of uranium varies widely, from $1.2\text{-}37.5 \cdot 10^{-6}$ g/l. In general, the variable background concentrations in the waters of Quaternary deposits of the Kara-Balty river (typically $2\text{-}4 \cdot 10^{-6}$ g/l) is overshadowed by the effect of the contaminated infiltration from the tailings area, in which the concentration of uranium is almost 2 orders of magnitude higher. This proportion can also be different for various wells, depending on the depth of water intake and the paths of infiltration taken by the tailings drainage waters. In addition, Figures 2 and 3 include the system of wells (points of water sampling), outlines of the tailings area and the town of Kara-Balty, the Kara-Balty river, railways and the Big Chui channel (BChCh) in the northern part of the area. The ground water flow is oriented northwards from the tailings, in keeping with the local groundwater gradient.

Based on the spatial distribution of uranium in the Kara-Balty area ground water, it is apparent that:

- The most intensively contaminated ground water (uranium concentrations $\geq 10^{-5}$ g/l) are in the western part of the town of Kara-Balty and in the eastern outskirts of the village of Alexeevka. However, most of Kara-Balty is located in regions of circulating ground water, which is either not contaminated ($\leq 4 \cdot 10^{-6}$ g/l) or only slightly contaminated by technogenic uranium;
- The surface and ground water of the Kara-Balty area, although contaminated by technogenic uranium as a result of operations at KMC, are not hazardous based on the concentrations of uranium observed. The concentrations in the water do not exceed the limits established for waters that are potable or used domestically.

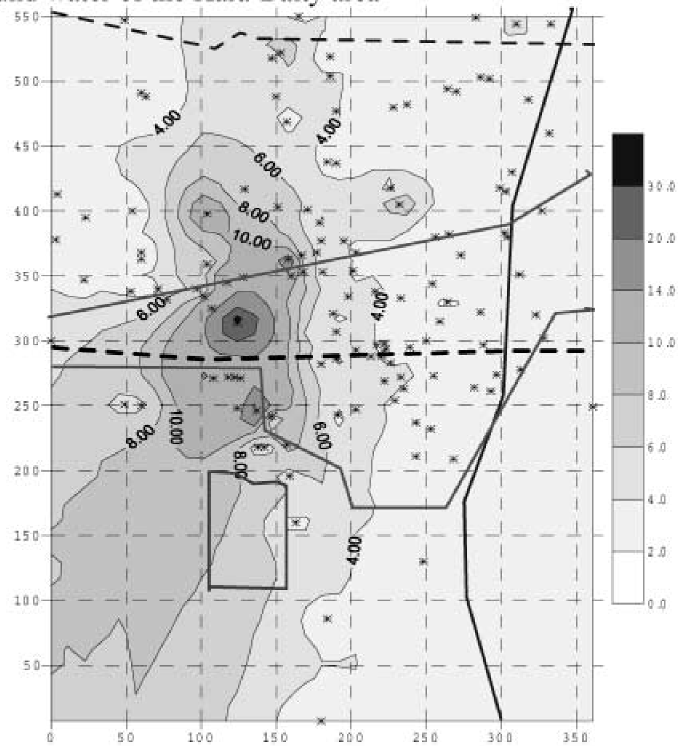
The spatial variations in isotopic composition are shown in Figure 3. The clean ground waters of the Quaternary deposits of the Kara-Balty river (γ≈1.8) are clearly distinguished from the water polluted by the KMC industrial plants (1.8≥γ≥1.6). Note, that in the northern section of the tailings area, there is a

Figure1. Space modifications of potency of γ-radiation on Kara-Balty area



- - - - railways, — - boundaries of inhabited areas,
- - - - industrial plot, ·-·-·-· - contours of tail storage.

Figure 2. Content and space distribution of uranium in ground water of the Kara-Balty area



Conventional signs are shown in Figures 3 and 4.

plot, represented by 9 wells, producing water from the deeper Quaternary aquifers with γ≈1.8. The western part of the area to the west of isoline 1.6, contributes additional ground waters with γ~1.3. However, a detailed analysis of that area is not possible due to the limited number of wells.

Based on the isotopic dilution data, it is possible to estimate the extent to which drainage waters, which have γ=1, affect the wells of the investigated area. This parameter is shown in Figure 4 as a pattern of isolines. It is clear that the distribution of technogenic uranium is directed to the north, in accordance with the ground water gradient. Also, the contribution of tailings drainage water to the natural ground water of the Kara-Balty area does not exceed 5-7%.

In addition to radioactive isotopes, other contaminants generated during uranium production can negatively influence the environment. These include sulfate, nitrates, and heavy metals. Nitric and sulfuric acids used in the technological process contributed the sulfate and nitrates. The content (mg/l) and spatial distribution of nitrates in the ground water of the Kara-Balty area are shown in Figure 5. By way of comparison, the legal limit for nitrates in waters that are potable and used domestically is 45 mg/l. This limit is approached or exceeded in practically all of the western part of Kara-Balty and the eastern outskirts of Alexeevka. In addition, there is a second zone of intense contamination to the north of an area, contiguous to BChCh. The concentration of nitrates in the areas where the ground water is contaminated reaches 75-215 mg/l. The direction of migration corresponds to that of all earlier observed contaminants.

Figure 6 shows the concentration (mg/l) and spatial distribution of sulfate in the ground water of the Kara-Balty area. The contamination of waters by sulfates is similar to the pattern of nitrate contamination. However, because the legal limit for sulfate is much greater (500 mg/l), sulfate is of less concern.

Conclusions

It should be noted that this study was conducted during 1997-2000, when uranium production was relatively low. Disposal of liquid and solid wastes in the tailings was less than 1% of the maximum historical rate. The infiltrating tailings water

Figure 3. Distribution of ratio of activities $^{234}U/^{238}U$ in ground water of the Kara-Balty area

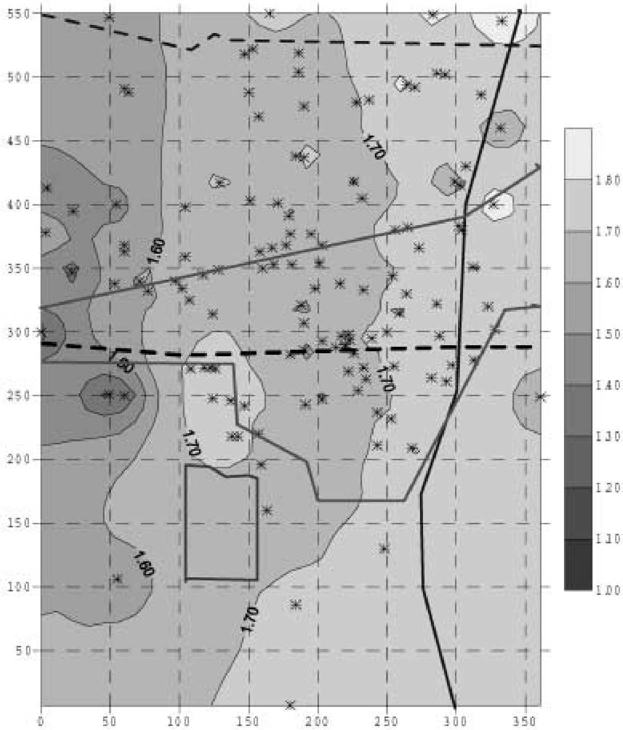
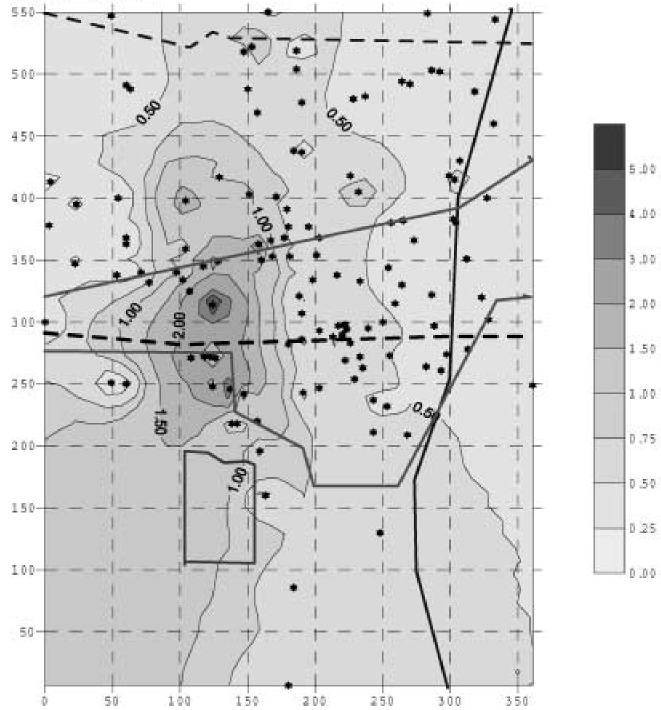


Figure 4. The contribution of drainage waters of tailings to the ground water of the Kara-Balty area (% of volume)



- contours of tail storage, - boundaries of inhabited areas, Alexeevka, Kara-Balty

— - Kara-Balty river, - - - - railway (in inhabited area), - - - - BChCh (north part of the region), * - locations of sampling.

represents wastes that were largely generated during the more active phase.

Uranium production at the Kara-Balty Mining Complex has not caused noticeable magnification of the dose rate of γ-radiation in local inhabited areas. Near the industrial platform and in the sanitary-protective zone, isolated locations of significantly heightened radioactive background are observed (360-5440 μR/hour), due to losses of ores and manufactured products.

On the surface of the tailings disposal area, a dose rate of γ-radiation reaches 1.5 mR/hour in regions where the tailings are not covered by non-radioactive material. Windblown dust from such areas might be a problem.

The migration of uranium from the tailings into ground water has not created extraordinary radio-ecological problems. The utilization of isotopic ratio $^{234}U/^{238}U$ as an indicator allows us to distinguish areas where the uranium is at natural background levels. Based on our analysis, the drainage water from the tailings area in the Kara-Balty area does not exceed 6% of the recharge of the aquifer.

The concentration of nitrate and, to lesser extent, sulfate, in the ground water is of greater concern. Nitrate concentrations in some ground water exceeds legal standards for domestic use. As a result of contaminated water, wells 116-120 had to be taken out of production.

It is recommended that:

1. All tailings should be covered by non-radioactive material.
2. Areas of γ-radioactive anomalies in the industrial platform area in the sanitary-protective zone should be rehabilitated and revegetated. All radioactive metal scrap should be buried.
3. The use of ground water should be avoided in the western part of Kara-Balty and the eastern outskirts of Alexeevka due to high concentrations of nitrates and sulfate.
4. Engineering processes should be modified to minimize the amount of water discharged from the

Figure 5. Content and space distribution of nitrates (mg/l) in underground waters of Kara-Balty area

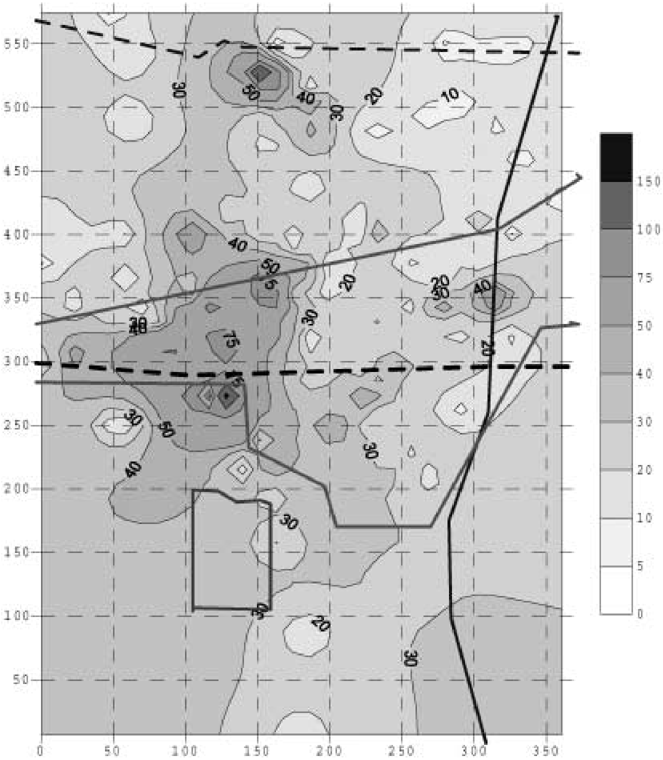
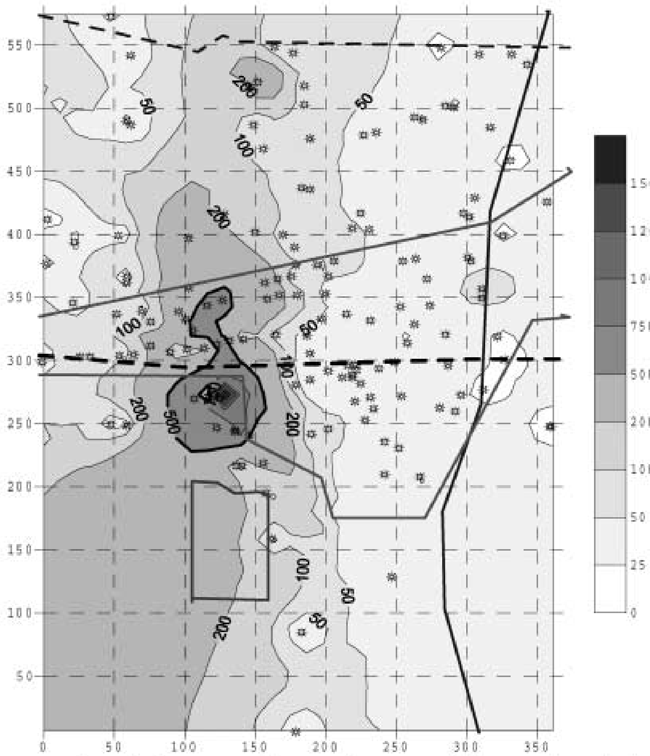


Figure 6. Content and space distribution of sulfates (mg/l) in underground waters of Kara-Balty area



Conventional signs are shown above on Figures 3 and 4.

plant and to recycle water where possible. Effort must be made to prevent spillage of ores and metals to avoid contamination problems.

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