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The Current Radiation Situation of the Territory Near the Uranium Mining Enterprises of Northern Kazakhstan

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Abstract

Radioactive waste near the industrial zones of the mining administrations of the Stepnogorsk Mining and Chemical Combine, which occupy vast areas of the territory, remains an urgent problem for Northern Kazakhstan. For example, waste rock processing referred to as "tailings", is contained in huge industrial basin-lakes, called tailings. Each liter of jelly-like "pulp", in addition to carbonates of arsenic, molybdenum, phosphorus and other chemical elements, contains up to 1 g of active uranium, as well as radium and thorium. As a result of the pedestrian gamma survey, the authors identified a locally contaminated area in the northwest direction from the sanitary protection zone of the tailing dump of the Stepnogorsk Mining and Chemical Combine. It has been established that, according to the indices of radioactive contamination of water bodies, the stagnant water bodies of the Manybaiskiy and Sulukamysskiy thalweg located behind the sanitary protection zone of the tailing dump of the Stepnogorsk Mining and Chemical Combine are classified as contaminated.

1. Introduction

Technogenic pollution of the environment with radionuclides in the process of mining and processing of minerals is a problem in many countries, including Kazakhstan, which has deposits of natural uranium and other minerals.

Because of the activities of uranium mining enterprises in the Republic of Kazakhstan, more than 170 million tons of radioactive waste which require constant radiation monitoring, as well as the rehabilitation of the territory have been accumulated. At the same time, in the northern region alone, about 61 million tons of radioactive waste with a total activity of 168.4 thousand curies have accumulated [1–2]. In 2001–2008, work on the conservation and liquidation of uranium deposits in the specified region was carried out [3]. At present, several tailing dumps of radioactive waste are used in the republic, and the largest among them is the tailing dump of the Stepnogorsk Mining and Chemical Combine (SMCC), which has been operating since 1956. The main types of industrial waste at SMCC are tailings from the processing of uranium ores, which, in terms of their radionuclide content, are classified as hazard class I.

Behind the sanitary protection zone of the tailing dump, there are Sulukamyssky and Manybaysky thalweg. For watering cattle, the population uses water near the located rural settlements. The tailings dump is located 4 km west of the hydrometallurgical plant, 3–5 km north of the villages of Aksu, Zavodskoy and Kvartsitka, Akmola region, where over six thousand people live. By the content of radionuclides and their isotopes in natural waters, it is very difficult to judge the rate of their migration from the tailing dump, since these parameters vary within wide limits and for obviously "clean" natural waters. The only exceptions are "hurricane" concentrations when the introduction of radionuclides from the tailing dump is obvious.

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In this regard, for an unambiguous answer to the question about the possible entry of radionuclides from the tailing dump into natural waters, it is necessary to measure the radiation background of the coastal part of natural waters and determine the content of radionuclides in water samples; to reduce the concentration of radionuclides in water [4–5]. At the same time, taking into account that other unaccounted factors may act in real conditions, it is justified in predictive calculations to use the maximum values of the calculated parameters [6].

In this regard, complex radioecological studies of the territory beyond the sanitary protection zone of the storage of radioactive waste and laboratory radiochemical analyzes of the content of radionuclides to assess their migration paths in environmental objects (air, water, soil) is an urgent task.

2. Materials and methods

The objects of the study were the territories beyond the sanitary protection zone of the tailing dump of radioactive waste.

Field radiometric studies. Pedestrian measurements of gamma background in background areas, on the territory were carried out using dosimeters DKS-96, DKS-AT-1123, RKS-01-SOLO. At each point of the survey, the ambient dose equivalent rate of gamma radiation (ADER GR) was measured. To determine the coordinates, a Garmin satellite navigation device, which allows you to determine the location of points in a geographic coordinate system has been used. Measurement of ADER GR on the territory was carried out according to the methodology "Methods for measuring the gamma background of territories and premises" approved by the Deputy Chief State Sanitary Doctor on 06 August 1997. An exploration gamma survey of the study area was carried out using a mobile automobile radiological laboratory "Gamma-Sensor".

Soil samples were taken by the triangle method (3 points – at the corners and in the center) at a depth of 0–5 cm. Deep soil samples from 1 cm to 55 cm with a step of 5 cm were taken at each point where the ADER GR exceeded the background value. Water samples were taken in accordance with the guidelines of GOST 17.1.5.05-85 "Nature protection. Hydrosphere. General requirements for the selection of surface and sea waters, ice and atmospheric precipitation" and GOST P 51592-2000 "Water. General requirements for sampling".

Laboratory radiochemical and radio spectrometric analyzes of samples were carried out at the Testing Laboratory of Radio Spectrometry and Radiochemistry of the Institute of Radiobiology and Radiation Protection of the NJSC "Astana Medical University", which is accredited in the accreditation system of the Republic of Kazakhstan for compliance with the requirements of GOST ISO/IEC 17025-2009 "General requirements for the competence of testing and calibration laboratories".

The total alpha and beta activities in water samples were carried out according to the methodological recommendations "The total activity of alpha and beta emitting radionuclides in natural waters (fresh and mineralized)", registration No. KZ.07.00.01080-2010, and were measured on the UMF radiometer-2000 "(No. KZ.07.00.00441-2005 "Methods for measuring the total alpha and beta activity of water samples with the alpha and beta radiometer UMF-2000").

Uranium-238 in natural water samples was investigated in accordance with the "Methodology for measuring the volumetric activity of uranium isotopes (234, 238) in natural waters with mineralization up to 5 g/dm^3 by the alpha spectrometric method with the radiochemical release. Registration No. KZ.07.00.01641-2012. Detection of alpha particles was carried out using an alpha spectrometer "Progress-alpha" with software "Progress-2000". The uranium content in water samples was also determined using an Agilent 7800 IS MS mass spectrometer.

The measurement of the volumetric activity of radium-226 in samples of natural waters was carried out according to the "Procedure for measuring the volumetric activity of radium (226, 228) in samples of natural waters with a salinity of up to 5 mg/dm^3 by the alpha, beta radiometric method with radiochemical preparation". The measurements were carried out on a UMF-2000 low-background alpha-beta radiometer certified for measuring radium isotopes (226, 228) in the geometry of a powder sample weighing 100 mg in a standard cuvette. The processing of the measurement results was carried out by calculating the volumetric activity of radium-226 and assessing the total uncertainty of the result.

Measurement of the activity of radionuclides in soil samples was carried out on the spectrometric complex "Progress" No. 0104-G gamma and beta spectrometric paths, according to the methodology "Methods for measuring the activity of radionuclides using a scintillation gamma", beta-spectrometer with software "Progress", No. KZ.07.00.00303-2004.

Statistical processing of the results was carried out by conventional methods using Microsoft Excel and Statistica 6.0 programs.

3. Research and discussion

The tailing dump is a flat, bulk type that has been in operation since 1968, it has accumulated 44455.984 million m^3 of waste. The tailing dump complex includes:

– map number 1 with the size of 900×1800 m (162 ha), has been worked out by now;

– valid card No. 2 with the size of 1500×1800 m (270 ha), used by the Stepnogorsk hydrometallurgical plant;

– evaporation map 1500×2000 m (300 ha), has been worked out by now (Fig. 1). It should be noted that map 1 and the evaporation map of the tailing dump are not transferred to the balance of the regional executive authority, they are ownerless.

The conducted field studies of the territory beyond the sanitary protection zone of the tailing dump showed that the ADER GR varies from 0.19 to 0.69 μSv/h. In the eastern part of the tailing dump, ADER GR ranges from 0.12 to 0.15 μSv/h, in the western part – from 0.09 to 0.11 μSv/h, in the southern part – from 0.09 to 0.12 μSv/h.

The carried out comprehensive studies of the northern part of the tailing dump confirmed the previously revealed facts on the contamination of a site with an area of 500×3000 m with ADER GR from 0.35 μSv/h to 0.85 μSv/h [7]. Studies have shown that the area of contamination in this area is preserved and the ADER GR varies from 0.41 to 0.69 μSv/h. At a distance of up to 2200 m to the north of the radioactively contaminated area, the value of ADER GR decreases to 0.23 μSv/h. In this area, the flux density of alpha particles varies from 0.32 part/(min×cm^2) to 0.61 part/(min×cm^2). At 3 km from the radioactively contaminated area, the flux density of alpha particles reaches up to 2.26 parts/(min×cm^2), which indicates the continued transfer of radioactive dust from the tailing dump.

As a result of a pedestrian gamma survey in the northwestern part of the tailing dump, a radioactively contaminated site with an area of 420 m^2 with an ADER GR value of up to 0.33 μSv/h was revealed for the first time. It was found that a part of the surveyed territories, where increased values of ADER GR (above 0.12 μSv/h) and alpha-particle flux density (above 2.0 parts/(min×cm^2) were registered, is located in the northern and north-western parts tailing dumps outside the sanitary protection zone.

When carrying out work on assessing the levels of radioactive contamination of environmental objects, attention has been paid to the study of the radionuclide composition of the soil sampled for the sanitary protection zone of the tailing dump. To study the nature of the areal distribution of the

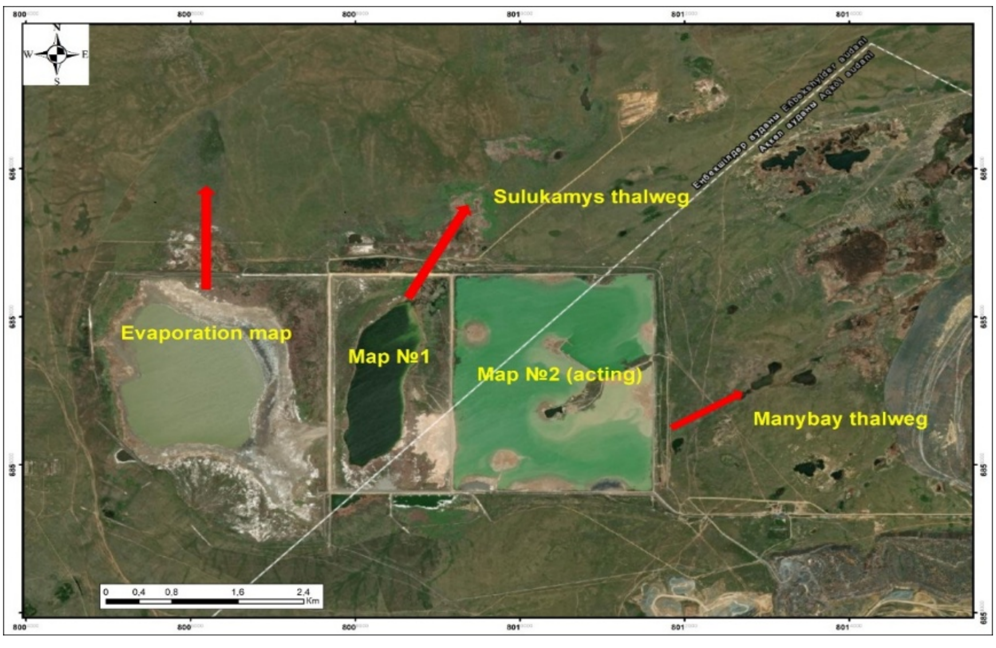

Fig. 1. Tailings storage facility for radioactive waste.

main dose-forming radionuclides and their vertical distribution at a number of sampling points, surface soil samples were taken (layer by layer with a depth of 0–5, 5–10, 10–15, 15–20, 20–30, 30–35, 35–45, 45–50 cm) at a distance of 400 and 1100 m from the border of the sanitary protection zone of the tailing dump.

A radio spectrometric study revealed that the average specific activity of radionuclides in soil samples taken in the northern part behind the sanitary protection zone of the tailing dump varied:

– at a distance of 400 m:
for ^{40}K – from 286 ± 175 to 770±369 Bq/kg;
for ^{226}Ra – from 28±9 to 558±88 Bq/kg;
for ^{232}Th – from 69±20 to 328±66 Bq/kg;
for ^{137}Cs – from 9±2 to 189±44 Bq/kg;

– at a distance of 1100 m:
for ^{40}K – from 297±177 to 734±317 Bq/kg;
for ^{226}Ra – from 18±9 to 290±55 Bq/kg;
for ^{232}Th – from 100±30 to 249±53 Bq/kg;
for ^{137}Cs – from 11±4 to 115±32 Bq/kg.

The maximum values of the specific activity of ^{226}Ra and ^{232}Th were noted in the surface layers of the soil at a depth of 0–5 cm at distances of 400 and 1100 m from the border of the sanitary protection zone of the tailing dump (Fig. 2). So, in soil samples taken at a depth of 0–5 cm from the boundary of the sanitary protection zone in the northern part of the tailing dump at a distance of 400 m, the excess of the specific activity of radionuclides for ^{226}Ra was 37 times compared to the background area and for ^{232}Th – 25 times.

At a distance of 1100 m from the border of the sanitary protection zone of the tailing dump, the concentration of ^{226}Ra and ^{232}Th in the upper soil layer was 19 times higher than the background values.

The surface waters of the Manybaiskiy and Sulukamyskiy thalweg are predominantly sulfate and chloride-sulfate, refer to neutral and slightly alkaline, SO_4^{-2} (1.15–2.70 g/l) and Na^{+}+K^{+} (0.31–2.22 g) ions prevail/l) (Table 1). The dry residue in these reservoirs varies from 0.93 to 23.34 g/l.

The standard for the content of radioactive substances, established in the hygienic standards for drinking water, indirectly applies to the regulation of the water quality of various water bodies used for domestic drinking water supply, including for irrigation of agricultural land. Radiochemical studies of water samples taken from open reservoirs showed that the total alpha activity reaches up to 144.47±47.15 Bq/kg, beta activity up to 24.9±7.4 Bq/kg. In the water sampled from the Manybai and Sulukamysk thalweg, the specific activity of ^{238}U is 3.17 and 3.95 Bq/l, respectively (Table 2).

Thus, the high activity of the studied radionuclides is observed on surface soil samples and decreases with depth. Investigation of the nature of the vertical distribution of various radionuclides in the soil layer makes it possible to determine the main method for the entry of radioactive pollutants into the soil [9]. Thus, for radionuclides ^{226}Ra and ^{232}Th, a pronounced exponential form of vertical distribution is noted with a maximum concentration in the surface layer and its sharp decrease as the depth of sampling increases. An exponential

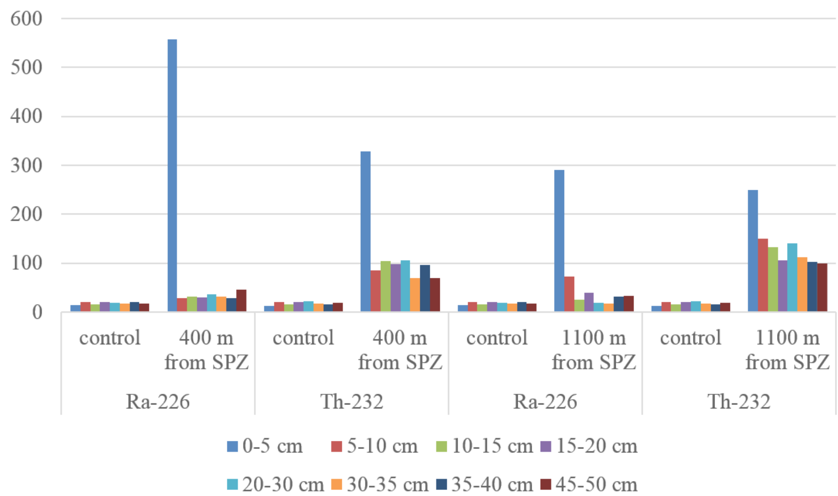

Fig. 2. Average specific activity of radionuclides in the soil behind the sanitary protection zone of the tailing dump of SMCC, Bq/kg. (SPZ – sanitary protection zone).

Table 1
Hydrochemical indicators of water bodies

Water	Anions, g/l			Cations, g/l		
	HCO_3^-	SO_4^-	Cl^-	Ca^{2+}	Mg^{2+}	Na^++K^+
The reservoir of the Manybayskiy thalweg	0.41±0.03	2.70±0.06	0.43±0.10	0.43±0.06	0.46±0.05	0.31±0.10
Reservoir of Sulukamysskiy thalweg	0.74±0.02	1.15±0.07	0.52±0.13	0.81±0.08	0.10±0.01	2.22±0.65

Table 2
Total alpha-, beta-activities and specific activities of radionuclides in water, Bq/l

Name of the reservoir	Total alpha activity	Total beta activity	^{238}U	^{226}Ra
The reservoir of the Manybayskiy thalweg	7.32±1.43	24.9±7.4	3.17±1.02	0.04±0.01
Reservoir of Sulukamysskiy thalweg	144.47±47.15	17.92±5.67	3.95±0.70	0.16±0.05
Interference levels of radionuclides in drinking water [8]	0.2	1.0	3.0	0.49

distribution is characteristic of pollution, the entry of which into the soil is due to atmospheric deposition. The main mechanism of ^{226}Ra and ^{232}Th input is wind erosion of the tailing dump surface and subsequent dust transfer. The specific activity of ^{40}K practically does not depend on the depth of sampling of layer-by-layer samples and is in the range of values typical for the soils of the region; thus, we can conclude that there is no ^{40}K introduced.

High concentrations of alpha and beta emitting radionuclides were found in water samples taken from natural reservoirs located behind the sanitary protection zone of the tailing dump. The authors propose methods for combating pollution of natural waters: detoxification using biodegradation; localization of the spread of pollutants by converting them into an insoluble form; pumping out contaminated waters with their subsequent purification [10]. The data presented indicate the presence of a negative impact of the tailing dump of the Stepnogorsk Mining and Chemical Combine on the environment of the adjacent territories, due to wind erosion of the object's surface and subsequent contamination of the surface layers of the soil as a result of the spread of radioactive dust.

4. Conclusion

1. On the territory beyond the sanitary protection zone of the tailing dump, local, radioactively contaminated areas with an ambient equivalent dose rate of gamma radiation up to 0.69 μSv/h have been identified.

2. The specific activity of natural radionuclides ^{226}Ra, ^{232}Th in surface soils (0–5 cm) of radioactively contaminated areas exceeds the control levels from 19 to 37 times.

3. In water samples taken from natural reservoirs of the Manybaiskiy and Sulukamyskiy thalweg, the total alpha and beta activities are more than 700 times higher than the control values.

4. The degree of contamination by man-made radionuclides of natural objects around the radioactive waste storage facility is many times higher than the control levels, requires intervention, constant radiation monitoring and environmental and sanitary-hygienic measures.

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