HYGIENIC ASSESSMENT OF RADIATION SAFETY OF WATER BODIES NEAR FORMER URANIUM MINES IN THE TASHKENT REGION

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Abstract. *The aim of the study was to perform a hygienic assessment of the radiation safety of mountain rivers and the Angren Reservoir located near the former uranium mines of Yangiabad, Tashkent region. In 2024–2025, water, bottom sediment and adjacent soil samples were collected at four monitoring points: the Kattasay and Dukentsay rivers near the former uranium mines, the Akhangaran River at the confluence, and the Angren Reservoir. Gross alpha and beta activity of water, the specific activities of ^{226}Ra, ^{232}Th, ^{40}K, ^{137}Cs and ^{90}Sr in water, sediments and soils, the equivalent dose rate (EDR) of gamma radiation above the water surface and the volumetric activity of radon-222 in ground-level air were determined. The EDR ranged from 0.17 to 0.45 μSv/h and was highest at the Kattasay and Dukentsay rivers. Gross alpha and beta activity of water (0.05–0.18 and 0.93–1.25 Bq/L) did not exceed the screening levels of 0.2 and 2.0 Bq/kg, and the sum of the ratios of radionuclide activities to their intervention levels was 0.85–0.93. The specific activity of ^{226}Ra in bottom sediments (39.5–87.9 Bq/kg) and soils (42.5–78.1 Bq/kg) was highest near the former mines, and the volumetric activity of radon-222 in air was 5.4–12.7 Bq/m^3. Water in the studied water bodies meets radiation safety requirements. The radiation situation in the Angren Reservoir area is favourable, whereas locally elevated radiation levels near the former mines require regular monitoring.*

Keywords*: radiation safety, drinking water, gross alpha and beta activity, gamma spectrometry, radium-226, radon-222, bottom sediments, Angren Reservoir, uranium legacy sites*

INTRODUCTION.

Providing the population with safe water is a key element of life support and a primary determinant of public health. Water quality in drinking and agricultural water supply systems determines the level of sanitary and epidemiological well-being and is a key parameter in environmental studies. Freshwater scarcity, which has been a global problem since the late 20th century, is driven by population growth and increasing water consumption.

Humans are constantly exposed to ionizing radiation from cosmic rays and from naturally occurring radionuclides in air, food and water [8]. Drinking water is one of the routes by which radionuclides enter the human body, and the key indicators for assessing its radioactivity are the activity concentrations of radionuclides and the corresponding annual effective dose [9]. Radiological protection of the public, including protection against radionuclides in drinking water, is based on the recommendations of the International Commission on Radiological Protection [4] and the IAEA Basic Safety Standards [2].

Radionuclides enter the aquatic environment from natural sources (naturally occurring radionuclides of the uranium and thorium series and ^{40}K) and from artificial sources (global fallout from nuclear weapons tests, emissions and discharges from nuclear and industrial facilities). Gross alpha activity of water is mainly determined by ^{238}U, ^{234}U, ^{226}Ra, ^{224}Ra, ^{210}Po and ^{232}Th, while gross beta activity is mainly due to ^{40}K, ^{228}Ra and ^{210}Pb [9]. Significant exposure of the population can occur as a result of radioactive contamination of rivers, lakes and reservoirs.

According to international recommendations, the effective dose from drinking water should not exceed 0.1 mSv per year at an annual consumption of 730 L [9]. According to SanPiN No. 0193-06 "Radiation Safety Standards (NRB-2006) and Basic Sanitary Rules for Ensuring Radiation Safety

(OSPORB-2006)" [6], radiation monitoring of water starts with the determination of gross alpha and beta activity (A_α, A_β). If the screening levels are exceeded, the specific activities of ^{210}Po, ^{210}Pb, ^{226}Ra, ^{228}Ra, ^{238}U and ^{234}U are determined, and at the next stage those of ^{228}Th, ^{230}Th, ^{232}Th, ^{90}Sr, ^{137}Cs, ^{238,239,240}Pu and ^{241}Am. The results are compared with the intervention levels for drinking water.

^{226}Ra in water is commonly determined by alpha spectrometry after radiochemical separation, or by gamma spectrometry via its short-lived progeny ^{214}Pb and ^{214}Bi after radioactive equilibrium has been reached; direct use of the 186.2 keV line of ^{226}Ra is hampered by its overlap with the 185.7 keV line of ^{235}U [9].

The radioactivity of reservoirs depends on the chemical composition of the inflowing water, runoff from adjacent agricultural and industrial areas and the presence of radionuclides in the rivers that feed them. Studying the radioactivity of reservoirs provides information on the sources and levels of environmental contamination and on the potential risks of exposure.

The Angren (Akhangaran) Reservoir in the Akhangaran District of the Tashkent region is an important source of water for the population, industry and irrigated agriculture. Surface water from the former uranium mines does not flow into the reservoir; however, the region has a long history of uranium mining and ore processing during the Soviet period, which left waste rock dumps, tailings and contaminated soils that could affect local water bodies. Uranium was mined in Yangiabad and the surrounding area from the early 1950s until the 1980s, after which the mines were closed. The Yangiabad sites are among the priority uranium legacy sites in Central Asia included in international remediation programmes [1, 3]; similar legacy sites in the region have been the subject of radiological assessments [7].

Radioecological monitoring of the reservoir, the rivers of its basin and the adjacent territories is therefore an important task for protecting public health.

The aim of the study was to perform a hygienic assessment of the radiation safety of mountain rivers and the Angren Reservoir located near the former uranium mines in the Tashkent region.

MATERIAL AND METHODS OF RESEARCH.

The Angren Reservoir is a hydraulic structure on the Akhangaran River in the foothills of the Western Tien Shan. It was built in 1989 and has a capacity of 260 million m^3. A rock-and-earth dam with an inclined core (length 1,350 m, crest width 12 m, maximum height 100 m) is located in the southeastern part of the reservoir. Downstream of the reservoir, the Akhangaran River is partly canalized and flows underground towards Jigiristan. Water from the reservoir is used for irrigation in the Akhangaran and Urtachirchik districts and for the water supply of industrial enterprises and the population.

The climate of the area is sharply continental, with cold winters and hot, dry summers. Average January temperatures range from −1 to −2 °C, with minimum temperatures in some years reaching −25 to −33 °C. Summer temperatures average 28–30 °C and on some days reach 42–44 °C. Precipitation is unevenly distributed: about 50 % falls in spring and up to 30–35 % in winter, while summer receives only 4–5 %.

The Akhangaran River originates on the northern slopes of the Chatkal Range and is one of the major rivers of the eastern Tashkent region. It is fed mainly by snow and rain and, to a lesser extent, by groundwater. The average annual discharge in the middle reaches is 22–25 m^3/s, reaching 200–250 m^3/s during spring and summer floods. Its most significant tributaries within the Angren Valley are the Dukentsay and Kattasay rivers, which flow near the former uranium mines of Yangiabad and join the Akhangaran River downstream of the Angren Reservoir. Their water is used for domestic purposes and irrigation.

Laboratory analyses were performed at the Scientific Research and Testing Radiological Laboratory of the Center for the Development of Professional Qualification of Medical Workers of the Ministry of Health of the Republic of Uzbekistan. The laboratory holds Certificate of Approval No. ML/2098 issued by the Inspectorate for Supervision of Technical Regulation under the Agency for Technical Regulation of Uzbekistan (valid until 5 October 2027).

Samples of water, bottom sediments and adjacent soils were collected in winter 2024 and in spring and summer 2025 at four radioecological monitoring points:

1) No. 1 — the Kattasay River near Rudny Dvor;
2) No. 2 — the Dukentsay River near the Alanga section;
3) No. 3 — the Akhangaran River at the confluence of the rivers;
4) No. 4 — the Angren Reservoir (southeastern part).

Water samples (10 L) were collected in accordance with ISO 5667-1 [5] from a depth of 30–50 cm below the surface into thoroughly washed plastic containers, which were filled to the brim and hermetically sealed. Owing to the low activity of radionuclides, direct measurement was ineffective; the samples were therefore concentrated tenfold by evaporation from 10 L to 1 L at 70 °C without boiling. Soil samples were collected near each monitoring point to a depth of 30 cm in 5-cm layers.

Prior to sampling, the equivalent dose rate (EDR) of gamma radiation was measured 10 cm above the water and soil surface using an identiFINDER field radiometer-spectrometer (verification certificate No. 1740, valid until 01.12.2025) and an MKS-AT1117 dosimeter-radiometer (serial No. 1162, verification certificate No. 421/05, valid until 27.12.2025).

For gamma spectrometric measurements, the concentrated water samples were placed in Marinelli beakers, filled to the mark and hermetically sealed. Measurements lasted 1800 s and were performed with a scintillation gamma spectrometer with a Ø80 × 80 mm NaI(Tl) crystal and an energy resolution of 8.5 % for the 661.7 keV line of ^{137}Cs. Energy and efficiency calibration was performed using certified reference sources, including a ^{232}Th source; temperature and relative humidity in the laboratory were kept constant and recorded. Spectra were processed with the software of the RADEK spectrometric complex (STC RADEK, Russia) to determine the natural radionuclides ^{40}K, ^{226}Ra and ^{232}Th and the artificial radionuclide ^{137}Cs. Strontium-90, a pure beta emitter, was determined by beta spectrometry.

Compliance of water with radiation safety requirements was assessed by comparing gross alpha and beta activity with the screening levels and by the sum of the ratios of the specific activities of ^{137}Cs, ^{90}Sr, ^{226}Ra and ^{232}Th to their intervention levels ($\sum A_i/IL_i \leq 1$) [6]; ^{40}K was not included in the sum.

The volumetric activity of radon-222 in ground-level air was measured with an AlphaGUARD ionization-chamber radon monitor equipped with a weather station and data logger.

RESULTS AND DISCUSSION.

The results of EDR measurements above the water surface are presented in Table 1.

Table 1.

Average EDR of gamma radiation 10 cm above the water surface of water bodies near Yangiabad, Tashkent region, 2024–2025

Monitoring point	Water body	EDR, μSv/h
No. 1	Kattasay River (Rudny Dvor)	0.45
No. 2	Dukentsay River (Alanga section)	0.37
No. 3	Akhangaran River (confluence)	0.19
No. 4	Angren Reservoir	0.17

The highest EDR values were recorded above the Kattasay and Dukentsay rivers (0.45 and 0.37 μSv/h), which flow near the former uranium mines; they were 2–2.6 times higher than at the confluence and the reservoir (0.17–0.19 μSv/h).

The results of gross alpha and beta activity measurements in water are presented in Table 2.

Table 2.

Average gross alpha and beta activity of water in rivers and the reservoir near Yangiabad, Tashkent region, 2024–2025

Monitoring point	Water type	Gross activity of water, Bq/L	
		A_α	A_β
No. 1	surface fresh water	0.18	1.22
No. 2	surface fresh water	0.17	1.25
No. 3	surface fresh water	0.08	0.93
No. 4	surface fresh water	0.05	0.97
Screening level [6], Bq/kg		0.2	2.0

According to SanPiN 0193-06 [6], the gross alpha and beta activity of drinking water should not exceed 0.2 and 2.0 Bq/kg, respectively (for fresh water, 1 Bq/L ≈ 1 Bq/kg). The values obtained at all points were below these levels; thus, from the standpoint of radiation safety, the water can be used for drinking purposes. Gross alpha and beta activity at points 1 and 2 (0.17–0.18 and 1.22–1.25 Bq/L) was higher than at points 3 and 4 (0.05–0.08 and 0.93–0.97 Bq/L).

The specific activities of natural and artificial radionuclides in water are presented in Table 3.

Table 3.

Average specific activity of natural and artificial radionuclides in water of the studied water bodies, 2024–2025

Monitoring point	Specific activity, Bq/L					$\sum A_i/IL_i$	Standard [6]
	^{137}Cs	^{90}Sr	^{40}K	^{226}Ra	^{232}Th		
No. 1	≤0.17	≤0.02	≤37.8	0.61	0.34	0.90	≤1.0
No. 2	≤0.17	≤0.02	≤21.1	0.53	0.47	0.93	≤1.0
No. 3	≤0.17	≤0.02	≤32.2	0.52	0.38	0.85	≤1.0
No. 4	≤0.17	≤0.02	≤25.3	0.55	0.42	0.91	≤1.0

Note: "≤" — below the minimum detectable activity; ^{40}K is not included in $\sum A_i/IL_i$.

The activities of ^{137}Cs and ^{90}Sr in water were below the minimum detectable activity. The sum of the ratios of the specific activities of radionuclides to their intervention levels was 0.85–0.93, i.e., less than 1 at all points. This confirms the radiation safety of the water and means that the annual effective dose from its consumption does not exceed 0.1 mSv [6, 9].

The specific activities of radionuclides in bottom sediments and adjacent soils are presented in Tables 4 and 5.

Table 4.

Average specific activity of natural and artificial radionuclides in bottom sediments of the studied water bodies, 2024–2025

Monitoring point	Specific activity, Bq/kg				
	^{137}Cs	^{90}Sr	^{40}K	^{226}Ra	^{232}Th
No. 1	2.57	1.21	≤135.1	87.9	47.8
No. 2	3.42	0.62	≤122.3	72.1	37.4
No. 3	3.21	0.81	≤127.6	39.5	38.6
No. 4	2.17	0.94	≤118.9	42.7	41.5

Table 5.

Average specific activity of natural and artificial radionuclides in soils adjacent to the studied water bodies, 2024–2025

Monitoring point	Specific activity, Bq/kg				
	^{137}Cs	^{90}Sr	^{40}K	^{226}Ra	^{232}Th
No. 1	1.51	0.12	≤127.1	78.1	37.5
No. 2	2.74	0.24	≤118.3	72.8	28.4
No. 3	0.57	0.22	≤124.5	48.9	32.0
No. 4	1.23	0.34	≤119.3	42.5	39.4

In Uzbekistan, the content of radionuclides in bottom sediments and soils is not regulated. The specific activity of ^{226}Ra in bottom sediments and soils at points 1 and 2 (72.1–87.9 Bq/kg) was 1.5–2.2 times higher than at points 3 and 4 (39.5–48.9 Bq/kg) and exceeded the upper limit of the worldwide range for soils (17–60 Bq/kg; median 35 Bq/kg) [8]. At points 3 and 4, ^{226}Ra activity was within this range. The specific activity of ^{232}Th (28.4–47.8 Bq/kg) was within the worldwide range (11–64 Bq/kg) [8].

The activities of ^{137}Cs (0.57–3.42 Bq/kg) and ^{90}Sr (0.12–1.21 Bq/kg) were low. ^{137}Cs in soils originates mainly from global fallout from atmospheric nuclear weapons tests and is retained mostly in the upper soil layer [8].

The volumetric activity of radon-222 in ground-level air at the monitoring points is presented in Table 6.

Table 6.

Average volumetric activity of radon-222 in ground-level air near the Kattasay, Dukentsay and Akhangaran rivers and the Angren Reservoir, 2024–2025

Monitoring point	Volumetric activity of radon-222, Bq/m^3	Standard [6], Bq/m^3
No. 1	12.7	≤100
No. 2	9.5	≤100
No. 3	7.8	≤100
No. 4	5.4	≤100

The volumetric activity of radon-222 (5.4–12.7 Bq/m^3) did not exceed the standard value established by SanPiN 0193-06 [6] and was comparable to the typical outdoor radon concentration of about 10 Bq/m^3 [8].

The study covered water, bottom sediments, adjacent soils and ground-level air at the Angren Reservoir and the Akhangaran, Kattasay and Dukentsay rivers. All measured parameters — the EDR, gross alpha and beta activity of water, the specific activity of ^{226}Ra in bottom sediments and soils and the radon-222 concentration in air — were consistently higher at points 1 and 2 on the Kattasay and Dukentsay rivers, which flow near the former uranium mines, than at the confluence and in the reservoir. This spatial pattern indicates a local influence of past uranium mining and is consistent with the absence of surface water inflow from the former mines into the reservoir. A local character of radiological impact has also been reported at other uranium legacy sites in Central Asia [7].

Despite the elevated values near the former mines, water at all points met the radiation safety criteria for drinking water [6]. At the same time, the use of river water for domestic purposes and irrigation, as well as livestock grazing in the river valleys, creates potential pathways for radionuclides to enter locally produced meat and dairy products, which requires further research. Continued monitoring is also necessary during and after remediation of the legacy sites [1, 3].

CONCLUSION.

1. The EDR of gamma radiation above the Kattasay and Dukentsay rivers (0.45 and 0.37 μSv/h) is 2–2.6 times higher than at the Akhangaran River confluence and the Angren Reservoir (0.17–0.19 μSv/h); these sites are located away from residential areas.

2. Gross alpha and beta activity of water at all monitoring points (0.05–0.18 and 0.93–1.25 Bq/L) is below the screening levels of 0.2 and 2.0 Bq/kg, and the sum of the ratios of radionuclide activities to their intervention levels (0.85–0.93) is less than 1; the water meets radiation safety requirements for drinking water.

3. The specific activity of ^{226}Ra in bottom sediments and soils near the former uranium mines (72.1–87.9 Bq/kg) is 1.5–2.2 times higher than at the confluence and the reservoir; the activities of ^{137}Cs and ^{90}Sr are low and correspond to global fallout.

4. The volumetric activity of radon-222 in ground-level air (5.4–12.7 Bq/m^3) does not exceed the standard value.

5. The radiation situation in the Angren Reservoir area is favourable, and in the Yangiabad area it is relatively favourable for public health. Locally elevated radiation levels near the former uranium mines require regular monitoring, and the possible accumulation of radionuclides in locally produced meat and dairy products requires further research.

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