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Radiation Situation of Industring Objects SMCC and the Nearby Settlements

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Abstract: The analysis of the radiation environment of workplaces and personnel dose load hydrometallurgical plant of the Stepnogorsk Mining and Chemical Combine and the accumulated doses of the personnel group A. Studied the soil, water and plants in the area around workers' settlements and uranium mining companies as well as sanitary protection zone of the tailings of radioactive waste. Identified local contaminated areas in the North-East of the sanitary protection zone of the tailings SPZT Stepnogorsk mining and chemical plant extending up to 5 km. The most contaminated with radionuclides is the top layer of soil 0-5 cm. In the North-East and South-East directions from SPZT specific activity of U238, Ra226 in soil exceed the reference value of 16 times, Pb210 up to 7 times. The plant samples taken from the vicinity of the village in the South-East and North-East directions from SPZT have high concentrations of natural radionuclides. In ponds and Sulukamysskogo Manybayskogo thalwegs specific activity of artificial radionuclides in the tens of times higher than the control values.

Key words: Uranium, radioactivity, migration of radionuclides, radon, dose, environmental pollution

INTRODUCTION

Companies of uranium, mining and oil industries are potential sources of contamination of the environment by various pollutants including natural radionuclides (Drichko, 1983; UNSCEAR, 1982; Kozlov and Shvetsov, 2004).

Stepnogorsk Mining-Chemical Complex (SMCC) are over 50 years and is one of the largest complexes for the production of uranium oxide and other rare metals. In 2015, the total number of personnel of group A Hydrometallurgical Plant (hereafter HMP) SMCC was 480. SMCC radioactive waste accumulated in the tailings pond area of 7.82 km^2, located 4 km North of the village of Aksu and 20 km North of the city of Stepnogorsk where the concentrated mass of waste is 44,170,000 Tons, 146.4 thousand activity Curie. The complex tailings includes three cards, two pumping stations, coal slurry, rockfill dam, two tier drainage system, three drainage pumping stations and impervious screen below the map No. 2 (Fig. 1).

The purpose of this study is to assess the radiological condition of the soil, plants, open reservoirs around the tailings SMCC, territory and industrial communities Aksu factory as well as analysis of the radiological situation of jobs and staff dose burden of group A SMCC.

Fig. 1: Space photo tailings HMP (red arrows indicate the spreading of groundwater from the tailings cards)

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MATERIALS AND METHODS

Were measured flux densities of a and b particle, the Equivalent Dose Rate (EDR) g radiation in the workplace HMP SMCC to the territories in South-East and North-East directions outside SPZT as well as in places of soil sampling, plant, water and sediments in the vicinity of Aksu towns, factory and outside SPZT where there is grazing animals. Radiation environment were analyzed data of jobs and personal dosimetry of external and internal exposure HMP staff of >20 years.

Soil samples were collected by the method of "envelope" with the probe at a depth of 0-20 cm layers. Since, soil sampling sites were collected plants (herbs) for radiological studies. Served as a control sample of soil and plants in the village Akkol which is located 100 km from the city of Stepnogorsk.

Samples of water and sediment were taken from ponds Manybay and Sulukamyss thalwegs located at a distance of 1.5 and 2 km in the East and North-Eastern part of the tailings SMCP. Served as a control sample of water and sediments of the Aksu River.

PED gamma-radiation flux density and α, β-particles was measured by a dosimeter-radiometer "RCS-01-SOLO" with range of energy γ-rays from 20 keV to 10 MeV.

The specific activity of radionuclides in the samples was determined by scintillation γ-spectrometer using the software "Progress" as well as γ-ray spectrometer DSA-1000 «Canberra» with a planar Ge-detector. Radiochemical studies were carried out in accordance with standard methods (Marey and Zykov, 1997).

Radio spectrometrical and radiochemical studies were performed in the laboratories of the National Nuclear Center of the Institute of Nuclear Physics and Radiation Services and Toxic Security of Limited Partnership "Stepnogorsk Mining and Chemical Plant".

RESULTS AND DISCUSSION

In the workplace, the personnel of A HMP γ-radiation EDR ranging from 0.37-1.64 mSv/h, the maximum rate for γ-radiation EDR was recorded in the extraction of the shop. α-particle flux density ranges from 23×35.6 ppm/Sm^2×min, indicators of density of α-particles and γ-radiation DER in the workplace does not exceed the permissible levels of radioactive contamination of the surface of the periodic residence premises personnel and equipment located in them.

Long-lived α-active nuclides of the uranium series in the working area ranges from 0.19-1.62 Bq/m^3, the maximum rate of 1.62 Bq/m^3 was recorded in the extraction of the shop which is greater than the rate of <0.3 Bq/m^3, radon EEVA ranges from 83-380 Bq/m^3, the maximum rate of 380 Bq/m^3 was registered in the shop milling fractions and heap leaching and does not exceed the allowable concentration in the air of the working area 1200 Bq/m^3.

The maximum length of service of employees is 47 the average value 13 years. According to the results of individual monitoring personnel group A at workers with experience of HMP to 5 years, the average cumulative dose at 95% confidence interval was 18.8 mSv (16.08, 21.52), up to 10 years 60.1 mSv CI (57.31, 62.89), up to 15 years 101.8 mSv CI (95.4; 108.4), up to 20 years 140 mSv (126.88, 152.92) 95% CI, a 20-260.5 mSv (237.31, 283.69) CI 95% (Table 1).

As a result, pedestrian-scale survey of the North side SMCP identified an area of anomalous 500×3000 m with a capacity equivalent dose (PED) γ-radiation from 0.35 and 0.85 mSv/h. γ-radiation dose rate in a South-Easterly direction up to 3 km and a North-Easterly direction up to 5 km from SMCP not exceed background values and amounted to 0.08 and 0.25 mSv/h. At low dose rate γ-radiation in a South-Easterly direction flux density β-particles was 0.97 frequently (min/Sm^2), β-particles from 11-145 frequently (min/Sm^2). At a distance of 2000 m to 2750 m flux density of α-particles in a North-Easterly direction varies in the range 0.97-2.91 frequently (min/Sm^2).

In the area of anomalous soil samples from the Northern side of the specific activity of SMCP ^{238}U 2 times, ^{226}Ra 31 times, ^{232}Th 7 times, ^{210}Pb is 10 times more than in the control sample (Fig. 2).

Table 1: The cumulative dose of the personnel of Group A HMP SMCC during work mSv

Work experience with source of ionizing radiation (year) (ranges)	No. of employees	Cumulative dose (mSv) Min.	Max.	Middle	CI 95%
5	55	3.13	48.4	18.8	18.8±2.70
10	209	16.4	172.2	60.1	60.1±2.80
15	93	34.1	181.6	101.8	109.9±6.50
20	40	69.8	232.9	140.0	139.9±13.0
>20	83	87.3	538.6	260.5	260.5±23.2

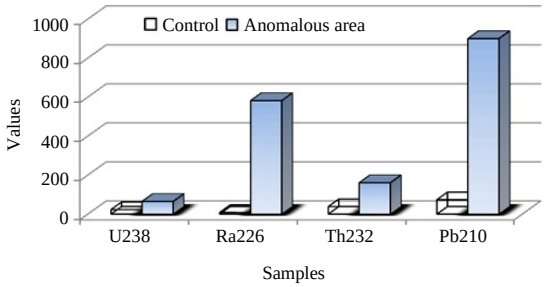

Fig. 2: The specific activity of radionuclides in soil samples from the anomalous area of the Northern part SMCP

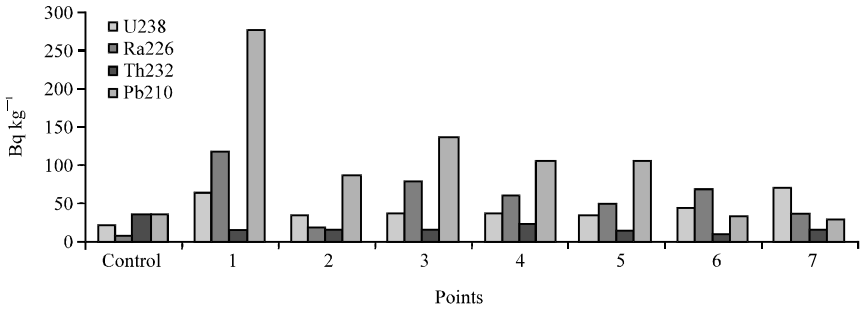

Fig. 3: Specific activity of radionuclides in the soil North-Easterly direction from SMCP

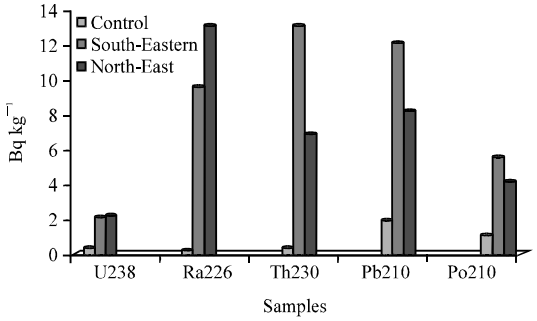

Fig. 4: Concentration of natural radionuclides in samples of plants South-Eastern and North-Easterly direction from SMCP

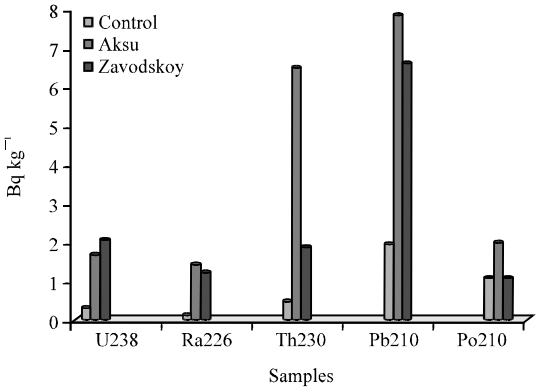

Fig. 5: Concentration of natural radionuclides in samples of plants South-Eastern and North-Easterly direction from SMCP

In soil samples from the North-East SMCP of up to 1,750 m (points 1-7) the maximum content of U238, Ra226, Pb210 formed 72, 120, 278 Bq kg^{-1} which exceeds 3, 14 and 7 times the control (Fig. 3).

In soil samples from radioactively contaminated areas specific activity of natural radionuclides U238, Ra226, Th232 is higher than for soils of Kazakhstan in the 10-31 times (Kazakhstan, 2002).

The samples of plants South-Eastern and North-Eastern areas of concentration SMCP Th230, Ra226 and Pb210 than the reference value of >10 times (Fig. 4).

In the vicinity of the surveyed localities and Aksu factory flux density α and β-particles is <1 and 10 parts (min/Sm^2). In the village of Aksu found five abnormal areas ranging from 25-1000 m^2 with the intensity of γ-radiation to 0.86 mSv/h which is 3 times higher than the average for the Republic:

- In the high school identified an area of from 25-1000 m^2 with a level of intensity γ-radiation dose rate from 0.49-0.63 mSv/h
- On the street Satpayev identified local site area of 56 m^2 where γ-radiation dose rate ranged from 0.28-0.62 mSv/h
- Plot with an area of 25-1000 m^2 at the intersection of Titov and mine with the intensity level of PER γ-radiation from 0.39-0.72 mSv/h
- Street-mine an area of 25 m^2 with a level of intensity of the radiation dose rate γ from 0.68-0.70 mSv/h
- An area of 100 m^2 on the street, Satpayev at the intersection of the road, the γ-radiation dose rate from 0.81-0.86 mSv/h

In the soil of the village of Aksu specific activity of Ra226 is 1.5 times higher than the average value for soils of Kazakhstan.

The samples of plants from the surveyed villages of Aksu and factory specific activity of Th230 and Pb210 4-6 times higher than control values (Fig. 5).

Taking into account the residence time of the individual groups of the population in radioactively anomalous areas Aksu Village revealed that the likely radiation dose from external gamma radiation to critical groups of the population is from 0.86-1.53 mSv/year.

In the coastal waters of the investigated γ-radiation dose rate varies from 0.11-1.94 mSv/h. The highest value of γ-radiation dose rate in excess of background levels

Table 2: Level range the background and the flux densities of α, β-particles in the coastal area of surface water

Name of the water	PER mSv/h	The density of α-particle flows, particle (minxsm^2)	The density of β-particle flows, particle (minxsm^2)
Waters of Manybay thalweg	0.69±0.15**	0.98±0.30***	6.52±1.33***
Waters of Sulukamyss thalweg	0.47±0.13*	0.95±0.17***	3.86±1.20**
Tailings MMP	1.94±0.62***	0.95±0.25**	6.76±2.13***
Aksu River (control)	0.11±0.03	0.00±0.00	1.46±0.48

The reliability of the results compared with the control; *p≤0.05; **p≤0.01; ***p≤0.001

Table 3: The hydrochemical parameters of water bodies (Bq/L)

	Anions (g L^{-1})			Cations (g L^{-1})		
Water	HCO_3^-	SO_4^-	Cl^-	Ca^{2+}	Mg^{2+}	Na^++K^+
Waters of Manybay 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
Waters of Sulukamyss 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
Aksu River (control)	0.37±0.02	0.53±0.02	0.82±0.03	0.12±0.02	0.16±0.04	0.16±0.03

Table 4: Radionuclides (Bq/L) in water

Name of the water	U238	Ra226
Waters of Manybay thalweg	3.17±1.02***	0.04±0.01
Waters of Sulukamyss thalweg	3.95±0.70**	0.16±0.05*
Aksu River (control)	<0.5	0.03±0.01

The reliability of the results compared with the control; *p≤0.05; **p≤0.01; ***p≤0.001

(4-18 times) recorded in the coastal part of the tailings SMCP, ponds Manybay and Sulukamyss thalwegs (Table 2). In these waters there is increased density of contamination of the coast of alpha and beta particles.

Surface water of Manybay and Sulukamyss thalwegs mainly sulfate and chloride-sulfate are neutral and weakly alkaline, dominated by the ions SO_4^{-2} (1.15-2.70 g L^{-1}) and Na^++K^+ (0.31-2.22 g L^{-1}) (Table 3). The dry residue in these reservoirs ranged from 0.93-23.34 g L^{-1}.

In water samples from the Sulukamyss thalweg concentration of U238 and Ra226 in 21 and 4 times, respectively higher than the reference value. In water, selected from the specific activity of the Manybay thalweg U238 at 28 times the control value (Table 4).

Bottom sediments are the main place of deposit of artificial radionuclides entering the water. The specific activity of U238 in the bottom sediments of water bodies Manybay and Sulukamyss thalwegs respectively over the control values of 105 and 70 times. Ra226 content in the Manybay thalweg control over 76 times in the Sulukamyss thalweg 83 times.

Thus, in soils and waters near the tailings area SMCP revealed high concentrations of artificial radionuclides, pose a potential threat to the environment.

CONCLUSION

The extraction workshop hydrometallurgical plant of the Stepnogorsk Mining and Chemical Combine long-lived alpha nuclides of the uranium series in the air exceeds the limit up to 2 times in other shops hydrometallurgical plant radiation parameters correspond to the regulations valid values. The maximum cumulative dose of the personnel of A hydrometallurgical plant of the Stepnogorsk Mining and Chemical Combine was 260.5 mSv.

In the territory of the sanitary protection zone of the tailings Stepnogorsk mining and chemical plant and the nearest village of Aksu identified local contaminated sites with a capacity equivalent dose of gamma radiation to 0.86 mSv/h. Possible additional radiation dose from external exposure for specific groups of the population of the village of Aksu is from 0.86-1.53 mSv per year.

Identified local radioactively contaminated sites, require intervention and continuous radiation monitoring of relevant environmental and hygienic measures.

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