

Assessment of the Influence of the Process of Underground Uranium Leaching on Soil and Groundwater

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Abstract: The paper presents the results of evaluating the influence of the process of underground leaching of uranium on the state of soil and groundwater. The value of the equivalent dose rate of gamma radiation (EDR) was determined, in laboratory conditions the concentrations of rock-forming chemical elements were determined by the X-ray fluorescence method, the effective specific activity of alpha radiation - A_{eff} , the specific activity of radionuclides in soil samples were determined as well as dry residue, pH value, anions - Cl^- , NO_2^- , NO_3^- , CO_3^{2-} , HCO_3^- , SO_4^{2-} , and their sum, cations - Ca^+ , Mg^+ , Na^+ , K^+ , Fe^{3+} , NH_4 and their sum and concentration of metals - Mn, Pb, Cu, Zn, Co, Cr, Ni in groundwater samples.

Keywords: underground uranium leaching, soil condition, groundwater state, X-ray fluorescence analysis method, chemical element, effective specific activity of alpha radiation, specific activity of radionuclides, soil samples, underground samples, dry residue, pH values, anions and their sum, cations and their sum, metal concentration.

1. INTRODUCTION

Urgency. During mining of uranium deposits - by the method of underground leaching of uranium, the soil and groundwater are contaminated to a varying degree, by the radionuclides of the uranium decay chain - U^{238} , U^{234} , Th^{230} , Ra^{226} , Rn^{222} , Bi^{214} , Pb^{214} , Po^{210} , etc. The reason for this phenomenon is a violation of the technological regulations for pumping, injection, leakage, condition of pipelines, improper organization of transportation of productive solutions, etc. Soil contamination and groundwater by radioactive elements negatively affect their radiation, chemical, biological, erosion, aesthetic characteristics, will lead to the death or degradation of the vegetation cover, loss of fertility, a change in the structure of the earth's surface and a deterioration in the quality of groundwater.

In addition, for such facilities, the limit of permissible concentration of radionuclides is established and their value is regulated by normative International and Republican documents [1]. Determination of values and their values in soils and groundwaters is an urgent task of analytical chemistry, applied nuclear physics and radioecology [2-8].

The purpose of this study was to determine the values of radioactive contaminants in soils and groundwater, their distribution in the acid method of underground leaching of uranium. To achieve this goal, samples taken from soil and groundwater were studied, concentrations of radioactive elements were determined, and their distribution was studied.

2. EXPERIMENTAL METHODS AND TECHNIQUES

Technique and experimental procedure. on the basis of certain values of the equivalent dose rate of gamma radiation (EDR) on the DKS-96 device, contaminated sites were found in the areas of underground leaching of uranium, in laboratory soil samples from these places under laboratory conditions were determined by the X-ray fluorescence method of the concentration of rock-forming chemical elements on the device EDX-7000 (SHMADZU, Japan), determined the value of the

effective specific activity of alpha radiation - A_{eff} on the BIA device and the specific activity of radionuclides - Ra^{226} , Th^{232} and K^{40} gamma - spectrometric method on the device "Gamma progress".

The following are determined in groundwater - dry residue, pH values, anions - Cl^- , NO_2^- , NO_3^- , CO_3^{2-} , HCO_3^- , SO_4^{2-} , and their sum, cations - Ca^+ , Mg^+ , Na^+ , K^+ , Fe^{3+} , NH_4 and their sum — by the photolorimetric method and metal concentrations — Mn, Pb, Cu, Zn, Co, Cr, Ni — by the atomic absorption method.

3. RESULTS AND DISCUSSION

Assessment of groundwater conditions during underground leaching of uranium. During underground leaching of uranium, groundwater is contaminated by various components contained in the working solution, as well as by substances formed as a result of the interaction of the leaching solution with ore-bearing rock. During sulfuric acid leaching, in addition to uranium, from the rock to underground waters in quantities exceeding the maximum permissible concentrations (MPC) for ground water, various chemical elements pass (Fe, Al, Ca, Cu, Mo, etc.). The total salinity of groundwater in such a process can reach up to 30 g / l (and the total salinity for industrial water is established - 1 g/l). The obtained technological uranium-containing solutions also contain radionuclides - U^{234} , Th^{230} , Ra^{226} , Rn^{222} , Bi^{214} , Pb^{214} , Po^{210} , etc.

Studies of the behavior of various radionuclides in groundwater show that when sulfuric acid underground leaching of uranium is observed pollution of these objects with different amounts of radionuclides.

Table 1 compares the composition of groundwater and technological solutions in the sulfuric acid method of leaching of uranium.

For the above samples in Table 1, the pH value varies between 7.2-8.5 for groundwater, and for solutions of underground leaching of uranium 1.5–5.2, the dry residue varies between (1840-28046) mg / l for groundwater, and for solutions of underground leaching (14964-70932) mg / l, the hardness varies in the range (10.2 - 12.7) mg / l for groundwater, and for solutions of underground leaching (53.2 - 74.6) mg / l.

Table1. Comparison of the composition of natural waters and technological solutions in the sulfuric acid method of leaching of uranium

No. of samples	CATIONS mg/dm ³						ANIONS mg/dm ³						
	Ca ²⁺	Mg ₂₊	Na ⁺ +K ⁺	Fe ₃₊	NH ₄ ⁺	Σ	CO ₃ ²⁻	HC O ₃ ⁻	SO ₄ ²⁻	Cl ⁻	NO ₂ ⁻	NO ₃ ⁻	Σ
groundwater samples													
1	122,24	52,29	244,60+7,30	0,25	0,67	427,35	7,50	222,72	511,62	237,52	<0,02	1,31	980,67
2	122,24	54,72	243,20+7,30	0,25	1,24	428,95	7,50	228,82	505,85	244,61	<0,02	0,60	987,38
3	122,24	71,75	169,00+7,70	0,27	1,37	372,33	4,50	228,83	510,38	173,71	<0,02	13,03	930,45
underground leaching solutions													
4	409	307			46				16390	663			

Table 2 shows the results of atomic absorption analysis of the concentration of metals in groundwater.

Table2. The results of atomic absorption analysis of the concentration of metals in groundwater

No.	Analysis results, mg/dm ³						
	Mn	Pb	Cu	Zn	Co	Cr	Ni
1	0,004	0,070	0,006	0,006	0,010	<0,001	<0,001
2	0,003	0,060	0,006	0,006	0,003	<0,001	<0,001
3	0,003	0,060	0,006	0,007	0,010	<0,001	<0,001
MPC *	---	0,100	1,000	1,000	1,000	0,100	0,100

MPC* - for domestic water. Handbook of an environmental expert. Tashkent 2009 Goskompriroda.

The main method of groundwater reclamation is natural demineralization. At the same time, the main part of environmental protection measures consists in creating a network of observation wells and conducting hydrogeological monitoring until the concentration of pollutants is reduced to the MPC level or background values.

Assessment of the soil condition during underground leaching of uranium soil condition is assessed in accordance with the requirements of SanPiN No. 0079-98 (liquidation, conservation, and re-profiling of uranium mining and processing facilities) in which the upper values of the specific activity of radionuclides, the effective specific activity of alpha radiation - Aeff are established, the power of the exposure dose of gamma radiation and the pH of the aqueous extract in agricultural and sanitary directions.

To determine the concentration of rock-forming chemical elements in soil samples taken from sites of underground leaching of uranium, an X-ray fluorescence analysis method was carried out.

Figure 1 shows the dependence of the energy of rock-forming chemical elements on the number of pulses per minute.

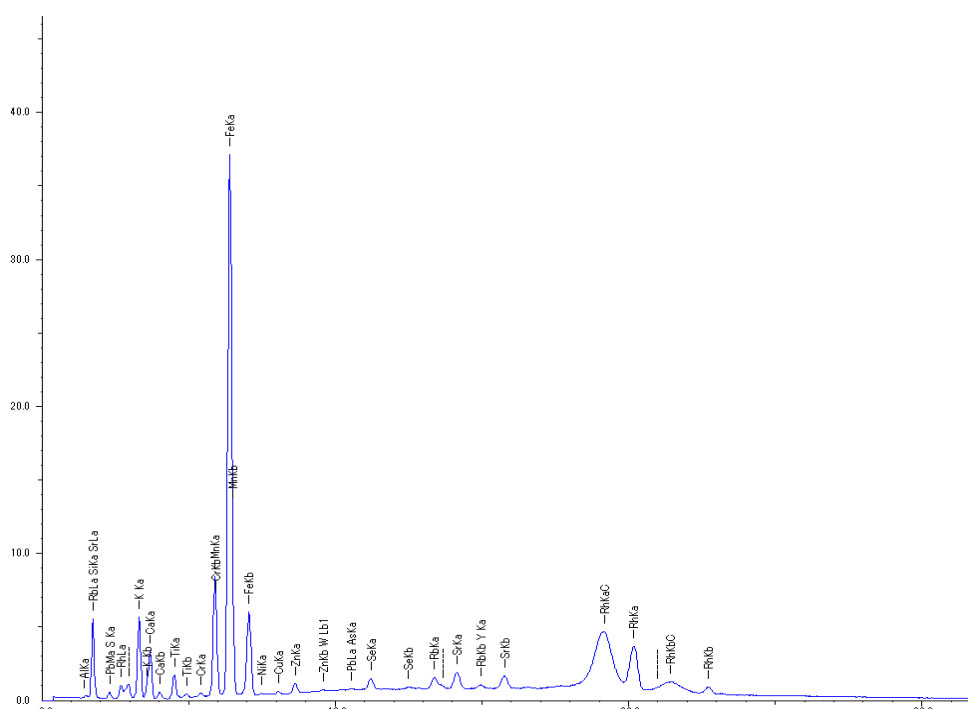


Fig1.dependence of the energy of chemical elements on the number of pulses per minute in soil samples

As can be seen from the dependence, the most important rock-forming chemical element in the soils shown in Fig. 1 is SiO₂. The results determined by the X-ray fluorescence method of concentration of chemical elements depicted in Fig. 1 are given in table 3.

Table3.The results of determining the concentration of rock-forming chemical elements in soil samples taken from areas of underground leaching of uranium by the X-ray fluorescence method

Element	SiO ₂	K		Al	Fe	Ca	Mn	S	Ti	Cr	Zn	Sr	Rb	Cu
Concentration%	91,7	2,5		2,4	1,5	0,8	0,4	0,4	0,2	0,018	0,015	0,014	0,009	0,004
Limit of definition	-	-		-	-	0,001	0,002	-	0,002	0,005	0,01	-	-	-

As can be seen from the results shown in Table 3, the concentration of 13 by the chemical element in the soils does not differ much from those given in various sources. The results of this table show that it is not possible to detect radioactive elements by the X-ray fluorescence method in soil samples. In these samples, the radioactive elements were determined by the gamma spectrometric method.

The results obtained by determining the value of the specific total activity of radionuclides, the effective specific activity of alpha radiation - Aeff, the exposure dose rate of gamma radiation and the pH value of the aqueous extract are given in table 4.

Table 4. The results of determining the values of the specific total activity of radionuclides, the effective specific activity of alpha radiation - A_{eff} , the exposure dose rate of gamma radiation and the pH value of the aqueous extract

Sample number	EDR, $\mu\text{R} / \text{hour}$	Soil specific activity				pH of the aqueous extract
		K^{40} Бк/кг	Ra^{226} Бк/кг	Th^{232} Бк/кг	A_{eff} Бк/кг	
1	15,6 - 21,7	566	357	31	449	7,47
		588	372	41	479	7,26
		574	287	34	383	7,23
		548	259	38	358	7,54
2	16,0 - 42,2	556	306	33	399	7,52
		565	741	40	844	7,13
		525	590	35	683	7,07
		593	449	34	547	7,26
3	15,8 - 25,3	552	497	22	576	4,65
		461	303	18	368	4,16
		459	528	19	594	4,18
		507	238	26	318	7,22
4	46,9 - 66,1	273	829	11	861	5,46
		105	1534	12	1543	4,25
		343	1348	15	1399	4,00
		180	1492	16	1516	3,97
5	50,1 - 67,2	562	1249	19	1324	5,96
		384	1504	16	1560	3,71
		383	1088	17	1145	3,60
		323	1173	17	1210	3,73

As can be seen from tab 4 of the results obtained - the EDR value varies from 15.6 $\mu\text{R} / \text{hour}$ to 67.2 $\mu\text{R} / \text{hour}$, the specific activity of radionuclides - K^{40} - varies within (105 - 599) Bq / kg, Ra^{226} - varies within (238 - 1534) Bq / kg, Th^{232} - varies within (11 - 41) Bq / kg, the effective specific activity of alpha radiation - A_{eff} - varies within (318 - 1560) Bq / kg, and the pH value of the aqueous extract - varies in the range of 7.54 - 3.60. Here, samples 1 and 2 were taken from the soil of the underground uranium leaching sites where mini reagent (concentration of H_2SO_4 in the solution is 10-15 g / l) is used; uranium leaching technology; samples 3, 4 and 5 were taken from the soil of the underground uranium leaching where acid (concentration H_2SO_4 in solution is 30-40 g / l) uranium leaching technology. The results show that the acidity of the soil depends on the technology used for leaching of uranium, that is, it sharply decreases from minoreagent - 7.54 to acid - 3.60. And the change in EDR values, on the contrary, increases from 15.6 $\mu\text{R} / \text{hour}$ to 67.2 $\mu\text{R} / \text{hour}$ with a change in the technology used for leaching of uranium from minireagent to acid. This fact shows that when using acid leaching of uranium, the soil is contaminated with radionuclides of the uranium decay chain to a greater extent.

Thus, on the basis of the research and the results obtained, it can be concluded that the magnitude of the influence of the process of underground leaching of uranium on the state of the soil and groundwater is estimated. It was established that the X-ray fluorescence analysis method can determine the concentration of rock-forming chemical elements in the soil, the analysis of groundwater shows that they are contaminated with radionuclides and that they have increased concentrations of chemical elements through the use of the acid method of underground leaching of uranium, the specific activity of radionuclides, the effective specific activity of alpha radiation - A_{eff} , the exposure dose rate of gamma radiation and the pH value of the aqueous extract.

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