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Experimental Study of the Negative Impact on the Environment During the Extraction of Uranium By In-Situ Leaching

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ABSTRACT

The purpose of this study was a detailed analysis of all aspects related to the impact of objects and structures of the planned economic activity on the environment on the territory of the Semizbay deposit in the Republic of Kazakhstan. In the course of the work, the geoecological characteristics of the Semizbay deposit were presented. The analysis of data on the state of the components of the natural environment, based on the materials of earlier studies at the facility, was carried out. On the basis of the actual material, a list of priority pollutants subject to monitoring was compiled. The methodology and organization of the projected works are given. The types, conditions, scope of work were indicated. During the study, the following were carried out: soil sampling was carried out in the vicinity of the deposit, radiochemical analysis, and X-ray diffraction analysis. As a result of the study, a program of geoecological research was developed on the territory of the deposit: the content of radionuclides and the mineralogical composition of the sample were determined, which can become an alternative for further research on the territory of the enterprise.

Keywords: geoecological characteristics, deposit area, uranium, radionuclide content, underground leaching.

INTRODUCTION

The underground leaching method is currently one of the most promising methods for the extraction of uranium, rare and non-ferrous metals. During the development of mineral deposits by in-situ leaching, the deposit is affected at its place of occurrence in order to transfer useful components into a solution and then extract them, as a rule, through the wells drilled from the surface to the location of the deposit. In-situ leaching is more attractive and efficient, compared to traditional mining methods, in the development of poor deposits, as well as deep-seated deposits characterized by complex hydrogeological and mining and technological conditions. Currently, about a quarter of all uranium is mined by in-situ leaching. This method is especially widely used in Kazakhstan, Uzbekistan and the USA, where practically all uranium is mined in this way.

The Semizbay deposit is located on the northeastern outskirts of the Kazakh upland, gradually turning into the West Siberian Plain. The largest air pollutants are 5 enterprises with gross emissions exceeding 50.0 tons/year.

An analysis of the dynamics of gross emissions of pollutants into the atmospheric air shows that there is an annual increase in their volumes, both from mobile and stationary sources of pollution. The increase in gross volumes of emissions from stationary sources of pollution is primarily due to the development of the mining industry and, secondly, to the restoration and operation of boiler houses. The increase in the emissions from mobile sources is associated with an annual increase in their number.

MATERIAL AND METHODS

Brief description of the object of study

The following areas were defined as the study areas: Semizbay Mine Semizbay-U LLP, the main activity is the extraction and processing of uranium at the Semizbay deposit, located on the borders of Akmola and North Kazakhstan regions (Fig. 1). The project is being implemented within the framework of the strategic partnership agreement between NAC Kazatomprom JSC and the China Guangdong Nuclear Power Corporation (China Guangdong Nuclear Power Co-CGNPC), signed in Astana in October 2008.

The Semizbay deposit is located 130 km north-east of the city of Stepnogorsk on the territory of the Enbekshilder district of the Akmola region.

The nearest settlements are as follows: Stepnogorsk (130 km), with. Zaozernoye (120 km), Bestobe mine (50 km), Kzyltu railway station (100 km), Valikhanovo (80 km), district center Stepnyak (165 km).

The field is confined to the north-eastern outskirts of the Kazakh highlands, which passes into Zapadnya – the Siberian plain. The relief of the deposit area is flat, hilly, absolute elevations range from 90 to 140 m, the relative elevation of hills and ridges on depressions is not more than 20–50 m. The landscape is typical for Northern Kazakhstan – steppe with fescue – feather grass vegetation and dry steppe forbs. Rarely, there are small pegs of shrubs and trees.

According to lithological and stratigraphic features, the following water-bearing zones and complexes are distinguished within the Semizbai deposit:

1. Complex of Upper Quaternary and modern alluvial and lacustrine-alluvial deposits.
2. Lyulinvor horizon of the Eocene (P2LL).
3. The first Upper Semizbai Complex of the Upper Jurassic of the Lower Cretaceous (RK) (supra-ore horizon).
4. The second Upper Semizbay horizon of the Upper Jurassic of the Lower Cretaceous (upper ore horizon – VRG).
5. Nizhnesemizbay complex of the Upper Jurassic – Lower Cretaceous (lower ore horizon – IRG).
6. Fissure waters of the Upper Riphean-Devonian rock complex (under-ore horizon).

Fresh waters with salinity up to 0.8 g/l are exposed outside the structure. In the structure itself, mineralization is 3.1–9.1 g/l. The composition of the water is chloride-sodium, less often chloride-sulfate-sodium. In the fault zones, with a general increase in mineralization up to 7.5–20 g/l, chloride-sodium-calcium waters were opened. The main food comes from precipitation. Due to the low water content and variegated mineralization, these waters have a very limited use outside the structure.

The hydrographic network is weakly broken. There are salt lakes in the area of the deposit (the largest lake is Zhamantuz) and temporary streams of the Kyzdymkarasu, Semizbai and Shat rivers. The rivers are fed mainly by melting snow and are characterized by a short spring flood peak.

Figure 1. Object of study on the Google map (satellite)

The flow of rivers is carried out to the local basis of the lake, Zhamanguz.

Due to the fact that the Semizbay deposit is located 130 km from the nearby settlement with centralized water supply (Stepnogorsk), drinking water is provided from two water wells located at a distance of 2.9–5.3 km from the industrial site.

The underground waters of the deposit itself, due to their high salinity (from 2–4 to 20 g/l), are suitable only for technical purposes.

Materials and methods of research

During the activities of the enterprise, the main source of environmental impact in the area of mining and processing of uranium ores by the methods of in-situ borehole leaching is (non-plugged wells, landfills and settling tanks, residual solutions):

- violation (physical impact);
- pollution (chemical impact);
- withdrawal or alienation of natural objects (the impossibility of their use by other users of natural resources);
- hydrochemical (pollution of surface and underground sources, the indicators of which are heavy metals, acid anions and other pollutants);
- mechanical (change in the engineering-geological characteristics of the rock mass, the indicator of which is the deviation from the primary parameters of fracturing and rock stability, landslides, displacement of blocks, dips, etc.);
- chemical (land pollution by various chemical components, determined by the excess of their content over the background and the maximum allowable concentration);
- thermal (changes in the temperature of media, thermal erosion, changes in the parameters of the permafrost zone);
- violation of the landscape (area and parameters of landscapes);
- violation or withdrawal of subsoil plots (volumes of subsoil and reserves of other minerals that fell into the exclusion zone or violation).

The main objects of influence include the main components of the environment (biosphere): atmosphere, hydrosphere (ground and surface waters), land and bioresources (various types of lands and landscapes, fauna and flora), and subsoil.

On the territory adjacent to the uranium handling enterprise, the author carried out sampling of the top layer of soil weighing 2.0–3.0 kg, together with vegetation, using the "envelope" method with a side of 1 meter (Fig. 2). About 1 kg of soil was taken from each point.

Primary samples were scattered on a tarpaulin or plywood sheet and mixed; then, a combined average sample of the entire area was taken and dried. After that, the sample was crushed, poured into a Marinelli vessel and weighed on an electronic balance with a measurement accuracy of 0.1 g. To determine the specific activity of radioactive elements, the soil sample was measured using gamma spectrometry (Fig. 3).

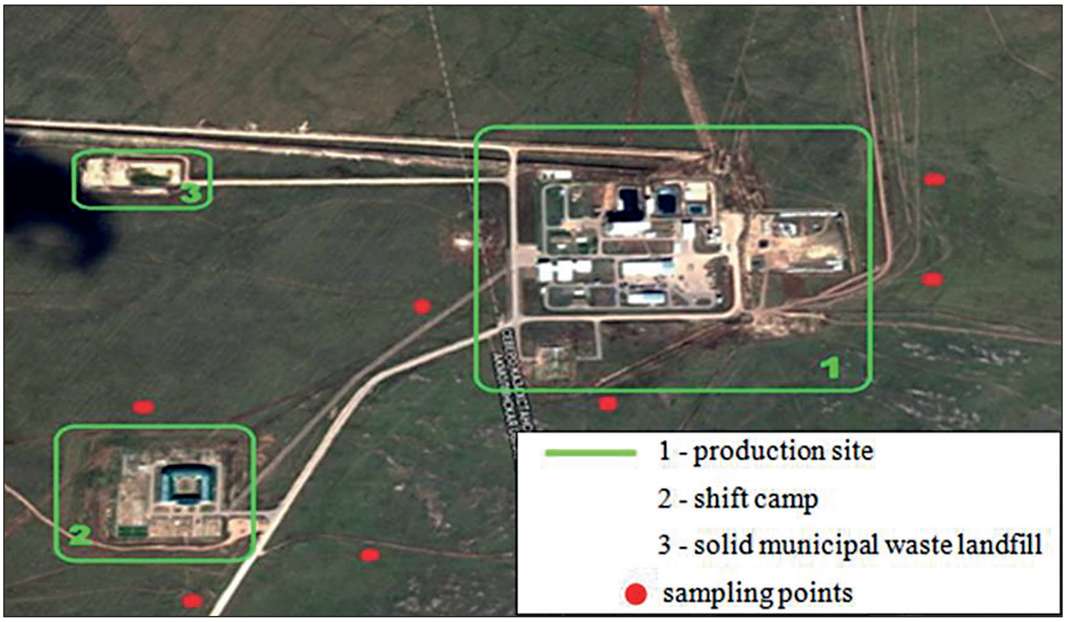

Figure 2. Map of the scheme of soil sampling in the territory of the mine "Semizbay"

To determine the mineral composition of the sample, X-ray diffraction analysis was used on a D2 PHASER setup (Fig. 4).

To take a diffraction pattern, the sample was thoroughly ground in an agate mortar with an agate pestle until powder was formed. Next, the powder was poured into the recess of a special quartz glass cuvette. The prepared sample was installed in the appropriate goniometric attachment.

Figure 3. Sample preparation for gamma spectrometry

After performing the analysis, the spectra were deciphered using the EVA program, which allows determining the qualitative and quantitative composition of the mineral.

RESULTS

Data analysis of gamma – spectrometric measurements of soil samples

On the basis of the results of measuring the dose rate of gamma radiation in the surveyed area, it was revealed that the behavior of radionuclides in the soil is regulated by the processes of formation of migration forms and their changes, leading to the loss of geochemical mobility.

From 7 soil samples, the specific activity of the following elements was determined: 226Ra, 235U, and 232Th.

In the isotopic composition, a high specific activity of the following radionuclides was found:

Table 1. Results of gamma spectrometry

No. samples	Ra-226	U-235	Th-232
one	18.40	0.03	-
2	18.89	1.69	15.02
3	20.25	-	16.67
4	15.76	-	18.18
5	9.47	0.39	13.18
6	18.56	-	20.09
7	15.12	-	17.07

* Specific activity of radionuclide, Aud., Bq/kg.

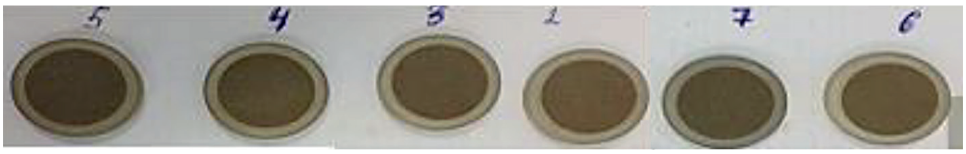

Figure 4. Samples for installation D2 PHASER

Table 2. Clark's comparison of concentrations according to Vinogradov

No. samples	U(Ra)g/t	Clark*	Kk	Thg/t	Clark *	Kk
one	1.5	2.5	0.6	0	Thirteen	0
2	1.5	2.5	0.6	3.7	Thirteen	0.3
3	1.6	2.5	0.6	4.1	Thirteen	0.3
4	1.3	2.5	0.5	4.5	Thirteen	0.3
5	0.8	2.5	0.3	3.2	Thirteen	0.2
6	1.5	2.5	0.6	4.9	Thirteen	0.4
7	1.2	2.5	0.5	4.2	Thirteen	0.3

* Clark terrestrial bark on Vinogradov.

226Ra – 20.25 Bq/kg, 232Th – 20.09 Bq/kg. And the results obtained by 235U are noticeable in samples 1 – 0.03 Bq/kg, 2 – 1.69 Bq/kg, 5 – 0.39 Bq/kg (Table 1).

To assess the technogenic contribution of radioactive elements in the studied soil samples, a comparison of uranium and thorium with the Clarke concentration according to Vinogradov was performed (Table 2). Table 2 shows that the concentration of uranium and thorium does not exceed the Clark.

Determination of the mineral composition using X-ray – structural analysis

To determine the mineral composition of the sample, X-ray diffraction analysis was used. The mineral composition of the soil sample was studied in the educational and scientific laboratory of electron-optical diagnostics of our university using the D2 PHASER installation.

D2 PHASER is an installation that diagnoses the structure of a substance using X-rays. Most often, this type of analysis is used to study solids with a crystalline structure, where the role of building units is played by atoms, ions, molecules, complexes, etc. The main pattern is the repeatability with a certain period in three directions (rarely in two) of the unit cell, which reflects the whole essence of the crystal structure of each substance, its symmetry, and elemental composition.

Comparing the lines of the main tabular intensities and interplanar distances with certain values, the missing value of the corundum number is written down. Thus, a set of minerals corresponding to the content of the substance under study was collected; that is, the resulting diffraction pattern was deciphered. Recording the corundum number and using it in further calculations allows obtaining a visual diagram of the expected composition of the sample under study and its percentage of the total composition.

In the work, the mineral composition of seven soil samples was studied, the Semizbay deposit was selected in the vicinity of the uranium deposit.

Figure 5 shows the experimental diffraction pattern of sample No. 1. The percentages of the composition of the sample are shown in Figure 6 and Table 3. From the results, it can be said that the highest content in the soil cover sample is dominated by particles of quartz sand, which make up 65%, then the content of Morelandite is about 1.9%, the presence of synthetic albite is also noted – about 15% and Microcline – 17.90%.

Figure 7 shows the experimental diffraction pattern of sample No. 2. From the Table 4 can be see

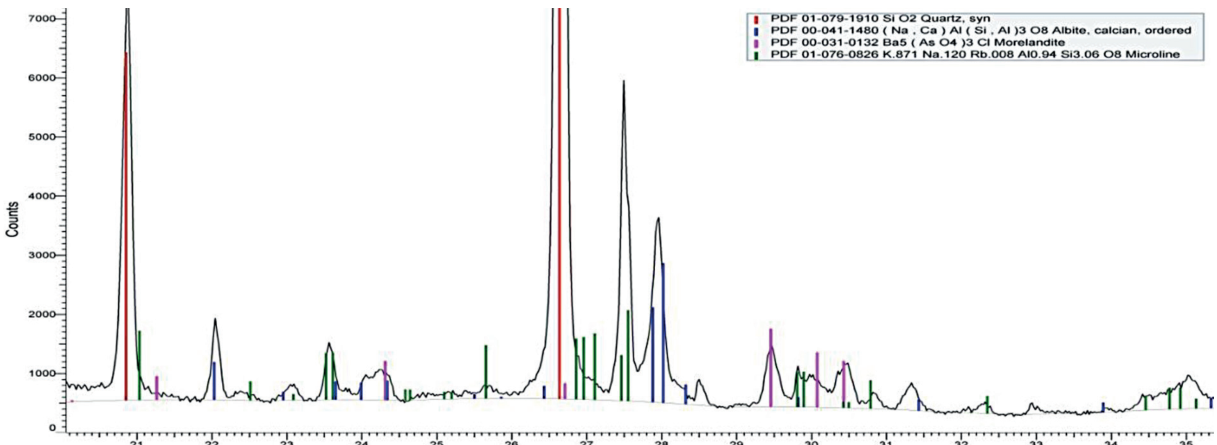

Figure 5. Diffraction pattern of soil sample No. 1

Table 3. Mineral composition of sample No. 1

Compound name	Formula	Quality	Y-Scale	I/Ic DB	I/IcUser	S-Q
Morelandite	Ba5 (As O4)3 Cl	Indexed	4.38%	-	4.68	1.90%
Quartz, syn	Si O2	Star (*)	98.14%	3.07	-	65.10%
Albite, calcian, ordered	(Na, Ca) Al (Si, Al) 3 O8	Indexed	7.84%	1.06	-	15.10%
Microline	K.871 Na.120 Rb.008 Al0.94 Si3.06 O8	Star (*)	5.10%	0.58	-	17.90%

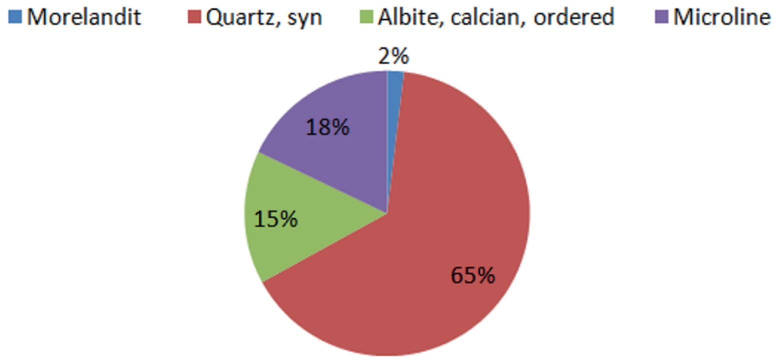

Figure 6. Sample composition percentage chart No. 1

Table 4. Mineral composition of sample No. 2

Compound name	Formula	Quality	Y-Scale	I/Ic DB	I/IcUser	S-Q
Quartz, syn	Si O2	Star (*)	61.15%	3.070	4.68	37.3%
Albite, calcian, ordered	(Na , Ca) Al (Si, Al) 3O8	Indexed	30.11%	1.060	-	53.2%
Gamagarite	(Ba1.8 Sr0.2) (Fe0.56 Mn0.44) (V1.83 As0.17O8) (OH)	Blank	2.61%	3.280	-	1.5%
Leakeite	Na2.7 K0.16 Ca0.10 Li0.67 Mg2.30 Al0.14 Fe1.48 Ti0.41 Si8 O22.82 F0.21 (OH) 0.97	Blank	2.64%	0.610	-	8.1%

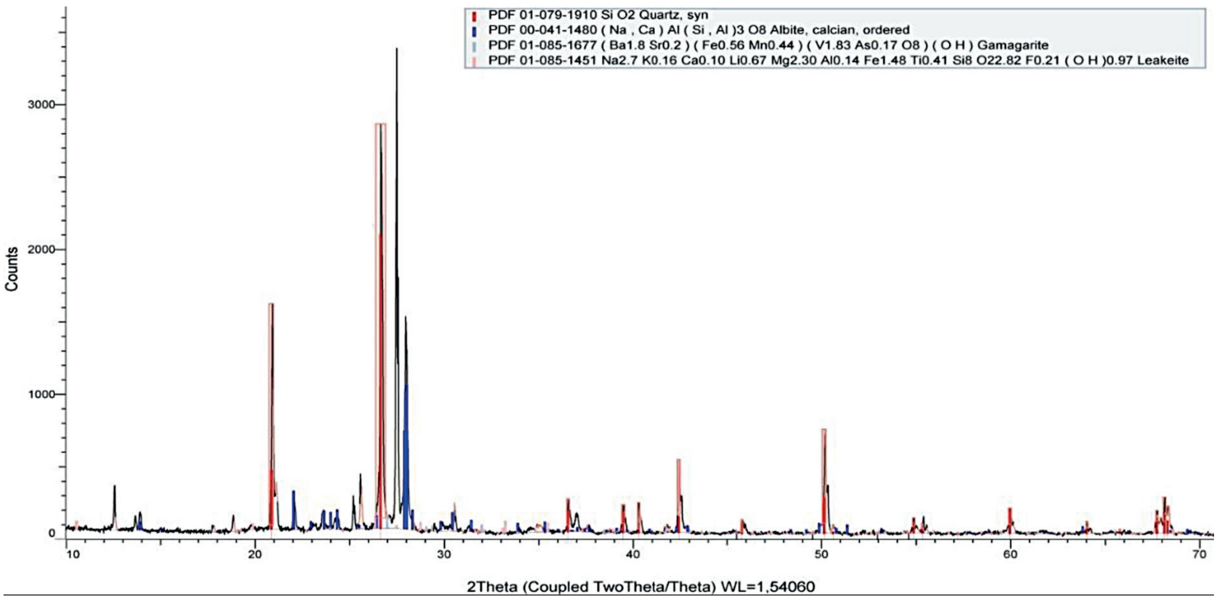

Figure 7. Diffraction pattern of soil sample No. 2

that the highest content in the soil cover sample is dominated by albite, which is 53.2%, then the content of quartz sand particles is about 37.3%, the presence of likeite was also noted – about 8% and Gamagarite – 1.5%.

The percentages of the composition of the sample are shown in Figue 7, 8 and Table 5. Figure 9 shows the experimental diffraction pattern of sample No. 3. Figure 10 shows sample composition percentage chart No. 3. From the Table 5 can be see that the highest content in the soil cover sample is dominated by Sanidin, which is 74.6%, then the content of a particle of quartz sand is about 20%, the presence of Andradite was also noted – about 15%. Figure 11 shows the experimental diffraction pattern of sample No. 4. The percentages of the composition of the sample are shown in Figure 12 and Table 6.

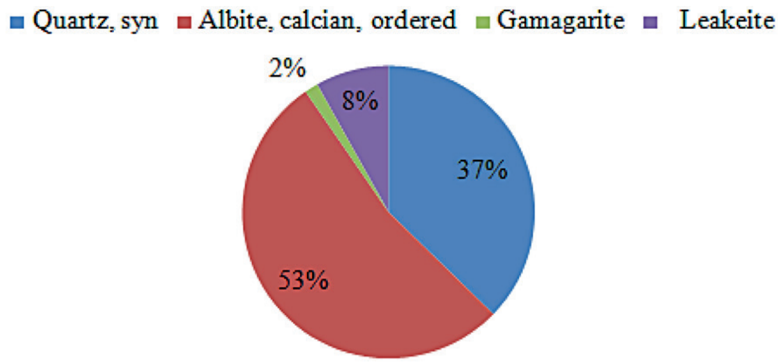

Figure 8. Sample composition percentage chart No. 2

Table 5. Mineral composition of sample No. 3

Compound name	Formula	Quality	Y-Scale	I/Ic DB	I/IcUser	S-Q
Quartz, syn	Si O2	Star (*)	3.050%	3.050	4.68	19.9%
Sanidine,potassian, disordered,	(Na, K) (Si3 Al)O8	Indexed	30.36%	1.060	0.760	74.6%
Andradite	Ca3 Fe1.88 (Si O4)3	Star (*)	1.32%	3.280	0.450	5.5%

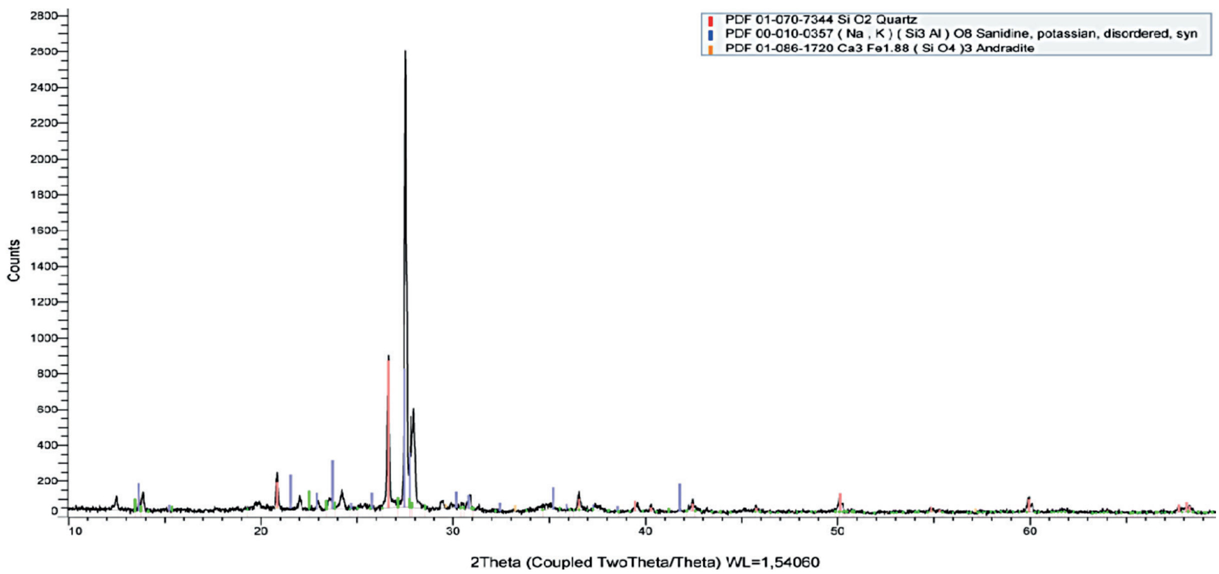

Figure 9. Diffraction pattern of soil sample No. 3

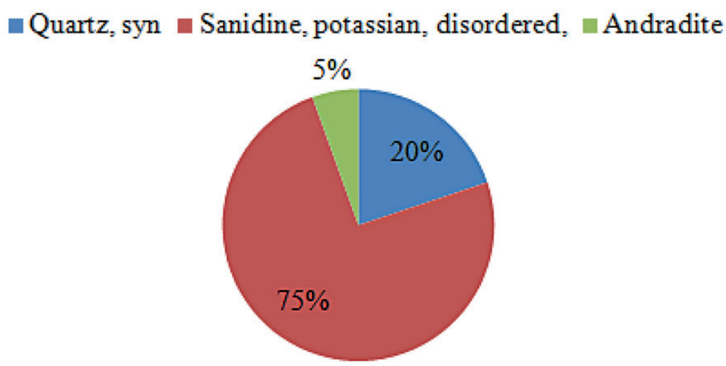

Figure 10. Sample composition percentage chart No. 3

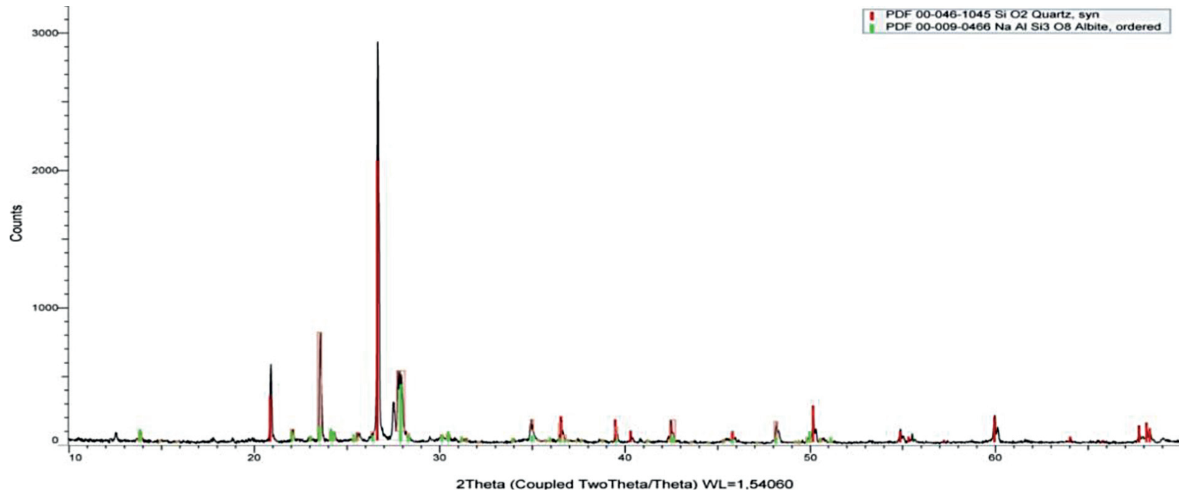

Figure 11. Diffraction pattern of soil sample No. 4

Table 6. Mineral composition of sample No. 4

Compound name	Formula	Quality	Y-Scale	I/Ic DB	I/IcUser	S-Q
Quartz, syn	Si O2	Star (*)	70.27%	3.410	-	75.6%
Albite, ordered	Na Al Si3 O8	Star (*)	13.93%	27.07	-	24.4%

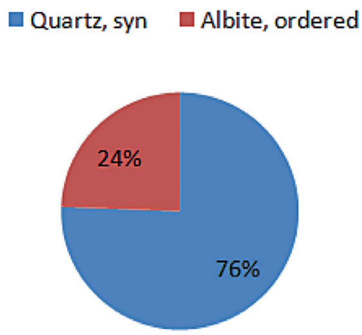

Figure 12. Sample composition percentage chart No. 4

From the Table 6 can be see that the highest content in the soil cover sample is dominated by particles of quartz sand, which make up 75.6%, then the content of albite is about 24.4%. Figure 13 shows the experimental diffraction pattern of sample No. 5. The percentages of the composition of the sample are shown in Figure 14 and Table 7.

From the Table 7 can be see that the highest content in the soil cover sample is dominated by Anorthoclase, which is 44.3%, then the content

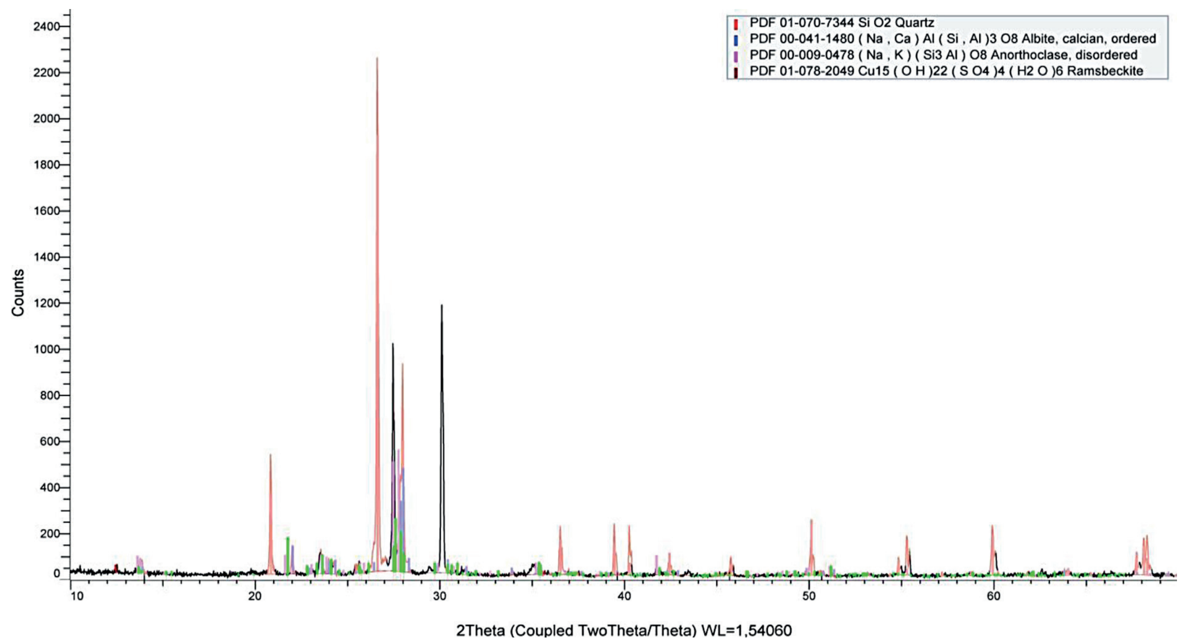

Figure 13. Diffraction pattern of soil sample No. 5

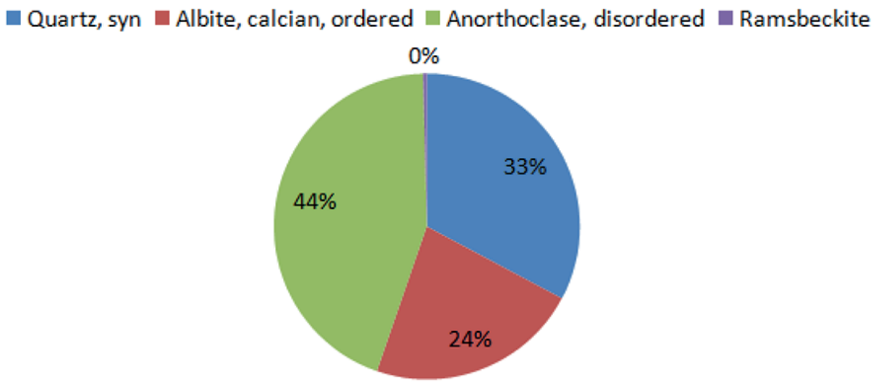

Figure 14. Diagram of the percentage composition of sample No. 5

Table 7. Mineral composition of sample No. 5

CompoundName	Formula	Quality	Y-Scale	I/IcDB	I/IcUser	S-Q
Quartz, syn	Si O2	Star (*)	3.050%	3.050		32.8%
Albite, calcian, ordered	(Na, Ca) Al (Si, Al)3 O8	Indexed	20.28%	1.060		22.5%
Anorthoclase, disordered	(Na, K) (Si3 Al)O8	Indexed	23.71%		0.630	44.3%
Ramsbeckite	Cu15 (O H)22 (S O4)4 (H2 O)6	Indexed	1.57%	4.180		0.4%

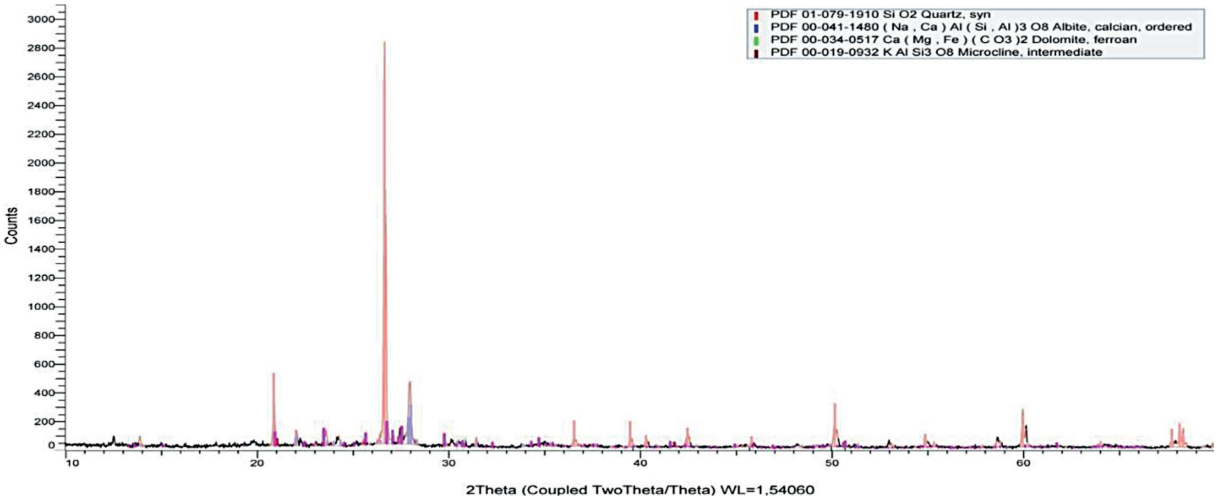

Figure 15. Diffraction pattern of soil sample No. 6

of quartz sand particles is about 32.8%, the presence of albite was also noted – about 22.5% and Ramsbeckit – 0.4%.

Figure 15 shows the experimental diffraction pattern of sample No. 6. The percentages of the composition of the sample are shown in Figure 16 and Table 8. From the Table 8 can be see that the highest content in the soil cover sample is dominated by quartz sand particles, which make up 63.2%, then the albite content is about 19.9%, the presence of Microcline was also noted – about 15.2% and dolomite – 1.7%.

Figure 17 shows the experimental diffraction pattern of sample No. 7. The percentages of the composition of the sample are shown in Figure 18 and Table 9. From the Table 9 can be see that the highest content in the soil cover sample is dominated by quartz sand particles, which make up 55.0%, then the albite content is about 32.4%, and the presence of Microcline was also noted – about 12.6%.

CONCLUSIONS

In the present work, environmental problems were considered during the extraction of uranium by the method of underground borehole leaching

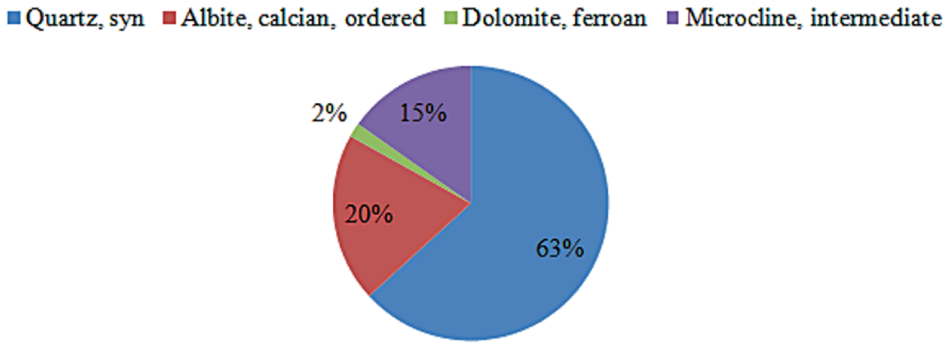

Figure 16. Diffraction pattern of soil sample No. 6

Table 8. Mineral composition of sample No. 6

Compound name	Formula	Quality	Y-Scale	I/Ic DB	I/IcUser	S-Q
Quartz, syn	Si O2	Star (*)	90.61%	3.070		63.2%
Albite, calcian, ordered	(Na, Ca) Al (Si, Al) 3 O8	Indexed	9.88%	1.060		19.9%
Dolomite, ferroan	Ca (Mg, Fe) (C O3)2	Indexed	1.99%		2.570	1.7%
Microcline, intermediate	K Al Si3 O8	Indexed	4.20%		0.590	15.2%

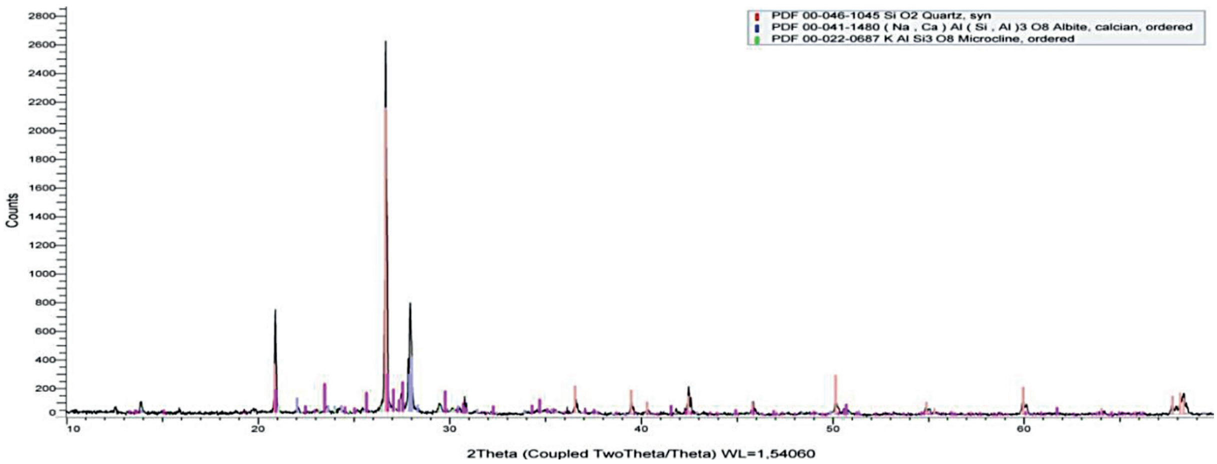

Figure 17. Diffraction pattern of soil sample No. 7

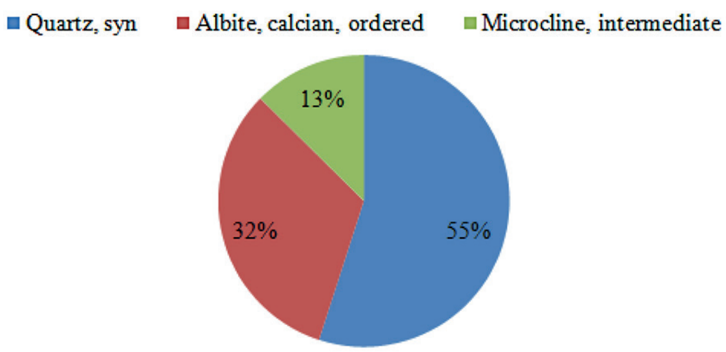

Figure 18. Diagram of the percentage of the composition of sample No. 7

Table 9. Mineral composition of sample No. 7

Compound name	Formula	Quality	Y-Scale	I/Ic DB	I/IcUser	S-Q
Quartz, syn	Si O2	Star (*)	82.09%	3.410		55.0%
Albite, calcian, ordered	(Na (Ca) Al (Si, Al)3 O8	Indexed	15.1%	1.060		32.4%
Microcline, intermediate	K Al Si3 O8	Indexed	3.25%		0.590	12.6%

using the example of the Semizbay deposit, and an assessment of the impact of the enterprise on the natural environment was given.

When studying the existing production activities of the enterprise, the sources of environmental impact were identified, and a component-by-component assessment of their impact on natural environments and objects was carried out. While analyzing the results of the impact assessment, the following conclusions can be drawn:

When developing uranium deposits by underground leaching, the negative impact on the atmospheric air turns out to be incomparably lesser than when using a quarry or mine mining method. There are no open, dusty radioactive surfaces of quarries and dumps, and there are no large tailing dumps. The volumes of processing production have been reduced due to the exclusion from the technological scheme of ore acceptance, ore preparation, crushing and leaching produced on the surface. On the basis of the calculation results, the radionuclide dispersion enterprise, including at the border of the sanitary protection zone and in the residential zone, allows us to conclude that the radionuclide emissions from emission sources do not have a significant effect on the atmospheric air and do not create the concentrations dangerous for the health of staff and the public.

The results of gamma-spectrometric analysis allow identifying the radionuclide composition, determining the ratios of radionuclides and assessing the technogenic component of uranium in the specific activity of the soil. Elements 226Ra, 235U, 232Th were revealed from 7 soil samples. According to the results obtained, it was established that their content is insignificant, the excess of Clark was not revealed.

The impact of the production activities of Semizbay-U LLP on the environment shows that if all the rules and regulations for the operation of equipment and mechanisms are adhered to, if the recommended environmental measures are employed, significant and irreversible harm to the environment will not be caused. The impact of all components on the atmospheric air, surface and ground waters, soil, flora and fauna, as well as on the population is quite acceptable and will not lead to a violation of the natural and anthropogenic balance that exists in the area where the Semizbay mine objects are located.

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