Section 3. Physics

https://doi.org/10.29013/AJT-23-3.4-17-22

Akhmedova G.,
Eshburiev R.,
Togaev B.,
Haydarov U.,
Samarkand State University, Samarkand, Uzbekistan

DETERMINATION OF THE IMPACT OF THE URANIUM INDUSTRY ON THE ENVIRONMENT

Abstract. In this study, we investigated the changes in the specific activity of natural radionuclides potassium-40 (K40), thorium-232 (Th232), radium-226 (Ra226), and anthropogenic cesium-137 (Cs137) in the soil composition of the Samarkand and Navoi regions. The primary objective of this research was to evaluate the impact of uranium production enterprises on the variations in the levels of natural radionuclides ^{226}Ra, ^{232}Th, ^{40}K, and technogenic ^{137}Cs found in soil samples collected from the Navoi region. Additionally, we conducted a comparative analysis of the specific activity of radionuclides ^{226}Ra, ^{232}Th, ^{40}K, and ^{137}Cs in samples not influenced by uranium production.

Keywords: radioactivity, radionuclide, radiobiology, geophysics, migration, spectrometer, gamma, crystal, photoreceptor, background, energy, specific activity, uranium, technogenic, effective, identification.

Introduction

The radioactivity of environmental objects, such as soils, depends on the biological properties of the object, the geographical characteristics of the area, and the concentration of natural, cosmogenic, and man-made radionuclides in the rocks forming the soil, as well as the degree of anthropogenic impact [1]. These factors influence the distribution of natural radionuclides, including uranium, in different regions, particularly in areas with mineral deposits. Data on radionuclide concentrations, uranium deposits, uranium mining, radioactive environmental pollution, and the degree of exposure are of great practical importance in such areas. One significant source of environmental radioactive pollution is the uranium industry, which mines, processes, enriches, and prepares uranium for nuclear fuel.

Throughout each stage of the uranium industry, there is potential for radioactive contamination of the environment. Natural uranium, consisting of ^{238}U (99.28%), ^{235}U (0.7%), and ^{234}U (0.006%), is mined, processed, and enriched to prepare ^{235}U nuclear fuel. Uranium, radium, and liquid waste generated at uranium processing plants are often stored nearby, potentially contaminating nearby ditches, lakes, and water sources with radioactivity. Accidents at these facilities can release significant quantities of enriched uranium, posing an ongoing risk of radioactive radiation. Additionally, the production of fuel rods presents a high probability of minor environmental pollution.

This research paper investigates the specific activities of natural ^{226}Ra, ^{232}Th, ^{40}K, and technogenic ^{137}Cs in soil samples taken from the Samarkand (without the impact of the uranium industry) and Navoi (without the impact of the uranium industry) regions. The goal is to assess the degree of influence that uranium production enterprises have on the levels of natural radionuclides (^{226}Ra, ^{232}Th, ^{40}K) and technogenic ^{137}Cs detected in samples taken from the Navoi region. Furthermore, the study aims to compare the amounts of ^{226}Ra, ^{232}Th, ^{40}K, and ^{137}Cs radionuclides in samples taken from the Samarkand region, which were not affected by uranium production [3].

Measurement technique and methods

Soil samples were collected from two points in each selected area at layer depths of 0–5.0 cm and 0–10.0 cm. The samples were dried, cleaned of foreign rocks, crushed into a homogeneous state, and weighed. Gamma spectra of samples taken from the Navoi region were measured using a "Progress-Gamma" scintillation spectrometer. The measurement results were processed with the "Progress" computer program connected to the gamma spectrometer.

For soil samples collected from the Samarkand region, a 63 × 63 mm NaI(Tl) scintillation gamma spectrometer with an energy resolution of 10% was used in the scientific laboratory at Samarkand State University's Department of Nuclear Physics and Astronomy. Specific activities of natural ^{226}Ra, ^{232}Th, ^{40}K, and technogenic ^{137}Cs radionuclides identified in the spectra were determined using reference radioactive sources from the OMACH set. The measurement results were processed on a computer using the ASW program.

Results and their analysis

Some of the gamma spectra of the studied soil samples are illustrated in Figures 1 and 2. In the measured spectra, photopeaks of the following radionuclides are observed, which are distinct from the background ones:

– photopeaks of Pb^{214} with an energy of 295 keV $(n_\gamma = 19\%)$, 351 keV $(n_\gamma = 36\%)$ and of Bi^{214} with an energy of 609 keV $(\eta_\gamma = 47\%)$, are produced by the radioactive decay of radium, which belongs to the decay chain of the natural radioactive family of uranium;

– photopeaks of Pb^{212} with an energy of 238 keV $(n_\gamma = 47\%)$, of Ac^{228} with an energy of 911 keV $(n_\gamma = 25\%)$, and Tl^{208} with an energy of 583 keV $(n_\gamma = 86\%)$, belong to the decay chain of the natural radioactive family of thorium;

– in all spectra, the photopeaks of the natural radioactive isotope ^{40} K with an energy of 1460 keV $(n_\gamma = 11\%)$ are clearly observed (n_γ – quantum yield of photopeak).

Table 1.– Specific activities of ^{226}Ra, ^{232}Th, ^{40}K, and ^{137}Cs radionuclides in soils taken from sown areas in various studied regions

№	Radioactive isotope / Samples	^{226}Ra	^{232}Th	^{40}K	^{137}Cs	Ra_{eq}	Sample mass (kg)
1	*2*	*3*	*4*	*5*	*6*	*7*	*8*
Results of samples taken from Navoi industrial zone							
1 point	0–5 cm	39	38	686	3	152	1
	5–10 cm	46	34	659	0	150	1
2 point	0–5 cm	46	38	643	3	154	1
	5–10 cm	45	30	627	3	142	1
Results of samples taken from the residential area of Navoi region							
1 point	0–5 cm	50	35	642	< 1.59	155	1.12
	5–10 cm	37	38	541	< 1.40	136	1.17

1	*2*	*3*	*4*	*5*	*6*	*7*	*8*
2 point	0–5 cm	70	54	742	< 1.56	208	1.11
	5–10 cm	45	46	695	< 1.87	170	0.83
Results of samples taken from Samarkand region							
1 point	0–5 cm	34	26	485	< 1.6	112	0.92
	5–10 cm	33	25	456	< 1.54	108	0.98
2 point	0–5 cm	51	26	510	4	132	1.1
	5–10 cm	31	34	586	3	129	1.03

The photopeak with an energy of 661 keV, formed during the decomposition of the technogenic radionuclide ^{137}Cs, is mixed with the photopeak of ^{214}Bi with an energy of 609 keV due to the gamma spectrometer's 10% energy resolution ability. To separately extract ^{214}Bi and ^{137}Cs photopeaks, a special program is implemented into the computer.

The measurement uncertainty for natural radionuclides ranges from 10% to 16%. The identified specific activities of ^{226}Ra, ^{232}Th, ^{40}K, and ^{137}Cs radionuclides in soils taken from sown areas in various studied regions are given in the table, in Bq/kg.

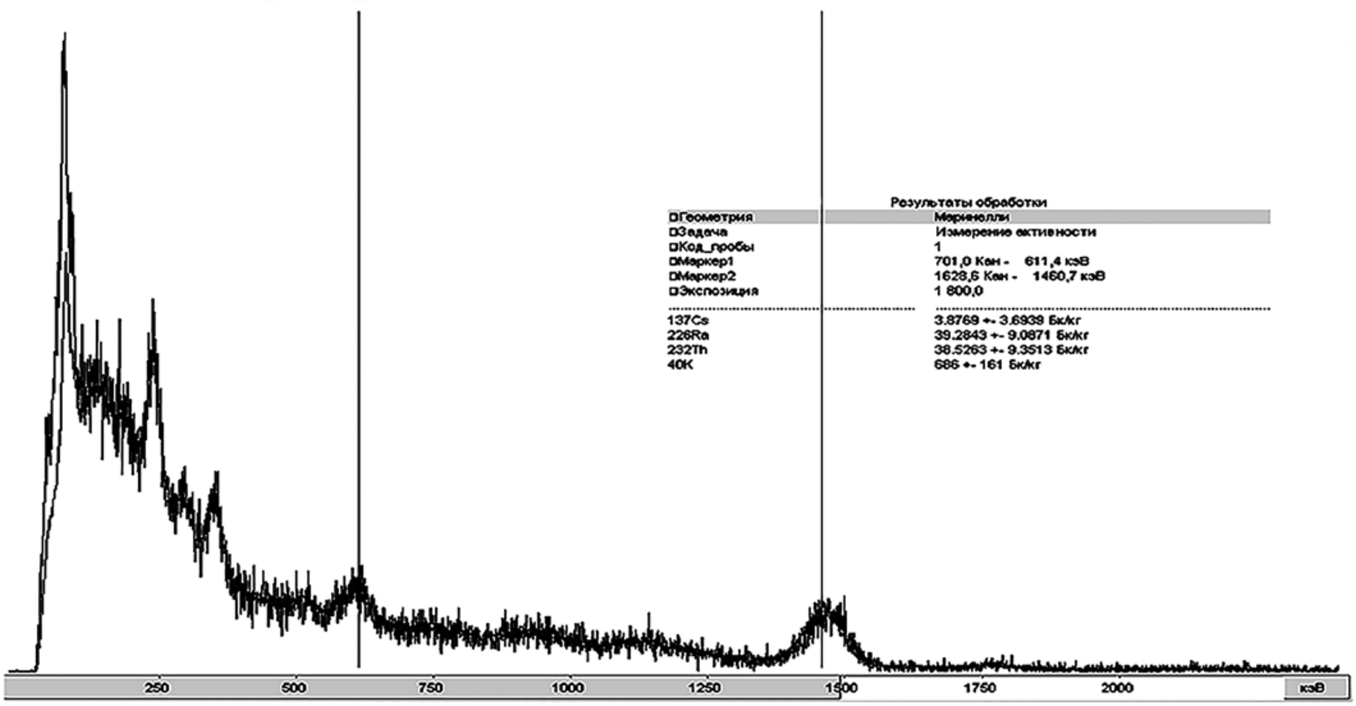

Figure 1. Gamma spectrum of soils of Navoi industrial zone

From the data in the table it can be seen that the radioactivity of the soils of different regions studied is mainly determined by natural radium-226, thorium-232, potassium-40 and small amounts of technogenic cesium-137 radionuclides.

K-40 Bq/kg	Ra-226 Bq/kg	Th-232 Bq/kg	Cs-137 Bq/kg	Ra_{eq} Bq/kg
686	39.28	38.52	3.87	152

$Ra_{eq} = 148 \pm 10.36$ *Bq/kg*

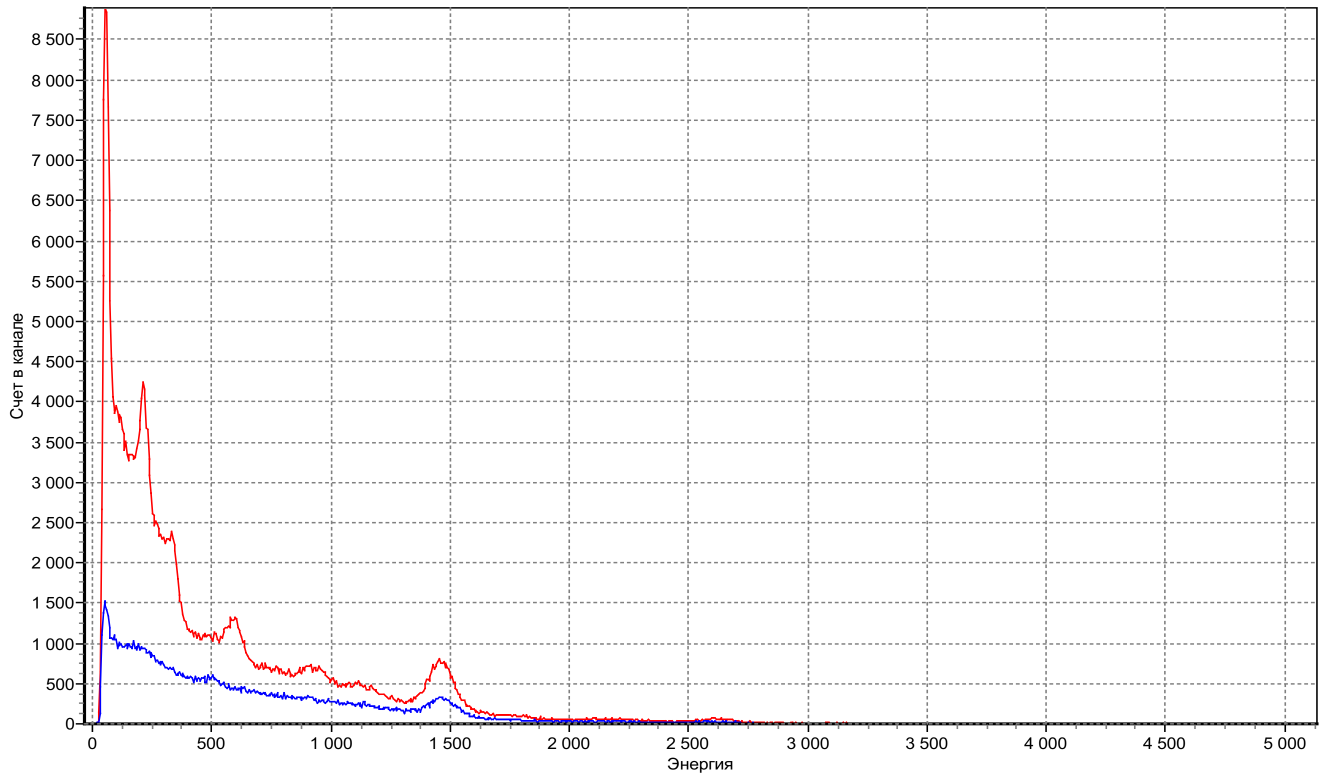

Figure 2. Gamma spectrum of soils of Samarkand region

Radionuclide	Activity, Bq	Uncertanity,%	Spec. activity Bq/kg	Absol. Uncer., Bq/kg	Relative Uncer,% (p=0.95)
Ra-226	35.482	0.1	33.954	5.6	16.5
Th-232	38.539	0.03	36.879	3.8	10.3
K-40	568.8	0.02	544.31	52	9.56
Cs-137	< 1.594	–	< 1.525	–	–

$Ra_{eq} = 131 \pm 8.82$ Bq/kg

The difference between the effective activity of samples taken from the territory of the Navoi uranium industry and the effective activity of samples taken from the territory of residence of the population of the Navoi region is insignificant within the measurement error, on average within (150–167) Bq/kg. But the specific activity of the technogenic radionuclide Cs^{137} is determined differently in different studied soils. The Cs^{137} ratio is 1.8 times higher.

The difference between the effective activity of soils with a depth of 0–5 and 0–10 cm, taken from the Navoi industrial zone, is also insignificant: a=153 Bq/kg per 0–5 cm, A=146 Bq/kg per 10 cm, while in urban soils A=181 Bq/kg per 0–5 cm, a=153 Bq/kg per 0–10 cm, in addition, 0–5 cm shows that the effective soil activity at a depth is ~ 1.2 times higher than soil activity up to 0–10 cm. It was noted that the effective activity of intra-urban soils of Navoi, although less than the effective activity of the industrial zone, is 1.12 times higher.

The effective soil activity at a depth of up to 0–5 cm, obtained from the Samarkand region, averages Ra_{eq}=122 Bq/kg, and at 0–10 cm Ra_{eq} = 118 Bq/kg.

The highest specific activity in the analyzed soils is accounted for by the isotope potassium-40, but this radionuclide has a different value in soils obtained from different regions and ranges from

456 Bq/kg to 742 Bq/kg. Such a difference may be due to factors such as the geographical location of soils, the degree of soil treatment with cultural fertilizers. The detection of potassium-40 in high concentrations compared to other natural radionuclides indicates its high concentration (2.4%) in the earth's crust [2].

The specific activity of natural Ra^{226}, Th^{232}, K^{40} and Cs^{137} radionuclides in soils depends on their physico-chemical properties, the degree of solubility in water, leaching from soils or entering the soil for various reasons, migration, half-life, geographical area of the location of soils, the degree of radionuclide distribution in the Earth's crust, soil type and soil treatment the dependence of irrigation water, atmospheric air on the radionuclide composition and other factors has been established by scientists.

Thus, the high value of the effective activity of the studied soils is detected in layers from the Earth's surface to a depth of 0–5 cm. From this it can be seen that a larger proportion of natural and technogenic radionuclides can accumulate in the upper layers of the Earth's surface to a depth of 0–5 cm.

Other authors have studied the migration of technogenic Cs^{137} in soils and have shown that its specific activity is determined at high values in the 0–5 cm layer of soils [5].

The effective activity of the studied soils of Navoi region was found to be 1.3 times higher than the effective activity of the soils of Samarkand region.

Conclusion

In conclusion, our study revealed that the difference in effective activity between soil samples from the Navoi uranium industry territory and those from residential areas in the Navoi region was insignificant within the measurement error, averaging (150–167) Bq/kg. However, the specific activity of the anthropogenic radionuclide Cs137 varied across different soil samples, with a 1.8 times higher ratio observed. The effective activity of intra-urban soils of Navoi was found to be 1.12 times higher than that of the industrial zone, despite being lower in value.

A comparison of soil samples from different depths (0–5 cm and 0–10 cm) in the Navoi industrial zone and urban areas revealed minimal differences in effective activity. The highest specific activity in the analyzed soils was attributed to the isotope potassium-40, with values ranging from 456 Bq/kg to 742 Bq/kg, depending on factors such as geographical location and soil treatment.

The specific activity of natural Ra226, Th232, K40, and Cs137 radionuclides in soils was found to depend on various factors, including their physicochemical properties, solubility, leaching, migration, half-life, geographical area, and soil type, among others. Our findings indicate that the upper layers of the Earth's surface (0–5 cm) tend to accumulate a larger proportion of natural and anthropogenic radionuclides. The effective activity of soils from the Navoi region was 1.3 times higher than that of soils from the Samarkand region.

This study contributes to the understanding of the distribution and behavior of radionuclides in soil samples from different regions and depths, providing valuable insights for assessing the potential environmental and health risks associated with exposure to these radionuclides. Future research should focus on monitoring radionuclide concentrations over time and evaluating the effectiveness of mitigation strategies to minimize their impact on human health and the environment.

References:

1. Muminov A. T., Muminov T. M., Kholbaev I., Akhmedova G., Mamatkulov O. B. "Study of environmental objects by gamma spectrometry". Monograph.– Tashkent, 2020.– P. 162–165.
2. Pertsov L. A. Ionizing radiation of the biosphere. Monograph.– Moscow, Atomizdat,– 7–8, 25–27, 1973.– P. 55–60.

3. Muzafarov A. M., Bisenova B., Allaberganova G. M., Sattarov G. S. Determination of radioecological factors for assessing the radiation situation of uranium production // Abstracts of the 9th International Conference "Nuclear and Radiation Physics".– Almaty., 2013.– P. 209–210.
4. Akhmedova G. "Radioactivity and its importance". Monograph.– Tashkent, 2020.– P. 129–132.
5. Eshboriyev R. M., Umrzakov E. A., Nurmurodov L. T., Kakhkharova A. N., Yunusova U. Kh. Features of migration of natural and technogenic radionuclides in the soils of Samarkand region. SamSU Bulletin,– No. 3 (121). 2020.– P. 134–139.