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Migration Characteristics of Natural and Technogenic Radionuclides in Soils of Samarkand Region

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Abstract. *In this study, the specific activity of natural radionuclides ^{226}Ra, ^{232}Th, ^{40}K , and technogenic radionuclides ^{137}Cs in soil layers using the gamma spectrometry method was studied. The results showed that natural radionuclides ^{226}Ra and ^{232}Th and technogenic radionuclides ^{137}Cs mainly have a high specific activity on the surface of 1-2 cm of soil. The lower layer of 15-20 cm activity was 20-30% lower than that of these radionuclides, and radionuclides undergo horizontal migration. It was found that the specific activity of the ^{40}K isotope reaches a maximum value of 10-15 cm in the soil layer, and this radionuclide is mainly redistributed in the soil as a result of vertical migration.*

Keywords: —radioactivity; isotope; technogenic; migration; radiation; functional; spectrum; intensity; background.

1. INTRODUCTION

Natural and cosmogenic radionuclides determine the state of the natural background in the Earth's region. The biosphere has always been under the influence of a radiation background. That is why all living organisms have also developed under intense radiation for thousands of years.

The effect of radionuclides on living organisms is determined by the following factors: 1. Number of radionuclides 2. The degree of exposure. 3. The half-life decay of radionuclides. 4. Chemical composition of radioactive elements.

Natural radioactive isotopes, mainly thorium-232, radium-226, and potassium-40, are found in large quantities in the Earth's crust; these isotopes first enter water bodies and then are washed out and absorbed into the soil. Natural radionuclides, located in the Earth's bowels during migration, under the influence of human activity, spread to the biosphere. This spread is called technogenic migration. The word migration means the movement (migration) of chemical elements in environmental components. However, not all elements have the same speed of movement (migration intensity). In gneral, the factors that cause the migration of radionuclides are not different from other chemical elements. The migration rate depends on the physical and chemical properties of each radionuclide. Depending on the formation mechanism, migration types are divided into natural and man-made (or anthropogenic). Natural migration processes (river water rise, strong winds, heavy rains, ground movement, fires, etc.) occur naturally. Man-made migration occurs directly connected with human activities (nuclear explosions, disasters at nuclear installations, mining of uranium, coal, oil, ores).

The direction of radionuclide release into the environment is also somewhat different. Vertical migration is the eruption of volcanoes, under the influence of rain, land cultivation, forests-trees, under the influence of which horizontal migration occurs-the flooding of rivers, the movement of radioactive dust particles, and aerosols under the influence of wind, the movement of some living microorganisms in the soil. Radionuclides also migrate under the influence of nuclear explosions, forest fires, oil production, processing, production of mineral fertilizers, and floods. One of the most important sources of natural radioactivity is radon-222 gas. According to the data, 50% of natural radioactivity is accounted for by radon-222. Out of naturally occurring radioactive elements, potassium-40 and rubidium-87 are also found mainly in rocks and volcanic remnants. A person cultivates soil that contains a lot of radioactive elements during agricultural activities. We are talking not only about the extraction of uranium isotopes (in the territory of the Samarkand region, uranium is extracted) but also about the content of radon-222 gas in the lithosphere that affects the radioactive background. Under the influence of anthropogenic activity, horizontal migrations of natural radionuclides are more often observed. Radionuclides are also found in the oil. If oil fields are located near shale clays containing uranium, then elements formed from its destruction accumulate in the sand and gravel layers below it. Coal is also rich in radioactive elements, mainly containing isotopes of potassium-40, polonium-210, rubidium-210, bismuth-218, and isotopes of uranium, thorium, and radium. For some properties, radionuclides are evenly distributed over the Earth's surface. Their number increases in muddy soils due to adsorption compared to sandy-gravel soils. The content of heavy radioactive elements in rocks is mostly limited. The study [1] showed that the dose of gamma radiation on the Earth's surface in different regions of the planet ranges from about 0.26 mg/year to 11.5 mg/year. The migration of

natural radionuclides to the soil is an essential link in their migration to ecosystems. One of the soil's crucial features is its increased absorption capacity, which makes it possible to accumulate vast organic compounds and nutrients in it. The suction mechanism depends on the state of radionuclides contained in the soil. Moreover, the colloidal state depends on the process of ion exchange between solid and liquid states and corresponds to normal mechanical absorption. Mud soils, including sandy ones, have a high molecular capacity for metabolism in a colloidal state. The migration of radionuclides can form insoluble compounds due to a chemical reaction with substances contained in the soil.

Soil is the primary basis of ecosystem exchange processes. Its functional state determines the effective exchange of radiation energy in biological structures. The processes occurring in the biosphere occur in the soil, starting from biological substrates and ending with organic compounds, where the synthesis of biological substances takes place.

The Earth's surface, formed over many years, has a fertile soil layer of 2-3 cm. Under normal conditions, this layer is formed over 150-200 years. Radioactive contamination of the environment, movement of radionuclides along the biological chain, and, ultimately, entry into the human body also occurs through the soil. Radionuclides that accumulate on the soil surface, under the influence of various factors, migrate in the right direction. The horizontal movement of newly fallen radionuclides occurs due to strong winds and snowmelt. For example, it was found that the strontium-90 isotope migrating due to snowmelt has a full cationic form[2].

2. METHODS AND MATERIALS

The measurements of the gamma spectra of the samples were performed in Marinelli beaker geometry on γ-spectrometer with NaI(Tl) scintillation detector, Ø 63 × 63 mm, an energy resolution of 10% on a gamma line ^{137}Cs with the energy of E = 661 keV. Registration and processing of the spectra were done on IBM PC with the automatic writing of the spectra into the computer memory every hour which allowed us to control the stability of the spectrometer and correct the spectra when necessary. The duration of measurement of samples taken from the inner layers of the soil is
t= 2 hours, and in the surface - 6 hours.

When processing the spectra, the soil-P spectrum is divided into separate components:- background (F), Th^{232}, Ra^{226} and K^{40}, normalized by the intensity of the Cs^{137} spectra. Figure 1 below shows the intensity of the gamma-ray spectra of natural radionuclides Th^{232}, Ra^{226}, K^{40} and technogenic radionuclides Cs^{137} against the background of Be^{7} radionuclide.

The Be^{7} radiation activity was determined with an energy intensity of 478 keV in the spectrum, taking into account the detector's detection efficiency, the quantum transit time, and the measurement duration. The minimum possible detection cases are ~ 20 Bq/kg for K-40, ~ 3-5 Bq/kg for other radionuclides. Errors in determining the activity of radionuclides identified in the gamma-ray spectra of soils were 10-15%.

3. RESULTS AND DISCUSSIONS

The degree of prevalence in the soil of the specific activity of natural radionuclides Ra-226, Th-232, and K-40 isotopes obtained in the experiment is shown in table 1. According to the results of experiments, the largest number of radionuclides of specific activity corresponds to the layer Ra^{226} (41.92±5.7 Bq/kg) and Th^{232} (56.166±6.15 Bq/kg), and for K^{40} (838.38±82 Bq/kg) - on the layer 10-15 cm. Similarly, potassium-40 radionuclides are not distributed evenly over the specified deep parts of the soil.

For example, in a 10-20 cm area, it confirms our opinion that potassium ranges from 838.38±82 Bq/kg to 803.786±80 Bq/kg. However, according to the results of experiments for Ra-226 isotopes, the activity in the surface part of the Earth (2-4)is 41.92±5.7 Bq/kg, while in the surface part of the Earth (8-10) cm, the activity is 32.31±3.3 Bq/kg, which indicates that for Ra^{226}, the activity on the Earth's surface is 17% higher. From these data, it can be seen that the horizontal migration of Ra-226 radionuclide on the soils of irrigated or cultivated areas is significantly higher.

The results obtained for the isotope of natural thorium (Th-232) are also similar to Ra-226, while the minimum amount of comparative activity is 5-10 cm of soil, and thorium activity at a depth of 10-20 cm is higher than 11%. The table 1 shows that the specific activity of the thorium-232 isotope is unevenly distributed in the layers of 6-20 cm. Such uneven distribution is due to the increased content of sulfates, nitrates, carbonates, and alkali metals in these layers, reacting quickly with the thorium isotope.

Besides, the high specific activity of the Th-232 radionuclide in the 10-20 cm layer is mainly characteristic of sandy-gravel soils, with vertical migration playing the primary role. However, for element K-40, whose half-life ($T_{1/2}=10^{9}$ year) is too long, the above general patterns will not be appropriate.

According to the experiment results, the lowest amount of activity (654.43+-83) corresponds to the soil layer
(20-30) cm; that is, the specific activity of K-40 radionuclide in the relatively upper layer is 33% higher than in the lower layers. This suggests that the potassium-40 isotope is dissolved mainly in the wet part of the soil and absorbed through the

plant's roots. Perhaps the most massive (838.38±82 Bq/kg) amount of K-40 at a depth of 10-15 cm of soil is due to the presence of elements in this part of the soil close in chemical properties the potash element, or a sufficient content of radionuclides in potash fertilizers. This suggests that in such a soil layer, the K-40 element is distributed due to vertical migration.

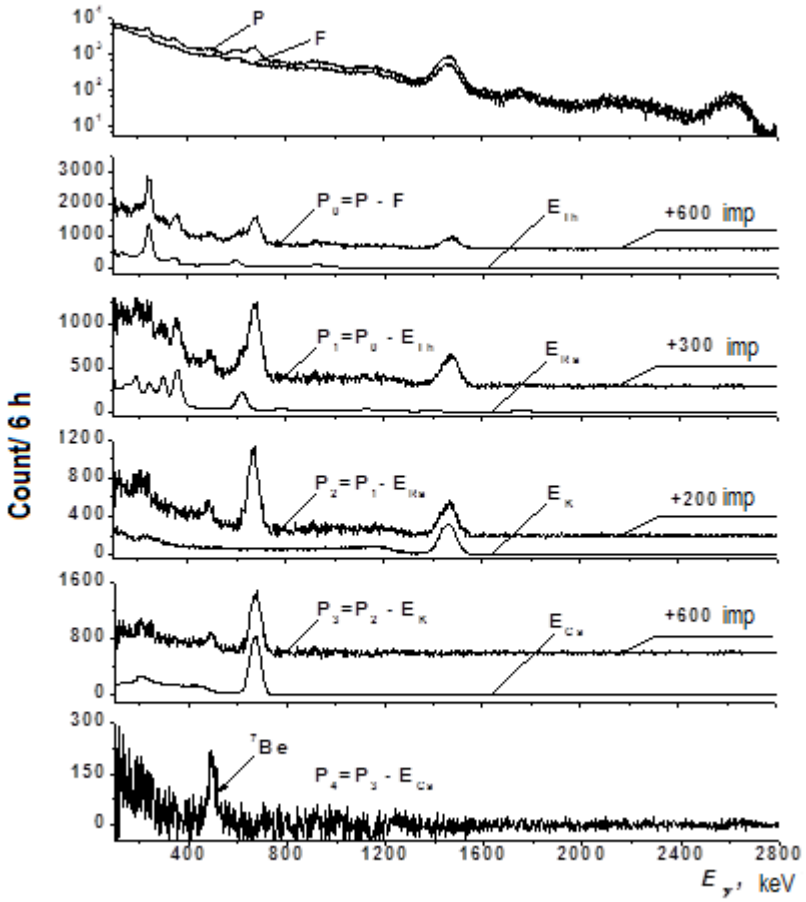

Figure 1. Gamma-ray spectra of natural and technogenic radionuclides in the content of the sample

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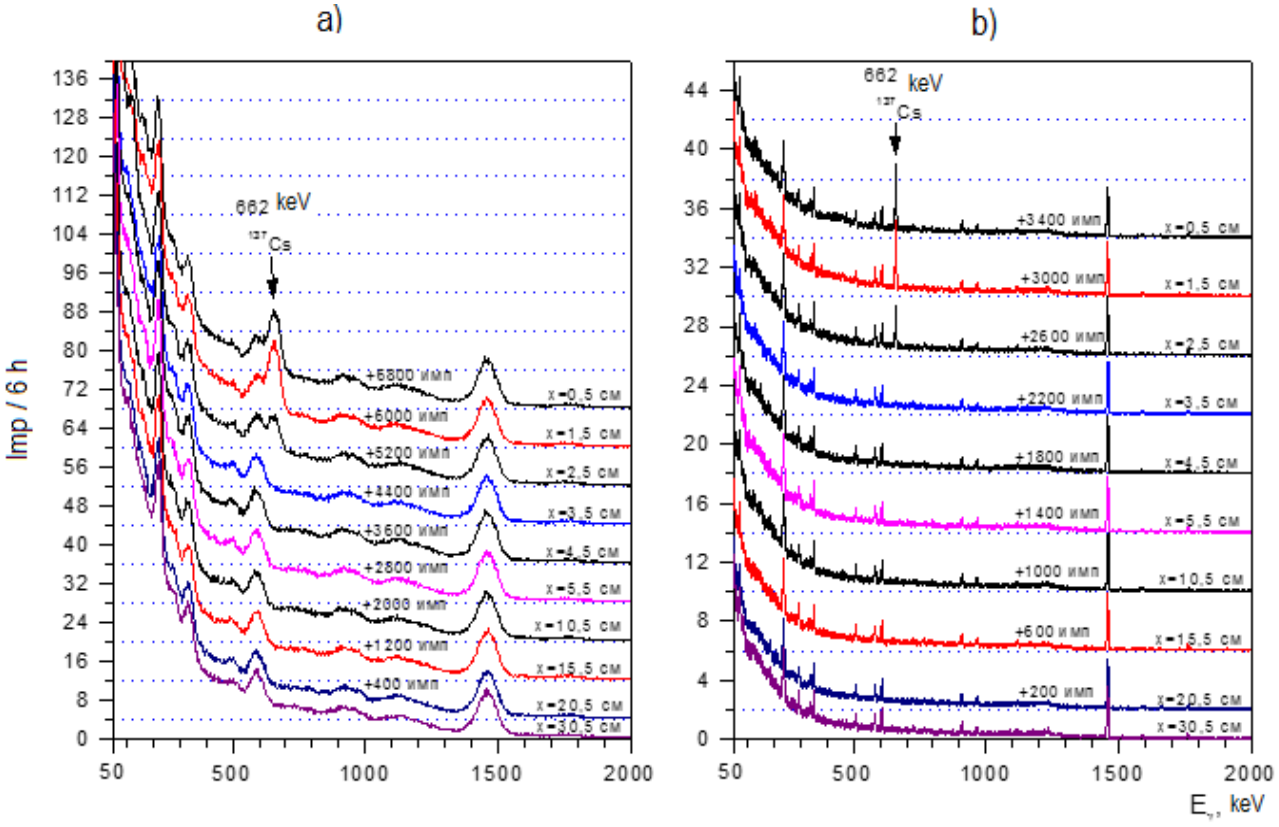

Figure 2. Gamma-ray spectra of a soil sample with scintillation (a) and semiconductor (b) spectra

Table 1. The degree of prevalence of the specific activity of natural radionuclides Ra^{226}, Th^{232}, and K^{40} in the soil

№	Soil layer (cm)	Ra-226 Bq/kg	Th-232 Bq/kg	K-40 Bq/kg	Cs-137 Bq/kg	Total mass
1	0-2	38.39±5,0	52.938±5.1	661.08±66	66.725±9.52	1430 g
2	2-4	41.92±5.7	52.872±5.1	707.93±69	38.946±3.9	1170 g
3	4-6	34.692±5.5	55.064±5.5	658.42±64	7.2342±2	1580 g
4	6-10	32.317±3.3	50.655±5.1	705.57±71	<1.472	1410 g
5	10-15	34.932±7.8	56.166±6.1	838.38±82	<1.676	1605 g
6	15-20	37.863±5.1	55.484±5.3	803.78±80	<1.1	1330 g
7	20-30	35.866±1,7	53.302±8,05	654.43±83	<1.413	1425 g

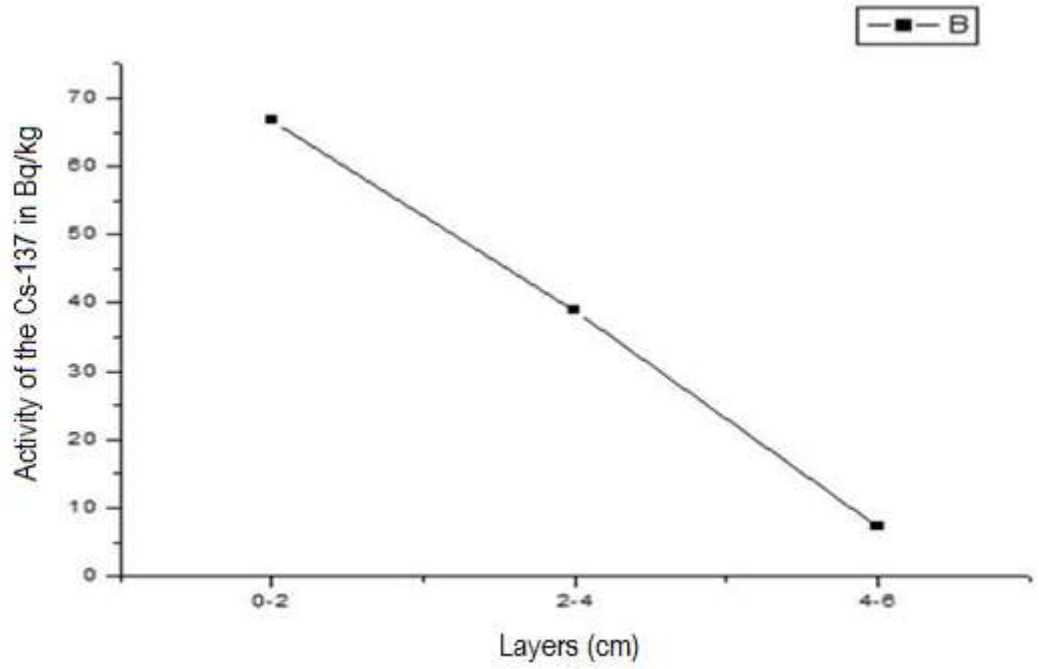

Figure 3. Specific activity of technogenic radionuclide Cs-137 in soil layers

Also, a more significant accumulation of potassium-40 radionuclide in the wet part of the soil and a uniform distribution depends on diffusion. Due to diffusion, the K-40 isotope is evenly distributed when interacting with soil particles. The isotope of potassium-40 resembles the properties of cesium-137 as a chemical element.

The migration of technogenic cesium-137 and strontium-90 isotopes into the soil is quite complicated [2]. Vertical migration of radionuclides in the soil system occurs due to the mechanical transfer of particles containing radionuclides and their partial movement on cultivated agricultural soils within the planting layer. The technogenic cesium-137 isotope's specific activity is greatest in the 1-3 cm layer of the Earth (66.725 Bq/kg). Figure 3 shows that the isotopes of cesium-137 decrease sharply (up to 1.0 Bq/kg) at a depth of 15-20 cm, increasing the height of propagation on the Earth's surface (mainly due to horizontal migration). Specific activity of caesium-137 on the Earth's surface (1-2)cm (66.72 9,5) Bq/kg. Radionuclides of cesium-137 are redistributed above the ground due to horizontal migration. This distribution confirms the accumulation of radionuclide mainly in the area of the root part of plants and gradually penetrates the deeper layer of the earth and joins the migration chain of the ecosystem. If the leading cause of horizontal migration of radionuclides is the impact of strong winds and soil erosion, then the processing of irrigated land also accelerates the migration process, and activity decreases by 15-20% at a depth of 60 cm compared to the surface part (70-80). The sharp decrease in the radionuclide of cesium-137 (15-20) cm in the deep layer is explained by the increased ion exchange of radionuclides in wet soil with other chemical elements in this layer. Such points of view are confirmed by analyzing the spectra of the scintillation gamma of the element cesium-137 with an energy 662 keV. Figure 2 shows the gamma spectra of the cesium-137 isotope with an energy 662 keV in different soil layers (0,5-30,5 cm)[3]. It can be seen from the spectra that the intensity of the gamma-ray spectra varies at different depths from the Earth's surface. Activity is high at a depth of 0.2-0.5 cm. This suggests that in this layer, there is indeed an increased activity of cesium-137, while in this layer, the horizontal migration of radionuclides is high at almost all seasons of the year.

The table shows that the Earth's surface layer (1-3 cm) is formed over long, and maybe hundreds of years, migrating through strong winds and rainwater. In this layer [2], the activity is also very high (90-137 Bq/kg) for strontium-70 and cesium-137 radionuclides, but the comparative activity is incredibly small in low layers (1.4 Bq/kg). According to the experiment results, if the comparative activity for strontium-90 in the 30 cm layer is 1,2 Bq/kg, then at such depth for the cesium-137 isotope, the comparative activity in the region where the samples were taken is 1,0 Bq/kg. Cesium also belongs to the group of elements that accumulate strongly in the soil. This depends on the state of primary environmental pollution and the time of assessment of the migration process. From the analysis conducted on horizontal migration of the isotope (soil-water-plant), it was found that it has a substantial accumulation mainly in the inorganic phase of the soil, and in combination with the conservation of the coefficient of accumulation in the biomass of the radionuclide strontium-90 (800-9000) migration of cesium in the soil depends on the composition [2]. Although the coefficient of accumulation in the soil is small compared to strontium, the radioactivity of the environment (soil, water, air) largely determines the cesium-137.

The vertical migration of decomposition products from untreated desert soils (sand-gravel) will be minimal. According to some data [4-6], if the main fragments of radionuclides are collected in a horizontal thin surface layer of soil (up to 3 cm), their vertical migration is 3-4 mm per year. In general, the soil's size and character depend on the radiation capacity, and the soil radioactivity is determined more by the cesium-90 isotope in combination with the strontium-137 isotope. The Earth's radiation capacity depends on the softness of the soil, the amount of solution, the cation content, the ability to swallow chemically, and the natural state.

4. Conclusion

Thus, the study of the distribution of the specific activity of elements of natural Ra^{226}, Th^{232}, and K^{40} on cultivated soils in the inner layers of the Earth of different thickness and the specific activity of the technogenic radionuclide element Cs^{137} mainly on the Earth's surface (2-3 cm)indicate that these radionuclides are mainly redistributed over the Earth's surface under the influence of horizontal migration. From the results obtained, it can be concluded that if the natural radionuclides thorium-232 and radium-226 undergo horizontal migration in sandy and gravel soils, then the technogenic radionuclide Cs^{137} will also have a horizontal migration property on the treated soil surface (1-2 cm). Moreover, the isotope of natural K^{40} is distributed to the environment by horizontal and vertical migration in the soil.

5. References

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