

MONITORING OF ENVIRONMENTAL RADIOACTIVITY IN SERBIA

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Abstract: The 2023 environmental radioactivity monitoring program in Serbia provided comprehensive data on the activity concentrations of natural and artificial radionuclides in various environmental samples, including air, precipitation, soil, vegetation, food, drinking water, and river sediments. The results confirm that radionuclide activity concentrations remained at low levels, posing no significant radiological risk to public health or the environment. Long-lived artificial radionuclides, such as ¹³⁷Cs and ⁹⁰Sr, detected in the food chain, were found to be within safe limits, resulting in annual effective doses significantly below the recommended thresholds. Gamma spectrometry measurements and assessments of alpha and beta activities in drinking water, surface waters, sediments, and food further demonstrated compliance with national safety standards. The maximum indoor radon concentration measured was approximately 500 Bq/m³. Monitoring of sites affected by depleted uranium munitions used in southern Serbia in 1999 showed no evidence of elevated radiological risks, with uranium isotope ratios confirming the natural origin of detected uranium. This study confirms that environmental radioactivity levels in Serbia remain stable, with no significant variations compared to previous years.

Key words: Environmental radioactivity, Serbia, radionuclides, monitoring, public health, cesium-137, strontium-90, depleted uranium.

1. INTRODUCTION

Radioactivity is a natural phenomenon resulting from the decay of unstable atomic nuclei. This process releases ionizing radiation, which has significant effects on the environment and human health. Natural sources of radioactivity include radionuclides such as uranium (²³⁸U), thorium (²³²Th), and potassium (⁴⁰K), which have been present in the Earth's crust since its formation. In the atmosphere, the cosmogenic radionuclide ⁷Be is constantly present [1], [2]. Tritium (³H) is also found in the environment, with its natural occurrence resulting from the interaction of cosmic rays with atmospheric nitrogen. However, anthropogenic production has disrupted the natural levels of tritium [3].

Artificial sources of radioactivity are also significant and have become the subject of intensive research, particularly following the nuclear tests of the 1960s, the Chernobyl nuclear disaster in 1986, and the Fukushima nuclear accident in 2011. During these events, large quantities of artificial radionuclides (such as cesium-137 (¹³⁷Cs) and strontium-90 (⁹⁰Sr)) were released into the atmosphere, causing environmental contamination on an enormous scale [1], [2], [4], [5]. For example, during the Fukushima nuclear accident, an estimated total radionuclide activity of approximately 520 (340–800) PBq was emitted, with about 80% being deposited in the Pacific Ocean [5]. These events have contributed to increased awareness of the importance of continuous monitoring of radioactivity at both global and national levels. Monitoring and controlling the levels of radioactivity from both natural and artificial sources are essential activities for ensuring environmental safety and public health [6].

Currently, artificial radionuclides can be detected in Serbia's environment, originating from nuclear tests and the Chernobyl nuclear accident [4]. Additionally, part of Serbia's environment was contaminated with depleted uranium during NATO operations in 1999. It is estimated that around 30,000 rounds of depleted uranium ammunition were used during NATO bombings of 112 separate locations in Kosovo and Metohija in 1999. Beyond these primary targets, an estimated 3,000–5,000 rounds with depleted uranium (DU) were directed at a smaller number of targets in southern Serbia. Most of the used ammunition missed heavy targets and remained buried in the soil, thus posing a potential threat of environmental contamination [7], [8]. Between 2002 and 2007, a cleanup operation was conducted to remove depleted uranium from the affected sites [9].

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Potential environmental contaminants with radioactive materials also include nuclear power plants, with four located in neighboring countries (Slovenia, Bulgaria, Romania, and Hungary), as well as various industrial activities. These industries can lead to increased concentrations of natural radionuclides in the environment [2]. Therefore, systematic monitoring of radioactivity is essential to assess environmental risks, provide timely responses to increased radiation levels, and implement radiation safety and security measures [6].

The annual effective dose received by an average Serbian resident primarily originates from natural radiation sources, such as cosmic radiation, ground radiation, the Earth's crust, and the human body. Under normal conditions, radiation from these sources constitutes background radiation, characteristic of each specific location. According to the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR), the average total annual effective dose from these sources is 2.4 mSv, of which 1.26 mSv is attributed to radon exposure, 0.6 mSv to medical exposure, 0.48 mSv to external and internal natural exposure, 0.39 mSv to cosmic radiation, and 0.29 mSv to ingestion [10]. Thus, the largest contribution to the total dose received by humans comes from natural sources of ionizing radiation.

Monitoring radioactivity in Serbia requires a multidisciplinary approach encompassing various aspects, from tracking radionuclide concentrations in air, water, and soil to analyzing their presence in products that come into direct contact with humans and animals. However, building materials are not included in radioactivity monitoring.

EU member states are obligated to conduct continuous (routine) monitoring of environmental radioactivity. This legal framework has been established by the European Commission through its Euratom (European Atomic Energy Community) organization. Systematic monitoring covers radionuclides in environmental samples such as air particles, surface water, drinking water, milk, and mixed food [11]. In Serbia, as a candidate country for the European Union, a monitoring system has been established that includes measuring gamma radiation levels in open spaces and analyzing radionuclide concentrations in air, surface water, drinking water, and food. Additionally, particular attention is given to monitoring radon, a natural gas that represents one of the primary sources of human exposure to ionizing radiation. Radon, which emanates from soil and building materials, has been identified as a significant risk factor for lung cancer development [12], further emphasizing the importance of its monitoring in residential and workplace environments. Heightened attention to radioactivity monitoring in Serbia has been observed following the onset of the conflict in Ukraine.

Digitalization and automation of monitoring processes further enhance the efficiency of early warning systems for elevated radiation levels. The use of Geographic Information Systems (GIS) allows for the visualization of radioactivity data on a regional level, facilitating strategic decision-making in environmental protection.

In Serbia, systematic examination of environmental radioactivity, or radioactivity monitoring, is conducted in accordance with the Law on Radiation and Nuclear Safety and Security [13]. This monitoring aims to detect the presence of radionuclides in the environment and assess population exposure to ionizing radiation under normal conditions, in cases of suspected incidents, and during incidents. The Rulebook for Establishing the Programme of Systematic Environmental Radioactivity Examination [14] defines the locations, intervals, types, and methods of systematic examination of environmental radioactivity.

The collection and analysis of samples included in the monitoring are carried out by legal entities authorized by the Directorate for Radiation and Nuclear Safety and Security of Serbia. Based on monitoring results, the Directorate assesses the environmental risk of ionizing radiation and population exposure, prescribes urgent measures in cases of increased radioactivity, and evaluates radiation doses for the population from environmental sources [9].

Environmental radioactivity monitoring, i.e., continuous measurement and tracking of radionuclide content in the environment, is regulated by the Rulebook on Establishing the Program for Systematic Examination of Environmental Radioactivity [14] and the Rulebook on Radioactivity Monitoring [15]. These regulations specify sample types, sampling locations, the number of samples, and methods for systematic examination of environmental radioactivity. The data collected provides essential information for assessing the radiation burden on the population and the average level of environmental radioactivity. Continuous monitoring of this data can indicate potential changes and undesirable events in the environment.

This paper presents an overview of the measured activity concentration values of radionuclides within the 2023 radioactivity monitoring program [9], and the obtained results are compared with values from previous years.

2. MATERIAL AND METHODS

The monitoring of radioactivity in the environment in the Republic of Serbia during 2023 was conducted in accordance with the Regulation on the Program for Systematic Examination of Environmental Radioactivity. Authorized institutions, including the Institute for Nuclear Sciences "Vinča," the Faculty of Sciences in Novi Sad, and the Institute of Occupational Medicine of Serbia, carried out investigations into various aspects of radioactivity.

The investigations included monitoring the ambient dose equivalent rate of gamma radiation in the air, radionuclide content in the air, solid and liquid precipitation, surface water, river sediment, drinking water, foodstuffs, and animal feed. Additionally, levels of exposure to ionizing radiation in indoor spaces and workplaces were measured. Special attention was given to examining locations affected by depleted uranium during the NATO bombing in 1999.

The assessment of public exposure to external radiation is based on the ambient dose equivalent rate of gamma radiation in the air. Continuous monitoring of this parameter across the territory of the Republic of Serbia is enabled by a developed early warning system for nuclear or radiological accidents. Data on measured air values in real time are available on the website of the Directorate for Radiation and Nuclear Safety and Security of Serbia.

In addition to continuous monitoring of the ambient dose equivalent rate of gamma radiation in the air, external radiation is also quantified by measuring the ambient dose equivalent of gamma radiation using thermoluminescent (TL) dosimeters. TL dosimeters are installed at a height of 1 meter above uncultivated grassy surfaces in locations such as Belgrade, Vinča, Zaječar, Prahovo, Golubac, Sremska Mitrovica, Lazarevac, Kragujevac, Kladovo, Novi Sad, Obrenovac, Niš, Palić, Kraljevo, Pirot, and Užice. Dosimeters are read and replaced every three months throughout the year [9].

For the examination of radionuclide content in the air, air samples are collected at various locations in Belgrade, Subotica (Palić), Vinča, Niš, Zaječar, Zlatibor, and Vranje. Samples are continuously collected over 24 hours each day using air sampling systems placed 1 meter above the ground. The radionuclide content in the air is determined from composite monthly air samples. The composite monthly sample is obtained by mineralizing all daily samples collected over one month. Sample analysis is conducted using gamma spectrometry with HPGe detection systems. This and all other gamma spectrometry measurements of the samples were conducted following the methodology described in Ref. [1]. The results of air sample testing are expressed in Bq/m^3 .

For the examination of radionuclide content in solid and liquid precipitation, samples are collected daily and continuously over 24 hours in Belgrade, Novi Sad, Vinča, Niš, Subotica (Palić), Zlatibor, Kragujevac, Zaječar, and Vranje. Precipitation collectors are installed 1 meter above uncultivated grassy surfaces [9]. The composite monthly sample is obtained from daily samples and analyzed similarly to the previous case. Measurement results for precipitation samples are expressed in Bq/m^2 .

For the purpose of examining radionuclides in surface water samples, samples are collected daily from the Danube near Bezdan, Vinča, Zemun, and Prahovo, the Sava near Sremska Mitrovica and Belgrade, the Tisa near Kanjiža, the Nišava near Pirot, the Drina near Loznica, and the Timok near Knjaževac. At the same locations, river sediment samples are collected twice a year from the riverbeds. Drinking water samples are collected daily from water supply systems serving settlements with more than 100,000 inhabitants. In 2023, drinking water samples were collected in Belgrade, Kragujevac, Niš, Leskovac, Čačak, Subotica, and Kraljevo [9].

In composite monthly drinking water samples, total alpha and beta activity and the content of gamma-emitting radionuclides are determined. The concentrations of gamma-emitting radionuclides are determined using gamma spectrometry in composite monthly river water samples from the Danube and Sava, while in other river water samples, the radionuclide content is determined in composite quarterly samples. For the concentration of radionuclides from large volumes of river water samples, the manganese (II) oxide, MnO , precipitation method is used. Total alpha and total beta activity in drinking water are measured with a liquid scintillation counter, following the standard method ASTM D 7283-06 [16].

In surface and drinking water samples, tests for ^3H and ^{90}Sr were performed in composite monthly samples. The content of ^{90}Sr was determined using a radiochemical method based on the extraction of strontium from the sample using oxalic acid. ^3H is determined using a rapid method that involves mixing the distilled sample with a scintillation cocktail and measuring the activity with a liquid scintillation detector [9].

Before analysis, sediment samples were dried at a temperature of 105°C until a constant mass was achieved. The samples were analyzed using gamma spectrometry. In the sediment samples from the Danube near Bezdan and the Sava near Sremska Mitrovica, in addition to gamma-emitting radionuclides, the content of ^{90}Sr was also determined. The content of ^{90}Sr was determined after the radiochemical extraction of strontium from the investigated sample.

Samples of food and milk are collected in Belgrade, Subotica, Novi Sad, Niš, Užice (Zlatibor), Zaječar, and Vranje. Food samples are taken from primary production, and the radionuclide content is tested according to the maturation of vegetation and breeding (for meat). Milk samples are collected daily from the milk collection network, and composite monthly samples are analyzed from each of the listed locations separately. Dairy product samples were taken twice in 2023. Composite mixed samples of baby food from public catering (kindergartens) were taken three times in 2023 in Belgrade, Novi Sad, and Niš. Food samples are analyzed using gamma spectrometry, and the content of ^{90}Sr is determined. The measurement results are expressed in Bq/l of milk and Bq/kg of fresh food. The annual intake of radionuclides into the human body is expressed in Bq/year, and the corresponding effective dose in mSv/year. The examination of the biologically significant fission radionuclide ^{137}Cs in animal feed includes fresh bulky feed, dry bulky feed, and mixed feed for the nutrition of various types and categories of animals. Samples of animal feed for testing the content of the radionuclide ^{137}Cs were taken from primary production twice in 2023 [9].

In the aggregate monthly milk samples, the content of gamma-emitting radionuclides and ^{90}Sr was determined. In other food samples, the content of gamma-emitting radionuclides and ^{90}Sr was determined in each individual sample. In each collected sample of animal feed, the content of gamma-emitting radionuclides was determined.

The levels of exposure to ionizing radiation in living spaces and the working environment were determined by measuring the concentration of radon, ^{222}Rn in the air. Measurements were carried out in older and newer buildings such as apartments, schools, and preschools in different cities, in a total of 69 buildings, once during the year. The concentration of radon in indoor spaces was determined using the adsorption method of radon in canisters with activated charcoal, which were exposed for an average of 2 days. The concentration of radon was determined based on the measurement of the activity concentration of short-lived radon progeny, ^{214}Bi and ^{214}Pb , using gamma spectrometry [9].

The presence of depleted uranium, residual from the NATO bombing, was confirmed in the municipalities of Preševo, Bujanovac, and Vranje, at locations such as Reljan, Bratoselce, Borovac, and Pljačkovića. To assess the environmental threat and health risk to the population, a radiation control was carried out in these areas. Water, plant, and soil samples were analyzed. Water was taken from wells and public taps used for drinking. Plants were collected from the investigated locations, while soil samples were taken from a depth of 10-15 cm after removing grass and vegetation. Samples were taken from the center of each location, as well as from the east, west, north, and south directions [9].

The measurement of total alpha and total beta activity in water was conducted in the same manner as in other water samples. Plant samples were dried at room temperature, and then mineralized at 400°C . Soil samples were dried at 105°C and sieved. The total alpha and total beta activity in the mineralized water samples were determined by measurement on a proportional α/β counter. All gamma emitters were analyzed using gamma spectrometry [9].

3. RESULTS AND DISCUSSION

The value of the ambient equivalent dose of gamma radiation in the air, measured using TL dosimeters at 16 measurement sites in Serbia, ranged from a minimum average value of 55 nSv/h measured in Užice to a maximum average value of 99 nSv/h measured in Lazarevac.

Gamma spectrometric analysis of composite monthly air samples at all measurement stations shows the presence of both man-made and naturally occurring radionuclides, including ^{137}Cs , ^7Be , and ^{210}Pb , at very low concentrations. The activity of ^7Be was below $12 \mu\text{Bq/m}^3$ in all examined samples. The activity of the man-made radionuclide ^{137}Cs ranged from the detection limit to $2.9 \mu\text{Bq/m}^3$, as measured in Vranje. The distribution of activity for the cosmogenic radionuclide ^7Be exhibits a seasonal pattern, with ^7Be activity reaching its maximum in the summer months (June, July, August), while activity is lower during the winter period. The third detected natural radionuclide, ^{210}Pb , also shows pronounced seasonal variations, with higher values measured in the second half of the year and lower values recorded during the winter and spring periods. The measured activity of ^{210}Pb was below $3 \mu\text{Bq/m}^3$ [9].

In most of the monthly samples of solid and liquid precipitation, the presence of the man-made radionuclide ^{137}Cs was not detected. The highest activity value of ^{137}Cs was measured in a precipitation sample from Belgrade, Zelena Brda, in December (0.18 Bq/m^2). Additionally, the presence of the cosmogenic radionuclide ^7Be was detected in both solid and liquid precipitation, with the maximum concentration value of 150 Bq/m^2 measured in a sample from Belgrade, Vinča, in April.

In the analyzed surface water samples, the radioactivity originates from natural radionuclides ^{226}Ra and ^{232}Th , which were measured in very low concentrations. ^{137}Cs , strontium, and ^{90}Sr were not detected in the analyzed surface water samples. ^3H , was only detected in a river water sample from the Sava River near Sremska Mitrovica taken in October, with a value of $7.2 \pm 0.8 \text{ Bq/l}$ [9].

In the river sediment samples, the content of ^{137}Cs ranged from 0.46 Bq/kg in the Danube near Prahovo during the period July - December 2023, while the maximum activity of ^{137}Cs of 12.2 Bq/kg was measured in the Sava River near Belgrade during the period January - June 2023. It can be said that the detected activity of ^{137}Cs originates from contamination caused by the Chernobyl nuclear accident in 1986, and a trend of stagnation or decline in the specific activity of cesium in river sediment compared to previous years can be observed [17], [18]. The specific activities of natural radionuclides in river sediment samples ranged within the following value intervals: ^{226}Ra from 8.2 Bq/kg to 30.8 Bq/kg , ^{232}Th from 8.4 Bq/kg to 29.4 Bq/kg , ^{40}K from 182 Bq/kg to 462 Bq/kg , and ^{238}U from 7.6 Bq/kg to 33.4 Bq/kg , which are within the typical values for sediment and soil in our region. The concentration of ^{90}Sr was measured only in one sediment sample from the Sava River during the period July - December 2023 $0.59 \pm 0.18 \text{ Bq/kg}$, while in other samples, the activity of strontium was below the detection limit [9].

The measured concentrations of total alpha activity in drinking water in seven cities in Serbia included in the radioactivity monitoring program ranged from < 0.010 to 0.034 Bq/l for total alpha activity, while the total beta activity in all drinking water samples was below the detection limit. The measured activities of alpha and beta emitters are well below the limit values for drinking water, which are 0.1 Bq/l for total alpha activity and 1 Bq/l for total beta activity.

^{137}Cs , and ^{90}Sr , were below the detection limit in the analyzed drinking water samples, while the activity of ^3H was measured at $2.1 \pm 0.7 \text{ Bq/l}$ in one sample. The results of gamma spectrometric analysis indicated the presence of natural radionuclides (^{226}Ra , ^{232}Th) in concentrations significantly below the derived concentrations. The obtained results indicate that the activities of the examined radionuclides in the drinking water samples are well below the limits prescribed by the regulations [19].

The measured values of ^{137}Cs in milk were below the detection limit in most of the examined samples. In the samples where ^{137}Cs was detected, the values were very low, below the reference value of 15 Bq/l . Measurable activities of ^{90}Sr were also found, which were very low compared to the reference value of 64 Bq/l [19].

The measured values of ^{137}Cs and ^{90}Sr in food products from the food industry and individual production show significantly low levels of activity in samples of vegetables, fruits, cereals, meat, dairy products, and baby food, and are mostly below the value of 1 Bq/kg . Based on data from the Republic Statistical Office on food consumption in Serbia on an annual basis, an estimate of the

annual effective dose for a person due to food ingestion was made, with all obtained values being below 0.01 mSv [17], [18].

The determination of radionuclide content in animal feed samples showed very low activities of the produced ^{137}Cs and cosmogenic radionuclide ^7Be .

Table 1 shows the average and maximum measured values of radon concentrations in working and living spaces in cities of Serbia.

Table 1 – Measured concentrations of ^{222}Rn (Bq/m^3) in working and living spaces during 2023 [9].

Measurement location	Belgrade	Novi Sad	Niš	Subotica	Užice	Zaječar	Vranje
Number of samples	21	8	8	8	8	8	8
Average $\pm$ SD	124 ± 132	93 ± 48	113 ± 48	94 ± 59	129 ± 158	100 ± 55	129 ± 117
Maximum value	483	186	187	215	504	178	383

SD – Standard deviation.

Intervention levels for chronic radon exposure in apartments are equal to the annual average concentration of $200 \text{ Bq}/\text{m}^3$ of ^{222}Rn in the air for newly constructed residential buildings, and $400 \text{ Bq}/\text{m}^3$ of ^{222}Rn in the air for existing residential buildings [20]. The measured radon concentrations in the majority of the examined buildings were below the intervention levels for chronic radon exposure in apartments. The highest measured value was $504 \text{ Bq}/\text{m}^3$. In buildings where measured values exceeded the intervention levels, appropriate measures were recommended to reduce the excess radon levels.

Gamma spectrometry measurements of drinking water at locations where depleted uranium ammunition was used, as well as the results of total alpha and total beta activity measurements from water supplies and wells, at all sites, are lower than the reference values of $0.1 \text{ Bq}/\text{l}$ and $1.0 \text{ Bq}/\text{l}$, respectively. Furthermore, it is assumed that the indicative dose is below the parameter value of 0.1 mSv , and that the tested samples meet the criteria for radiological safety of drinking water [19]. The concentrations of uranium isotopes (^{238}U and ^{235}U) in all water samples were below the minimum detectable activity. The values for ^{137}Cs and ^{232}Th are below the minimum detectable activity, while the measured values for ^{226}Ra are below the reference value of $0.5 \text{ Bq}/\text{l}$ [19].

The activity concentrations of ^{235}U and ^{238}U in soil samples from locations where depleted uranium ammunition was used ranged within the same intervals as in the previous two years, with the ratio of $^{235}\text{U}/^{238}\text{U}$ ranging from 0.041 to 0.075 [17], [18].

The measured activity concentrations of radionuclides in plant culture samples from locations affected by depleted uranium correspond to typical radionuclide content characteristic of plant cultures from other locations in Serbia. At all locations, the activity concentrations of ^{235}U and ^{238}U in all plant cultures were below the minimum detectable concentration. The measurable presence ^{137}Cs in some plant culture samples is a result of residual contamination following the Chernobyl accident [9].

Table 2 – Average values of activity concentrations of radionuclides in soil samples from locations where depleted uranium ammunition was used in Bq/kg [9].

Location	^{235}U	^{238}U	^{226}Ra	^{232}Th	^{40}K	^{137}Cs
Reljan	2.7 ± 0.6	39.2 ± 8.0	33.0 ± 7.2	63.4 ± 9.0	832 ± 46	19.4 ± 24.4
Bratoselece	6.7 ± 0.2	121 ± 19	109 ± 18	66.8 ± 5.8	980 ± 16	6.7 ± 1.9
Pljačkovica	2.0 ± 0.7	39.8 ± 13.6	34.8 ± 6.3	40.2 ± 5.4	532 ± 91	8.3 ± 6.1
Borovac	1.0 ± 0.2	17.6 ± 3.8	17.3 ± 4.6	18.6 ± 10.5	178 ± 13	3.3 ± 2.1

The average measurement results of gamma radionuclides in soil are presented in Table 2. Detected radionuclides include natural radionuclides ^{226}Ra , ^{232}Th , ^{235}U , ^{238}U , and ^{40}K , as well as the artificial radionuclide ^{137}Cs . The highest concentrations of ^{226}Ra , ^{235}U , ^{238}U , and ^{40}K in soil were measured in samples from the Bratoselce location. Although the measured activity levels of ^{235}U and ^{238}U were slightly higher than those at other locations, the $^{235}\text{U}/^{238}\text{U}$ activity ratio corresponds to their natural uranium ratio. This confirms that the uranium in the examined samples is of natural origin. Based on these findings, the presence of depleted uranium in the analyzed samples was not confirmed [9].

The measured values for all analyzed samples are comparable to the values measured in the previous two years [17], [18]. Therefore, it can be concluded that no additional environmental contamination with radionuclides occurred during 2023.

4. CONCLUSION

Monitoring of radioactivity in Serbia is a fundamental tool for risk assessment and the protection of human health and the environment. The development and enhancement of the monitoring system require a multidisciplinary approach and synergy between scientific institutions, industry, and government authorities. By applying modern technologies and aligning with international standards, Serbia can achieve a high level of radiation safety, ensuring long-term protection of the environment and the health of its citizens.

In the future, it is essential to further invest in the modernization of equipment and foster international cooperation to ensure greater reliability and accuracy of results. Special attention should be given to integrating data from various sources and developing software solutions for the analysis and interpretation of radioactivity data.

Based on the overall results of environmental radioactivity measurements conducted in 2023, it can be concluded that the activity concentrations of both natural and artificial radionuclides in various sample types (air, precipitation) remained at low levels. The results of radioactivity measurements indicate that the activity concentrations of long-lived artificial radionuclides, such as ^{137}Cs and ^{90}Sr , in the food cycle are at low levels. These levels ensure that the effective radiation dose to the population from these radionuclides, ingested through food, remains significantly below the recommended annual limit.

The results of radionuclide activity concentration measurements are comparable to those from the previous two years at the same locations, indicating that there was no excessive human exposure to ionizing radiation from the environment during 2023. It can be concluded that locations contaminated by depleted uranium ammunition in 1999 do not pose a radiological threat to human health.

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