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Current State of the Radiation Situation in Sarapan and Zhanan Settlements Located on the Territory of the Former Semipalatinsk Nuclear Test Site, Kazakhstan

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Abstract: The content of some extremely hazardous radionuclides and weapon plutonium in soils of the Sarapan and Zhanan winterings which are located on border of the former semipalatinsk test site was investigated. Results of research showed that content of ^{241}Am does not exceed the threshold limit values whereas content of ^{137}Cs and $^{239+240}$Pu exceeds the regulated values in some points of sampling.

Key words: Semipalatinsk test site, artificial radionuclides, weapons-grade plutonium, hazardous, Sarapan, sampling

INTRODUCTION

At the time of "cold war" the Central Asian Region implemented the Soviet program of nuclear weapons for extraction of uranium ores and production of military materials for ground and underground level tests. Especially, illustrative example is Kazakhstan. About 70% of all nuclear tests of the former USSR were carried out in the territory of Kazakhstan from 1949-1989 (Duyssembaev *et al*., 2017). The majority from them, including 113 air and ground level explosions was carried out at the Semipalatinsk Test Site (STS) (Kakimov *et al*., 2016). Nuclear explosions have serious consequences for human health (Mihailov and Nelutu, 2015) and environment (Barsan *et al*., 2018).

At the present time, the mass media discuss the offer of the National Nuclear Center of RK to transfer the STS's lands to the farming business. Some of such territories are territories of the Sarapan and Zhanan winterings which have been already actively used by local farmers for livestock pasturing and haymaking. In summertime, several families of stock-keepers live on these lands. It is known that the nuclear tests were not carried out on the investigated part of the test site, however, there is Balapan test site close to this territory.

This research represents data on the content of some artificial radionuclides and weapon plutonium in the soil of the Sarapan and Zhanan winterings which territories are actively used for the agricultural purposes.

MATERIALS AND METHODS

In this research, the Southeast area of the STS's territory including the Balapan technical site was surveyed. From earlier, published researches (Anonymous, 2010), it is known that the testing of underground nuclear explosions in wells with use of conventional explosives was carried out on this site. It should be noted that when carrying out underground nuclear explosions in wells with a typical radiation situation, the greatest part of radioactivity remains in explosion epicenter below ground, only its small part in the form of noble gases rises to the surface. However, considering rather long-lived contact of radionuclides and in particular, plutonium -239+240, formed as a result of these experiments with the soil, it is possible to accept with confidence establishment of all physical equilibriums in the soil. Such sites make it possible to determine the important quantitative characteristics of migration ability of the investigated radionuclides in the soil. When planning investigation of the explored territory we considered such factors as:

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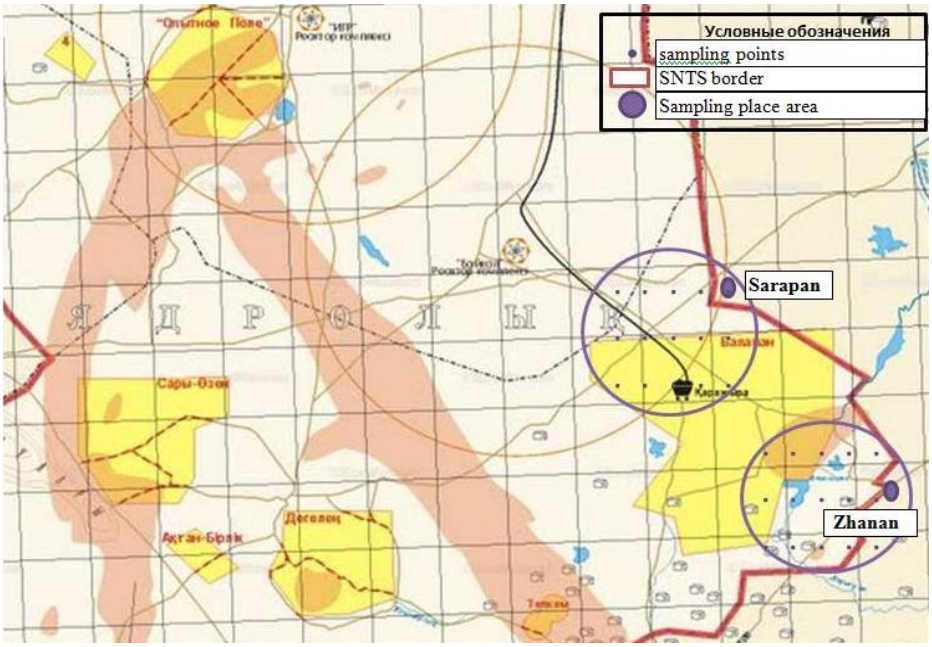

Fig. 1: Map of location of agricultural grounds and points of radio ecological investigation of the Sarapan and Zhanan winterings in the territory of the former semipalatinsk test site

- Available data on the content of the investigated radionuclides in the soil of the explored territory
- Exploration grid offered by IAEA's expert group with cell of 1*1 km
- Unified principles of formation of radio contamination after nuclear tests

Based on the factors above, the areal survey of the investigated territory was conducted, according to the grid with 1 km step with measurement of coordinates in each chosen sampling point, radiometric shooting and selection of soil sample from the area of 10*10 cm and depth of 5 cm.

The soil sampling was made during the field expedition in July, 2017. The map of the explored area of STS and the soil and vegetation sampling points as well as their arrangement are shown in Fig. 1.

To give preliminary assessment of radiation condition of the explored territory of STS, the measurements of Exposure Dose Rate (EDR) at 30 points on the surface and at the height of 1 m from the surface of the soil were taken, according to recommendations, "Procedure of measurements. Gosstandart, 1993, inv. No. 92", using calibrated dosimeter "Syntex". The arithmetic-mean value of 5 EDR measurements was taken as statically reliable. Measurements were also carried out using dosimeter "Harwell Instrument" with area of calculating window of 100 cm^2. Also device MKC-01P1 was used for these purposes. The tolerance of the used measuring devices made ±20%.

The soil samples were analyzed in radio ecological research laboratory of the Shakarim State University of Semey. Preparation of samples for the analysis of plutonium isotopes content included all stages of sample preparation necessary for its further radiochemical analysis.

When choosing method of $^{239, 240}Pu$ determination, the schemes of decay of defined radionuclide and its decay daughters were considered. The assumed range of defined radionuclide content in the soil samples and respectively, the sample size sufficient for the analysis was also considered.

The soil sample weighing 50 g was dried up in the drying chamber at the temperature of 120-130°C up to the constant weight. The averaged weighed quantity of soil (170-200 g) after weighing was incinerated for 2 h at the temperature of 600-650°C and calcinated for 3.5-4.0 h with intermediate mixing operation. A weighed quantity for the analysis weighing 10 g was selected from the calcinated sample. Such weighed quantity is enough to define $^{239, 240}Pu$ in the soil. Solution of ^{232}Pu radioisotope tracer was added by regular dropping using the repeater pipette in the analyzed weighed quantity of sample.

To determine the weapon $^{-239, 240}Pu$, an alpha-spectrometric method was used in the soil samples after the preliminary radiochemical preparation including the procedure of preliminary co-precipitation of isotopes on ferric hydroxide (III), transfer of sorbed isotopes in solution, freeing from interfering compounds, preparation of calculating sample. In this research, for determination

of isotope composition of plutonium in the analyzed samples we used α-spectrometer "Alpha analyst" of "Canberra" Company.

RESULTS AND DISCUSSION

Depending on the explored area and solvable tasks density of the investigation varied from 1 measurement for 2 km^2 to 1 measurement for 4 km^2. Results of EDR distribution in the explored territory changed from 0.009-0.15 μSv/h. EDR arithmetic mean values in representative points of the investigation are presented in Table 1.

According to results of measurements, it was established that in the territory of Southeast part of the test site on which the Sarapan, Zhanan and Atomic lake winterings are located, expose dose rate did not exceed the standards accepted in the Republic of Kazakhstan, according to the Anonymous (2015). But considering that values of radiation parameters were obtained using different measuring devices with various detection limits of defined values for correct interpretation of data, the values which are below detection limits of the used measuring instruments were removed from final indexes. The analysis of distribution of EDR values showed that results of measurements are in range from 0.009-0.15 μSv/h. To assess distribution of EDR values, the variation curve presented in Fig. 2 was plotted which shows natural distribution of EDR on the explored site. Observed right asymmetry forms the range of values exceeding a normal distribution that once again shows using of measuring devices different from each other when carrying out investigation of the explored territory. The hyperactivity of natural radionuclides in the soil and variation of EDR can be one more reason for the right asymmetry on variation curve of EDR.

Thus, EDR level in the explored part of STS's territory is at the level of the background rates established for Kazakhstan (Sonitary-hyeinic standard, 2015).

Results of gamma-spectrometric analysis of soil samples found in the samples under investigation artificial radionuclides ^{137}Cs and ^{241}Am. No noticeable anomalies in distribution or excess of detection limit for such radionuclides as ^{60}Co, ^{152}Eu are found. Level of their content in the soil of explored sites corresponds to values below of limits of their detection.

According to results of the investigation, it is established that content of ^{137}Cs in the soil samples of the explored part of STS varies from 0.5-1456.3 Bq/kg. However, the analyzed soil samples with maximal value (>40 Bq/kg) make about 1% of all studied samples that is explained by natural redistribution of ^{137}Cs (Fig. 3).

As it is seen from Fig. 3, the distribution of frequency of occurrence of points with particular concentrations has the nature of distribution close to lognormal distribution.

Table 1: Exposure dose rate in the explored territory

Name of wintering	EDR (μSv/h)						
Zhanan	0.009	0.11	0.11	0.07	0.12	0.070	0.06
Atomic lake	0.120	0.11	0.15	0.10	0.11	0.100	0.13
Sarapan	0.130	0.09	0.11	0.11	0.10	0.009	0.10

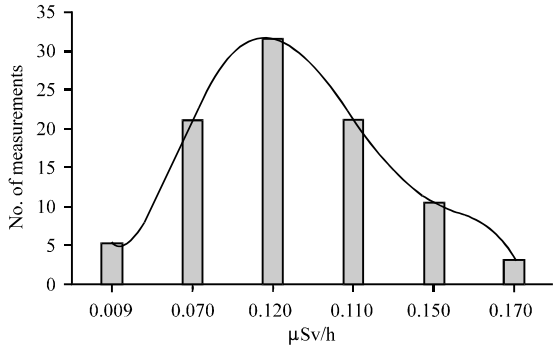

Fig. 2: Variation curve of the explored territory

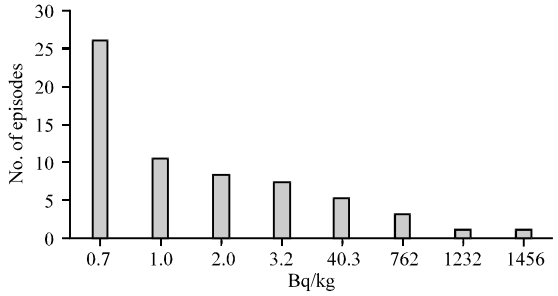

Fig. 3: Histogram of distribution of data on concentration of ^{137}Cs in the soil

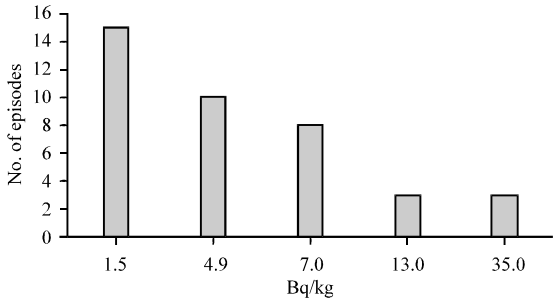

Fig. 4: Histogram of distribution of data on concentration of ^{241}Am in the soil

However, in this research, average value of concentration of ^{137}Cs in the explored territory does not exceed values of background of global fallouts for this radionuclide (Grosche *et al*., 2002).

The nature of contamination of the explored territory by ^{241}Am has unsteady nature, in sampling points near the "Balapan" and "Atomic Lake" sites there are increased values. The histogram of distribution of frequency of occurrence of points with particular concentration of ^{241}Am is presented in Fig. 4.

Table 2: Content of ^{239,240}Pu in the analyzed soil samples

Sampling point No.	Activity of ^{239,240}Pu (Bq/kg)
1 Atomic lake	16.2±0.4
2 Atomic lake	9.8±0.5
3 Atomic lake	9.6±0.3
4 Zhanan wintering	8.3±0.5
5 Zhanan wintering	1.5±0.1
6 Zhanan wintering	0.8±0.2
7Zhanan wintering	4.9±0.3
8 Zhanan wintering	0.2±0.1
9 Zhanan wintering	8±2
10 Sarapan wintering	5.9±3.5
11Sarapan wintering	0.9±0.5
12 Sarapan wintering	5.8±3.5
13 Sarapan wintering	<0.2
14 Sarapan wintering	5.4±0.2
15 Sarapan wintering	2±0.1
16 Sarapan wintering	1.5±0.2
Average content	7.8±0.3

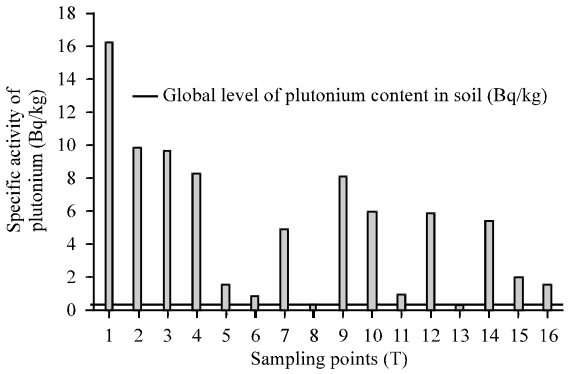

Fig. 5: Distribution of $^{239+240}$Pu in soils of the explored territory

Considering complexity of classical method for determination of plutonium isotopes in soil samples, the investigation of this radionuclide in the soil of explored territory was conducted partially and on a small scale. According to obtained measurements, the calculation of massic activity of $^{239+240}$Pu taking into account measurement errors was carried out. But the calculation of massic activity of ^{238}Pu is irrational because of its low limit of detection. Data on massic activity of plutonium isotopes in the analyzed soil samples are presented in Table 2.

As Table 2 shows, the majority of samples have the high levels of activity exceeding the level of global fallouts which has value of 0.2 Bq/kg (Rikhvanov, 2009). This investigation has determined that distribution of plutonium isotopes in the soil of analyzed samples is of "spotted" nature. It is a consequence of the fact that plutonium is classified as inactive element, its redistribution on the ground surface occurs mainly due to wind transfer and soil erosion and therefore, it is possible to assume that the hyperactivity of plutonium in soils of the explored territory is not caused only by the level of global fallouts (Fig. 5).

At the same time it should be noted that at the height of nuclear tests, content of $^{239, 240}$Pu in soils of the Northern hemisphere due to global fallouts, according to, the research data (Lehto and Hou, 2011) was 4100 Bq/kg.

CONCLUSION

As consequence of this investigation of the part of STS's Southeast Region, the increased concentrations of $^{239+240}$Pu and ^{137}Cs isotopes exceeding threshold limit values were found. Some points of the STS's explored area show the levels of contamination by artificial radionuclides which correspond to much higher concentrations that can lead to radiological consequences in spite of the fact that the considerable part of the region including the STS's territory itself, is characterized by the close to background levels of radiation contamination.

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