THE RADIATION SITUATION IN THE AREA OF THE METEORIT-5 PEACEFUL NUCLEAR EXPLOSION

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Pursuant to relevant provision of the Federal Law No. 190-FZ On Radioactive Waste Management and Amendments to Certain Legislative Acts of the Russian Federation of July 11, 2011, radioactive waste generated due to the peaceful uses of nuclear charges has been attributed to the non-retrievable radioactive waste (RW) category. Accordingly, relevant RW subsoil areas are currently considered as facilities holding non-retrievable RW with periodic radiation monitoring that should be performed and certain measures provided to ensure the long-term safety of the population. The article presents the results of a radiation survey performed in 2019 for the site with non-retrievable RW inventory generated from the Meteorite-5 peaceful nuclear explosion.

Keywords: *radioactive waste, peaceful nuclear explosion, non-retrievable radioactive waste, radiation inspection, critical group, technogenic radionuclides, buffer zone, specific activity, surface contamination.*

In 1965—1988, the Soviet Union was running a large-scale program of nuclear explosions for peaceful purposes. Under this program, a total of 81 underground nuclear explosions were performed in 21 subjects of the Russian Federation, including 33 explosions performed for seismic sounding purposes [1, 2]. The USSR program of deep seismic studies involved observations along a number of profiles (geotraverses) with the Meteorite profile being one of them passing from the northwest to the southeast, from Taimyr to Transbaikal. Peaceful nuclear explosion (PNE) Meteorite-5 of 8.5 kt was performed on August 11, 1977 in the Khiloksky district of the Chita region (now the Trans-Baikal Territory) 80 km southeast of the regional center, on the right bank of the river Ares. It is the only explosion that took place in the zone of river flow into Lake Baikal and is considered as the shallowest in Siberia.

Assuming such impacts on the geological environment, routine monitoring should be implemented to monitor the content of technogenic radionuclides in environmental samples at the site of the explosion and in the adjacent territory, where flows of matter ascending from the depths can appear, primarily, the pressure waters of deep fault zones [3].

Territory of Meteorite-5 peaceful nuclear explosion restricted area

The experimental site of the Meteorite-5 PNE is located in a sparsely populated area on the right bank of the Arey River (Figure 1).

Figure 1. Layout of the experimental site and the restricted area of the peaceful nuclear explosion Meteorite-5

Figure 2. Restricted area of Meteorite-5 peaceful nuclear explosion

Restricted area (RA) with a 300 m radius [3] is mainly located on the right bank of the Arey River (Figure 2). No landmarks informing on the PNE RA status have been installed on the territory.

The Arey River flows from the south border of the experimental site. On the north side there is a country road (almost parallel to the Baikal federal highway), behind which hilly landscape starts to appear.

Arey, Novosalia, Shebartuy 2, Khilogoson villages and a camp site on Lake Arey are located in a 30-kilometer zone from the explosion site. The nearest settlement (Arey village) is located at a distance of about 19 km.

The vertical borehole, into which the explosive device was installed, was drilled in the Late Mesozoic biotite leucogranites overlayed by several tens of meters of loose sediments. The well is located

1996 [5] 2019

Figure 3. Photos of a combat well taken in different years

Figure 4. Photos of the site in 2019

in a close proximity to the junction between various tectonic zones constituting to the modern valleys of the Arey River and its tributaries: Dusaleya, Khandagayki and Ekhe-Gorkhon [3].

In 1990, a benchmark, namely, a concrete pedestal and an information sign, was installed near the production wellhead. Its mouth is cemented to the earth's surface level, the conductor protrudes to a height of ~ 1 m [4]. Some metal structures of the drill mast remained near the borehole (Figure 3, left).

But already by 1996, the information sign has been cut off. Moreover, at present time, all metal structures of the drill mast are also missing, and the upper part of the well has been cut off as well (Figure 3, right).

There are numerous evidences indicating that the local population have been to the site near the well: fireplaces, household rubbish in the pits. Concrete remains and broken glass can be found on the territory. There are fallen dry trees on most part of the site, thus, the fire risk is high (Figure 4).

Radiation situation in the PEN area

In accordance with SanPiN 2.6.2819-10 [6], radiation studies were carried out:

- on the territory of the RA and around it;
- on the territory of the nearest settlements within a 30 km radius, as well as the background settlement Tanga, located at a distance of some 42 km from the site;
- on surface water bodies located within a 30 km radius from the PNE site. The ambient gamma equivalent dose rate (ADER) was measured at a

height of 1 m from the earth's surface via continuous pedestrian gamma survey method involving portable spectrometric complex MKS-01A Multirad-M. It provides gamma scanning of open areas with reference to geographic coordinates using the global navigation system.

Environmental samples were collected in accordance with the methodological recommendations [7] and taking into account relevant provisions of MR 2.6.1.27-2003 [8] and MR 2.6.1.0010-10 [9].

The samples collected were investigated using gamma-spectrometric, radiochemical and radiometric methods to identify the presence of ^{90}Sr, ^{137}Cs and ^{241}Am radionuclides, whereas water samples collected from surface water bodies were also checked for ^{3}H.

To measure gamma-emitting radionuclides ^{137}Cs, ^{241}Am (in soil and water samples), a gamma-spectrometer with a semiconductor detector manufactured by CANBERRA with a BE5030 detection unit was used.

To measure ^{137}Cs and ^{90}Sr activity in samples of drinking water and water from surface water bodies, radiochemical separation of radionuclides was performed in accordance with MR 2.6.1.0094-14 [10], followed by relevant measurements either on a UMF 2000 radiometric device or a gamma-spectrometer (^{137}Cs).

^{3}H activity in water samples was measured in accordance with the requirements of MUK 4.3.044-2012 [11] using Tri-Carb 3180 TR/SL alpha-beta spectrometric radiation radiometer.

Findings of the radiation survey

Tables 1—5 and Figures 5 and 6 present the findings of the survey.

Table 1. Ambient equivalent dose rate of gamma radiation

Area	ADER, μSv/h		
	Mean ± standard deviation	Min	Max
Restricted area (RA)	0.10 ± 0.01	0.07	0.13
Around the RA	0.10 ± 0.02	0.08	0.17
Arey village	0.11 ± 0.01	0.09	0.15
Tourist camp (Lake Arey)	0.11 ± 0.01	0.07	0.13
Novosalia village	0.11 ± 0.004	0.09	0.12
2nd Shebartuy village	0.09 ± 0.01	0.08	0.11
Khylogoson village	0.09 ± 0.01	0.07	0.12
Tanga village	0.11 ± 0.01	0.08	0.17

Table 2. Surface activity of radionuclides in a 5-centimeter soil layer

Area	Surface activity, kBq/m² (range of variation)	
	^{90}Sr	^{137}Cs
Restricted area	0.10 ± 0.14 (0.009–0.640)	0.29 ± 0.32 (0.02–1.20)
Arey village	0.31 ± 0.16 (0.09–0.46)	1.5 ± 1.2 (0.07–3.10)
Novosalia village	0.11 ± 0.01 (0.078–0.130)	0.43 ± 0.10 (0.35–0.59)
2nd Shebartuy village	0.12 ± 0.04 (0.059–0.150)	0.36 ± 0.25 (0,06–1,20)
Khylogoson village	0.16 ± 0.14 (0.041–0.380)	0.58 ± 0,42 (0.11–0.25)
Tanga village	0.07 ± 0,06 (0.030–0.160)	0.21 ± 0.21 (0.03–0.61)

Table 3. Specific activity of radionuclides in wild mushrooms and berries

Sampling site	Average specific activity, Bq/kg raw weight			
	^{90}Sr		^{137}Cs	
	Mushrooms	Berries*	Mushrooms	Berries*
Restricted area	0.13 ± 0.06	0.49 ± 0.40	1.6 ± 0.1	0.65 ± 0.040
Arey village	0.17 ± 0.08	0.11 ± 0.07	0.12 ± 0.10	0.045 ± 0.010
Tanga village	0.06 ± 0.05	0.13 ± 0.08	0.12 ± 0.10	Less than 0.10

*In the restricted area — blueberries and red currants, in villages — red currants.

Table 4. Specific activity of radionuclides in surface water

Water body	Specific activity, Bq/l		
	^{137}Cs	^{90}Sr	^{3}H
Arey River (site area)	< 0.003	< 0.004	< 3
Arey River (downstream the site)	< 0.003	< 0.004	< 3
Arey River (upstream the site)	< 0.003	0.013 ± 0.007	14
Arey Lake	< 0.003	< 0.004	< 3
Bludnaya River	< 0.003	0.01 ± 0.007	32
Tanga Lake	< 0.003	< 0.004	140

Table 5. Specific activity of radionuclides in drinking water

Settlement	Specific activity, Bq/l		
	^{90}Sr	^{137}Cs	^{3}H
Arey village	0.01 ± 0.005	< 0.001	< 3
Novosalia village	< 0.004	< 0.001	< 3
2nd Shebartuy village	0.01 ± 0.005	< 0.001	< 3
Khylogoson village	0.009 ± 0.006	< 0.001	< 3
Tanga village	< 0.004	< 0.001	< 3
Intervention level for drinking water, Bq/kg [NRB]	4.9	11	7600

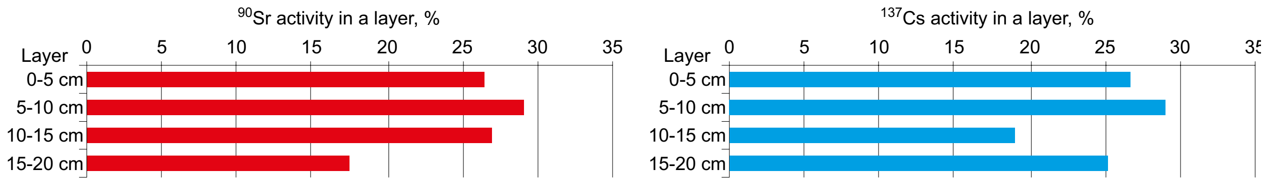

Figure 5. Radionuclide activity distribution along the soil depth at the site (as a percentage of the activity content in a 20-cm layer)

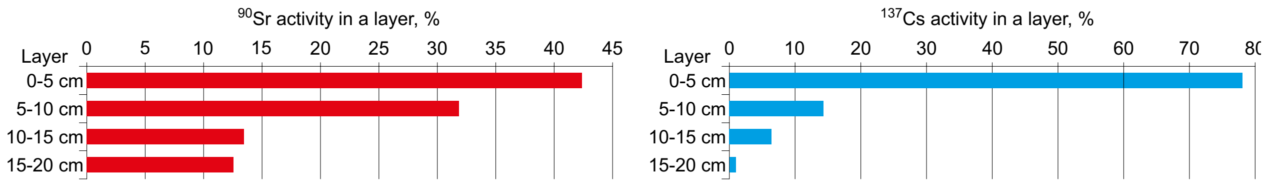

Figure 6. Radionuclide activity distribution along the soil depth in the territory of the Khilogoson village (as a percentage of the activity content in the 20-centimeter layer)

The Meteorite-5 explosion was executed in a routine mode, no radioactive releases into the atmosphere and onto the day surface was recorded at the moment of the explosion and in the subsequent period. Radiation levels at the Meteorite-5 site and the adjacent territory did not exceed regional natural background radiation levels [4, 12].

The RA was investigated in 1990 [5], 2001—2003. [12] and 2010 [4] and its was concluded that the radiation situation on its territory does not differ from the background one considered typical for this area.

The research implemented in 2019 revealed no significant differences in the ADER and the surface contamination at the RA territory, within the 30-km zone and the background settlement associated with ^{90}Sr and ^{137}Cs. These parameters characterizing the radiation environment were found to be within the range of the natural background variation considered common for the Trans-Baikal Territory [13].

Differences in ^{90}Sr and ^{137}Cs distribution by depth were noted in the soil and by their specific activity in wild berries and mushrooms. Within the RA, ^{90}Sr and ^{137}Cs radionuclides were found to be distributed more evenly within a 20 cm thick soil layer compared to the territory of the Khilogoson village. Apparently, this is due to the fact that the RA territory is mostly swampy. This may explain the increased content of radionuclides in mushrooms and berries. Moreover, the berry samples collected within the RA involved some blueberries, for which the radionuclide accumulation coefficients are higher than for other berries [14].

In terms of absolute levels, ^{90}Sr and ^{137}Cs specific activities in all samples of mushrooms and berries were found to be below the permissible ones set forth in SanPiN-2.3.2.1078-01 [15] and in the Unified Sanitary-Epidemiological and Hygienic Requirements for Goods Subject to Sanitary and Epidemiological Supervision (Control) [16]. ^{241}Am was not detected in the environmental samples (the minimum detectable ^{241}Am activity in soil samples was 0.1 kBq/m^2, in water — 0.002 Bq/l).

^{137}Cs, tritium and ^{90}Sr concentrations in all measured water samples collected from surface water bodies was found to be significantly lower than the intervention levels for drinking water established in NRB 99/2009 [17].

Effective doses for a critical group of population (fishermen, berry pickers) were evaluated under the following conditions assuming the intrusion on the RA territory and consumption of wild berries and mushrooms collected there:

- length of stay — 8 hours a day for 2 weeks in the summer (112 hours);
- consumption of water from the water body (the Arey river) on the RA territory in the amount of 2 l/day (28 l for 2 weeks of stay);
- consumption of 2 kg of mushrooms and 2 kg of berries harvested within the RA.

Assuming the above conditions, the total effective dose would amount 11.1 μSv/h with 11 μSv/h being associated with external irradiation.

Provisions of SanPiN 2.6.1.2819-10 [6] state that for a critical group of population the dose from additional technogenic exposure due to PNE should not exceed 0.3 mSv/year.

According to the estimates obtained, assuming the intrusion of a critical group of population to the RA territory, the total annual effective dose from the natural background and possible technogenic contamination resulted from a nuclear explosion would be significantly lower than above value.

Conclusion

The studies performed have shown that according to the indicators of previous years, the radiation situation on the territory affected by the Meteorite-5 PNE has practically remained the same.

The study showed that at present time the Meteorite-5 PNE site does not affect the radiation situation within the RA and in a 30-kilometer zone around the explosion site. Technogenic exposure associated with the Meteorite-5 PNE site is either absent or so minor that it cannot be reliably detected given the radiation background level.

Visual inspection of the PNE site in 2019 showed that the RA territory and the process well does not meet the requirements established in SaNPiN 2.6.1.2819-10 [6].

In this regard, the initial tasks are:

1. To install some information signs on the road at the northern border of the RA site notifying about the restricted access to the territory of the Meteorite-5 PNE, where any economic activities, drilling and other operations shall be prohibited unless relevant permit is granted by relevant authorities implementing state sanitary and epidemiological supervision and the administration of the Trans-Baikal Territory.
2. Development of designs for a process well, including the installation of a concrete pedestal at the wellhead, a metal fence around the pedestal, an information board with the PNE name, the date of the explosion, the size of the RA area, a radiation hazard sign notifying about the presence of RW in the subsoil and etc.
3. Improvement of the area and its cleaning from felled dry trees.
4. Development of designs stating the special nature of the allotment confined to the Meteorite-5 PNE site and approval of its legal status.

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Bibiliographic description

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