

Radioactive contaminated soil removal from the sites of the former Azgir nuclear test site

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Abstract

The research and engineering operations performed to clean and remove radioactive contamination from the Azgir test site improved levels of radiation in and around the site. After the operations, the possibility of contamination of personnel and the local population from radiation doses in the soil that exceed maximal permissible values for radiation were eliminated.

Keywords: Azgir nuclear test site, underground nuclear explosions, radionuclides, underground cavities from nuclear explosion, radioactive wastes.

1 Introduction

At the present time there are problems as a result of controlled peaceful nuclear explosions in Kazakhstan, which include clean-up activities in the contaminated area where the nuclear explosions were conducted. A considerable amount of time has passed since the explosions were carried out. This report addresses problems such as the removal of contaminated soil from the former AZGIR test site in the west of Kazakhstan. The pilot research was carried out from 1964 to 1979 by means of underground nuclear explosions in the rock salt massifs of an underground cavity used for multifunctional storage near to Azgir in Atyrau oblast (250 km from Caspian Sea and 70 km from the Volga River) at the salt dome of East and West Azgir. Among 39 peaceful underground explosions conducted in Kazakhstan (Table 1, Figure 1) [1], 17 explosions (22 blasting charges with energy release in trinitrotoluol equivalent from 0.01–103kt) were carried out at a depth of 160–1500m at 10 sites of the Azgir test site (Table 2). The total activity of underground cavities is about 10^6 Ci [2,3].



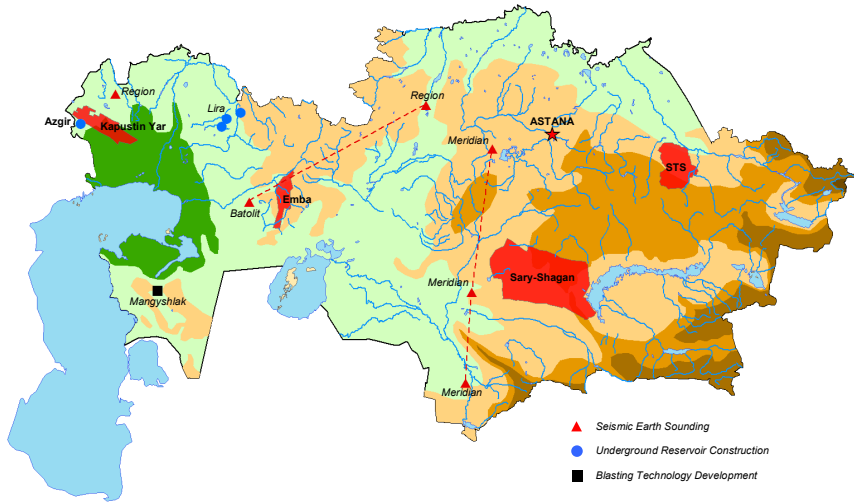


Figure 1: Peaceful nuclear explosions in Kazakhstan territory.

Table 1: Chronology of underground nuclear explosions at the Bolshoi Azgir salt dome.

Site	Explosion date	Depth of charge blasting, m	Explosion yield, trinitrotoluol equivalent, kt
A-I	April 22, 1966	160	1.1
A-II	July 1, 1968	600	27
A-III	December 22, 1971	1000	up to 64
A-IV	July 29, 1976	1000	up to 60
A-V	September 30, 1977	1500	up to 10
A-VII	October 17, 1978	1000	0.001 -20; 20-150
A-IX	December 18, 1978	900	103
A-VIII	January 17, 1979	1000	0.001 -20; 20-150
A-XI	July 14, 1979	1000	20
A-X	October 24, 1979	1000	0.001 -20; 20-150

As a result of the explosions conducted in the rock salt massif, 9 relatively resistant cavities of different volumes (from 10,000–240,000 m³) were formed over a period of 3 decades (Figures 2 and 3). All the explosions were projected as having been fully confined i.e. without radioactive products reaching the surface. However, this was not achieved, as shown by the data of radioactive discharge duration (having become the reason for the test site contamination) from cavities over a period of some days up to months and of its total activities up to 10¹⁸ Bq. Site contamination also occurred as a result of some technological operations related to the opening of the cavity by means of additional boreholes, as well as radioactive gases with activity up to 10⁷ Ci [4] that were injected into the atmosphere. Radioactive spots at the site were the source of secondary



radioactive contamination of the environment (radionuclide transfer by way of wind and atmospheric fallout) and radiation risk to the public. Therefore the problem of the clearance of contaminated land was considered as current in terms of sanitary and ecological aspects.

Table 2: Peaceful nuclear explosions in Kazakhstan.

Date, years	Place (oblast)	Condition	Amount of explosions
1966-1979	Guryev	Construction of underground tanks of large volume in rock salt massif (A-1 – A-XI)	17
1969-1970	Mangyshlak	Development of commercial explosion technology. T-1, T-2, T-3 boreholes	3
1965-1974	Semipalatinsk Test Site	Experimental works on NET development in behalf of the national economy	7
1972	Ural	Depth seismic “Region” sounding, P-5 borehole	1
1972	Kustanai	Depth seismic “Region” sounding, P-5 borehole	1
1973	Turgai	Depth seismic “Meridian” sounding, MN-1 borehole	1
1973	Shymkent	Depth seismic “Meridian” sounding, MN-2, MN-3 borehole	2
1983-1984	Ural	Construction of underground cavities “Lira” - 1÷6	6
1987	Aktyubinsk	Development of nuclear explosion technology “Batolit”, BT-2 borehole	1
TOTAL			39

Research and practical measures regarding the removal of radioactive contamination at the test site were carried out according to the following activities: mapping of the contaminated area, determination of radionuclide concentration in the soil, location and arrangement of radioactive soil disposal, cleansing of the area from radioactive contamination, transfer and burying of contaminated soil, dosimetry and determination of soil specific activity at the contaminated site, refilling of excavation with pure soil, estimation of mass and total activity of removed soil.

Radionuclide concentrations, especially Cs-137, as the concentration of other radionuclides were comparatively low (at the level of natural background and global fallout), allowed to subsume excavated soil (with maximal specific activity up to 9 000 Bq/kg) to the category of low-level radioactive wastes with established intervention level 10^4 Bq/kg and more by Radiation Safety Standards in Kazakhstan. Under this approach specified soil just had to be removed to a nearby ground disposal location at a depth of 10 m.



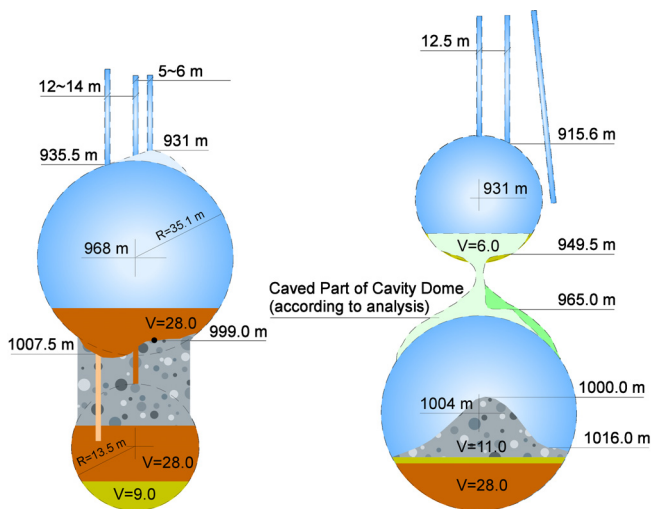


Figure 2: Cavity scheme A-VII and A-VIII.

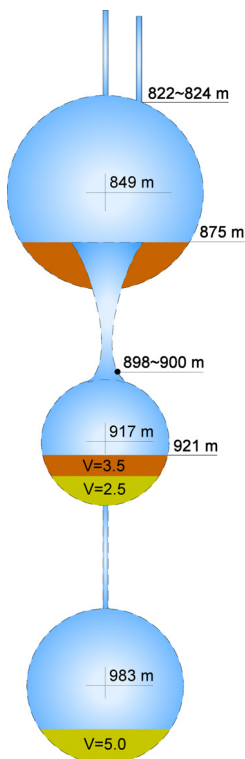


Figure 3: Cavity scheme at site A-XI.

2 Natural characteristics of AZGIR test site range

Geographical features of the region are its relative closeness to the Volga River and the Caspian Sea. The described area is situated in the north-west of the Caspian Sea lowlands. The test site is placed in semi-desert area on a sandy edge in a large basin with a size of approximately $15\text{km} \times 20\text{km}$. In geomorphological relation, the region is presented by a series of sand massifs divided by loamy plains. The basin bottom, where the test site is located, consists of clay and heavy loams alternating in some places by low-powered deposits of sand. Atmospheric fallout is accumulated in low relief, these reservoirs are completely dry from June to September. Ground waters underlie depending upon the season, the relief and geological structure at a depth of 0.1–16m from the surface. Soil cover of the territory is brown desert and salt soil. There is a definite differentiation on the genetic horizons: humus, carbonate, salt are characteristic of a brown soil profile. The thickness of the soil layer at the described area is insignificant (2–6 cm). The region's climate is strongly continental, arid; it is formed under the predominant influence of arctic, Iranian and Turan air mass. The average annual fallout is more than 200mm. The average annual air temperature is 7.3°C . North (Summer) and East (Winter) parts steady wind at a speed of 15–20m/s and more are characterized for the region.

3 Characteristic of radioactive contaminated areas at the site

Site radiation control was carried out by a detailed method through ground survey on a grid $10\text{m} \times 10\text{m}$ (orthogonally related directions with distances in 10m between them). At the surface of A-I, A-II, A-III, A-V and A-X sites radioactive contaminated $0.4\text{--}0.6\text{ m}^2$ areas (spots) are defined. These are the potential source of the second environment pollution. More contaminated sites are A-II and A-X, as by site quantity so by value of exposure (equivalent) dose rate (EDR), Figure 4. A-I, A-II, A-III, A-V and A-X sites in total amount of 200 spots are related to removal.

Soil samples selected from these spots were analyzed using alpha, beta and gamma-spectrometry methods. The following artificial radionuclides with specific activity: Am-241 up to 5.0 Bq/kg, Cs-137 up to 9 000 Bq/kg, Sr-90 up to 17 Bq/kg, Pu-239+240 up to 2.0 Bq/kg were identified; under the Radiation Safety Standards of Kazakhstan, these soils are not related to the radioactive waste category but to disposal at general industrial waste storage. In addition, Cs-137 content soil can determine the overrunning of the maximum permissible public dose because its specific activity is close to the criterion for radioactive waste (10^4 Bq/kg).

For the study of Cs-137 with soil particles degree of association the experiments on its leachability were carried out. Experiment results showed that no less than 95% Cs-137 was in linked form, which is not leachable with ammonium-acetated buffered solution [5].



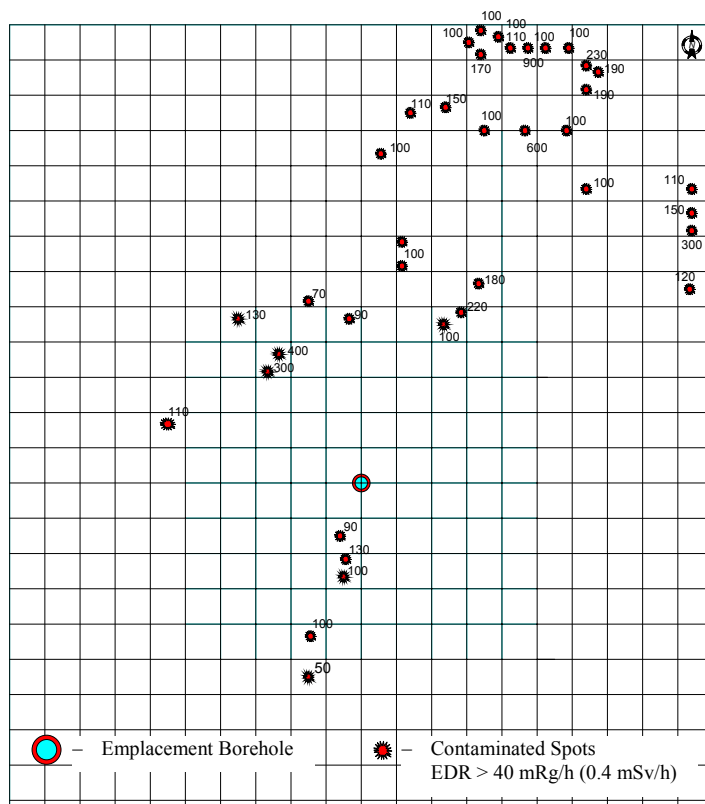


Figure 4: Radiation background at A-X site.

Even under infiltration waters, entry into the storage Cs-137 will not be leached by ground waters that exclude its further migration in solely unfavorable conditions.

Spots scheduled for elimination were located at topsoil. The total spot area does not exceed 90m^2 . These are formed during the process of cavity opening, under radioactive ground recovering, sampling of salt solution and different technological operations execution. The organization operating the test site (Russia) temporarily placed all the mentioned contaminations in a trench within the site and buried it in cavities A-III and A-X [6]. Analyses of layer-by-layer samples from local spots showed that basic activity was focused in the upper 10–15cm layer. Besides, maximal concentrations are defined in soil layer 5–10 cm, in comparison with 0–5 cm layer, from which the part of radionuclides was brought into the environment by the wind as well as the part that was washed by rain and melt waters. However, it is not possible to exclude the presence of radioactivity in more deep layers as excavation and re-disposal from the trench into cavity were carried out without proper quality controls. Consequently, soil cover was technologically damaged.

4 Elimination of hot spots

The sample of radioactive soil was drawn by 5 cm layers at the bottom of the excavation at a level of 30 micro-roentgens per hour before the moment of fixing. In cases when EDR values were neither decreasing nor increasing, the soil sample ceased at a depth where the backfilling with clean soil with the 10cm half-value layer made it possible to obtain EDR values in 30 micro-roentgens per hour on the daylight surface (Figure 5).



Figure 5: Dosimetry of pits.

Selected contaminated soil was intensively intermixed in special pans and then placed in a plastic sack. EDR was determined at the surface of each sack. Composited samples with high EDR were selected from the sack in order to determine the specific activity of Cs-137. Sacks were marked and data on the site index, position coordinates of soil sorting, EDR at the surface of sacks, volume and weight of soil from each radioactive spot was entered into the special log. Soil samples were transferred to the Institute of Nuclear Physics (Almaty city) where Cs-137 content was determined under laboratory conditions by means of gamma-ray spectrometry.

Sacks with contaminated soil were tightly placed in a burial trench of the following size: (width \times depth \times length): 1m \times 3m \times 6m. After placing all sacks, the exposure dose rate was measured on the ground level under the open storage and also at the surface of all packed sacks. The trench was backfilled with clean soil which was excavated during the preparation of the storage, the thickness of the layer was about 1m so that the Exposure Dose Rate (EDR) would not exceed 30 micro-roentgens per hour on the daylight surface. The trench coating was tamped and did not exceed 0.5m from the daylight surface.

Reference pegs were located in storage nooks for switching of these points in plan of regular monitoring. After samples of radioactive soil and its disposal, newly formed excavations were filled with clean soil that was excavated from the trench and imported additionally. The backfilled soil did not exceed the relief of the site within limits of 10cm. The results of EDR measurement showed that

the radiation situation in sites which had spots of radioactive contamination had significantly improved after taking some action on the decontamination of areas of sites. Values of EDR amounted to 900 micro-roentgens per hour before room works and they were between 20 to 30 micro-roentgens per hour after room works (Table 3).



Figure 6: Depositing of radioactive soil in trench storage.

Table 3: Dosimetry in A-X site after cleansing, EDR (*mR/h*).

before elimination		after elimination		before elimination		after elimination		before elimination		after elimination	
April		July	August	April		July	August	April		July	August
No of points	EDR	EDR	EDR	No of points	EDR	EDR	EDR	No of points	EDR	EDR	EDR
1	100	25	25	9	400	30	30	17	150	31	30
2	270	30	30	10	110	30	30	18	150	25	25
3	280	25	30	11	100	31	30	19	120	30	26
4	110	25	27	12	150	30	30	20	900	23	25
5	170	30	30	13	130	32	32	21	100	27	24
6	190	30	32	14	200	33	32	22	110	30	28
7	110	30	30	15	170	30	31	23	100	23	25
8	160	30	32	16	150	29	28	24	110	24	24

5 Conclusion

The total weight of the excavated radioactive soil was 5060kg. The average concentration and total activity of Cs-137 in the removed soil was 5000Bq/kg and 3×10⁷Bq. The research carried out and the engineering works on decontamination and the removal of radioactive contamination from the area of the Azgir test site made it possible to for the radiological situation at the test site and in surrounding areas to be improved. After performing the abandonment



operations, danger to personnel and population from radiation doses which were previously over the safe rating values for radioactive soil contamination were excluded.

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