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SHORT COMMUNICATION

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The Semipalatinsk nuclear test site: a first assessment of the radiological situation and the test-related radiation doses in the surrounding territories

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Abstract As a result of atmospheric nuclear tests at the Semipalatinsk test site 'Polygon', adjacent territories were contaminated by radionuclide fallout. The population of some districts in the Semipalatinsk oblast were exposed to elevated levels of radiation. Contamination and exposure mostly resulted from early atmospheric tests. The radiological situation of the Semipalatinsk oblast is described. Effective dose estimates due to external and internal exposure attributable to the 1949 and 1953 tests in villages near the Polygon range from 70 mSv to 4470 mSv.

Introduction

Within the scope of the Soviet nuclear program, 498 nuclear tests[1] of military and civil purpose were conducted at the Semipalatinsk Test Site (STS), located in the northeast of the Republic of Kazakhstan. The population of the Semipalatinsk oblast, which is defined as the administrative region, numbers 811,000 people; the oblast capital is Semipalatinsk City with 400,000 inhabitants.

In 1949, the STS was created as a large testing ground of 19,000 km^2 located about 150 km west of Semipalatinsk City. The test ground in the northwestern part of the Semipalatinsk oblast also covers parts of the Pavlodar and Karaganda regions (see Fig. 2).

A total of 118 atmospheric nuclear and thermonuclear explosions were performed before 1962, 26 of them near the ground. From 1965 to 1989, 370 underground nuclear explosions were carried out. Despite the first international ban on atmospheric nuclear tests in 1963, two additional atmospheric tests with deliberate soil excavation were conducted in 1965.

On February 12, 1989, the last underground nuclear explosion at STS took place. This explosion led to an abrupt increase of the radiation levels in, e.g., Chagan village, about 100 km east of the Polygon. On February 13, the level was 200 times above usual values due to a leakage of the radioactive noble gases xenon and krypton. The impact of this nuclear test stimulated the public's efforts for prohibition of nuclear testing near Semipalatinsk. Later in 1989, the government of Kazakhstan issued the edict prohibiting nuclear tests at STS (see Fig. 1).

The nuclear tests resulted in considerable radioactive contamination of large territories, and the most intensive fallout of radionuclides was registered in the Semipalatinsk oblast. Based on this short and introductory first paper, we will subsequently report on the health situation, e.g., cancer incidence and mortality relating to the affected area.

Radiation dosimetry

During the whole period of nuclear testing, the radiation doses to the population in the territories adjacent to STS were checked by the USSR Department of Defense without any alternative monitoring by federal or local institutions involved in public health. In 1957, a secret medical institution specialized in oncology was established, called 'Dispensary No 4'. In addition to the usual clinical and biomedical activities, radiation dosimetry was done by its staff until 1991. During almost 20 years, only the parameters of the two most important atmospheric explosions in 1949 and 1953 were used to assess the exposure, and calculations were carried out according to the methodology of the Department of Defense.

In 1991, as a successor to Dispensary No. 4, the Scientific Research Institute for Radiation Medicine and Ecology was established and inherited the formerly top secret health archives.

[1] The numbers given differ slightly from the official statements by the Ministry of Defense of the Russian Federation, since unsuccessful explosions (which led to contamination though) were taken into account by us. According to the official report by the Russian Ministry of Defense, a total of 456 nuclear tests were performed at the STS.

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Table 1 Estimates of mean doses from external γ-radiation to individuals in the villages of Dolon, Cheremushky, and Mostik, at different times after explosion (first test on August 29,1949)

	External radiation doses (mSv)					
Time after explosion:	1 day	7 days	30 days	90 days	365 days	Accumulated dose
Dose without shielding	810	1300	1600	1700	1900	2000
Dose with shielding	600	960	1200	1300	1400	1600

Table 2 Estimates of mean equivalent doses to individuals for specified organs from radionuclide intake with food and water, in Dolon, Cheremushky, and Mostik, at different times after explosion (first test on Aug. 29, 1949)

	Organ doses from internal radiation (mSv)				
Time after explosion:	7 days	30 days	90 days	365 days	50 years
Thyroid gland:					
adults	620	1100	1300	1300	1300
infants, children	3100–6200	5500–11 000	6500–13 000	6500–13 000	6500–13 000
Digestive tract	70	80	110	130	130
Bone marrow	30	50	70	90	90

Current radiological monitoring

The Division of Radioecology, which is part of the Institute for Radiation Medicine and Ecology, has been conducting radiation measurements and radiochemical analyses in the Semipalatinsk region since 1991. Soil, water, and vegetation samples as well as food samples (meat, milk, animal bones, vegetables, bread, etc.) have been analyzed every 3 months, and natural and artificial radionuclides have been identified.

Germanium detectors with a 10-cm lead shielding and multichannel analyzers are used for γ-spectrometry, which permits detection of the radionuclides ^{239}Pu, ^{241}Pu, ^{239}Am, ^{152}Eu, ^{154}Eu, and transuranic elements.

Radiochemical investigations of ^{137}Cs and ^{90}Sr are carried out as well as γ-ray surveys with the help of DR5-OIT dosimeters to assess exposures. Radionuclide depth migrations have been analyzed in soil samples from defined locations. Flux densities of α- and β-particles have been determined by MKS-OI radiometers. A database has been established, and external and internal doses have been calculated.

Atmospheric nuclear tests and radiation doses to the population

First USSR nuclear test in 1949

On August 29, 1949, at 7:00 a.m., the first nuclear test in the USSR was carried out at STS. The explosion occurred at an altitude of 30 m above ground (or „on the table", a phrase used by the military) with an energy release of 22 000 metric tons of TNT (trinitrotoluene). The wind velocity at test time was 45–50 km/h, and within 2 h a radioactive cloud reached densely populated areas inside a 100-km radius from the hypocentre. Due to the resulting radioactive fallout, the initial dose rates at ground level in some populated areas exceeded the natural level by millions of times. Territories located up to a distance of 2000 km from the explosion hypocentre were affected by the radioactive fallout. About 500 000 people were exposed to considerable doses of ionizing radiation. No radiation safety measures (e.g., evacuation or remedial measures) were taken, since the tests were conducted under top secret conditions.

Table 1 shows the external γ- and x-ray doses to individuals in some villages northwest of the test site (Dolon, Mostik, Cheremushky). Due to the predominance of short-lived radionuclides for near-site effects from atmospheric explosions, the population received 64% of the total (accumulated) dose during the first week and about 85% during the first 3 months following the explosion.

Table 2 shows the individuals' internal equivalent doses for specified organs, related to radionuclide intake with food and water. The thyroid doses due to iodine intake were highly significant especially for children.

Hydrogen bomb test in 1953

Four years later, on August 12, 1953, the first USSR hydrogen bomb test was performed at an altitude of 1000 m and with a yield of 470 000 metric tons of TNT, the wind velocity at that time being 80–85 km/h. The weather conditions – strong wind, low cloudiness, and rain – intensified the radiological risk to the population. By 1.2 h after the explosion, the cumulated exposure reached 1800 R in the village Tailan, which is located 100 km distant from the explosion hypocentre and 70 km from Sarzhal (situated on the eastern border of the Polygon) and which was evacuated prior to the hydrogen bomb test.

Table 3 Estimates of mean doses from external γ-radiation to individuals of some populated areas in the Abaisky district, at different times after explosion (hydrogen bomb test on Aug. 12, 1953)

	External radiation doses (mSv)					
Time after explosion:	1 day	7 days	30 days	90 days	365 days	Accumulated dose
Dose without shielding	10	80	230	430	540	
Doese with shielding	6	60	170	320	400	420

Table 4 Estimates of mean equivalent doses to individuals from intake of radionuclide with food and water, in Abaisky District, at different times after explosion (hydrogen bomb test on August 12, 1953)

	Organ doses from internal radiation (mSv)				
Time after explosion:	7 days	30 days	90 days	365 days	50 years
Thyroid gland:					
adults	20	130	180	180	180
infants, children	100–200	650–1300	900–1800	900–1800	
Digestive tract	10	30	50	70	70
Bone marrow	1	10	10	10	10

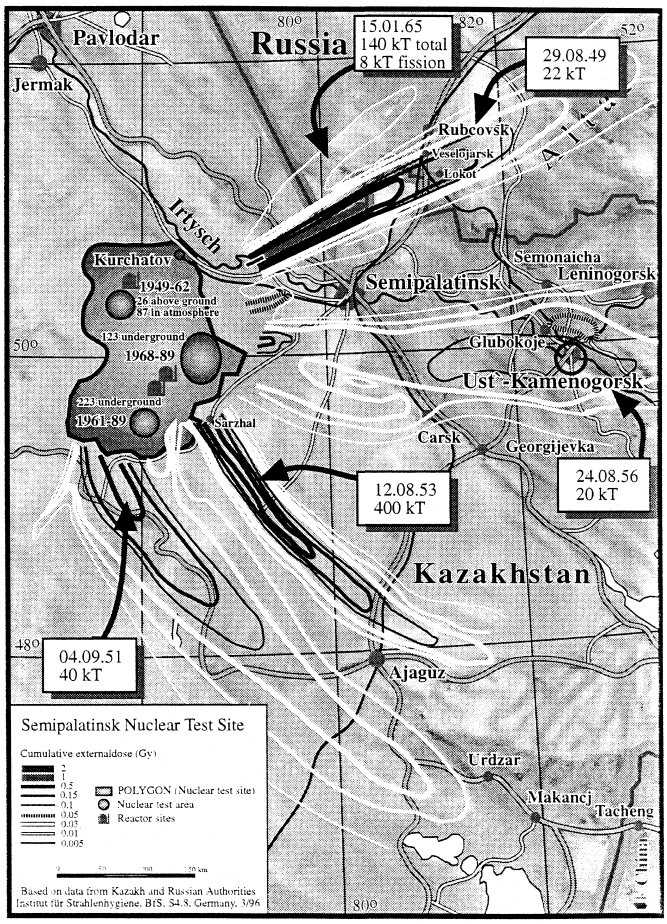

Fig. 1 Provisional map of fallout trails from atmospheric and ground tests on the Polygon test site near Semipalatinsk. *Isodose lines* give estimated cumulative unshielded external doses on the ground

The doses of external and internal exposures are presented in Tables 3 and 4. The major proportion of the dose due to external exposure was received during the first year.

Radiation risk zones

During the whole period of nuclear tests at STS, i.e., from 1949 to 1989, the population of the Semipalatinsk region has been exposed to ionizing radiation. Some 6 surface and 15 underground explosions are considered responsible for their high exposure. However, the most critical dose contributions resulted mainly from the following four surface tests: on Aug. 29, 1949 (22 000 tons of TNT), Sept. 24, 1951 (38 000 tons of TNT), Aug. 12, 1953 (470 000 tons of TNT) and Aug. 24, 1956 (26 500 tons of TNT). Based on an analysis of our data, these explosions caused 85% of the collective effective dose (Fig. 1).

Most of the tests were conducted in the respective late summer harvest seasons, with almost the entire adult population of the rural areas working in the fields. The external exposure for this part of the population can, therefore, be considered almost equal to the dose in free air.

According to the doses received by the population, four different zones of radiation risk have been distinguished (Fig. 2):

- Zone 1 with extremely high effective doses (more than 1000 mSv: e.g., 4470 mSv in Dolon, 2460 mSv in Sarzhal, 2250 mSv in Cheremushky and Mostik, 1790 mSv in Kanonerka); the territories of zone 1 are located within zone 2
- Zone 2 with effective doses ranging from 350 to 1000 mSv (e.g., 880 mSv in Karaul, 680 mSv in Kainar, 620 mSv in Znamenka)

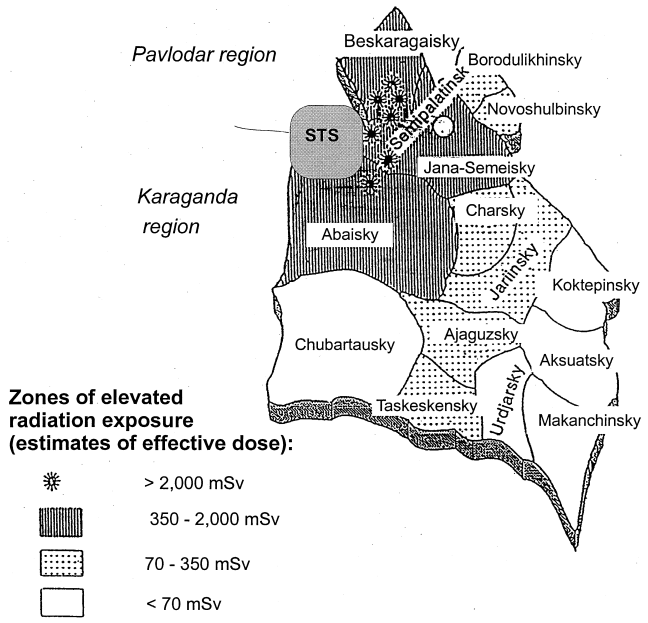

Fig. 2 Zones of elevated radiation in the Semipalatinsk oblast

• Zone 3 with elevated effective doses from 70 to 340 mSv (Chubartausky, Novoshulbinsky, Borodulikhinsky, Charsky, Zharminsky, Ayaguzky districts, and Semipalatinsk City)
• Zone 4 with effective doses of less than 70 mSv (Makanchinsky, Urdjarsky, Taskeskensky, Kokpektinsky, and Aksuatsky districts).

These zones will be used for analyses and comparisons in our upcoming reports on the health assessment in the affected areas.

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