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Radiological States around the Kraton-4 Underground Nuclear Explosion Site in Sakha

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A radiological survey around the site of Kraton-4, an underground nuclear explosion (Yield of 20 kt, depth of 560 m, 1978) in Sakha was carried out in March 1998. Gamma survey and in-situ spectroscopy on the ground exhibited quite normal levels: a dose rate of 0.022 μSv/h and Cs-137 surface contamination of less than 1.1 kBq/m^2 around the hypocenter. The results suggested no remarkable leakage of radioactivity from the epicenter to the ground surface at least not for non-rare gas elements as of 1998.

Twelve underground nuclear explosions (UNEs) with industrial applications were conducted in the Sakha republic of the Russian Federation between 1974 and 1987. Figure 1 shows a schematic time-table of the UNEs with information of output in kilotons and underground depth, taken from Yakimets (1996)[1)]. Most of the UNEs were carried out at a depth of 500 to 1500 m. The maximum yield was 20 kt. Four UNEs were conducted for a geological study of deep seismic waves of the earth crust, six UNEs to intensify oil recovery and gas inflow, one UNE to obtain underground crude oil, and one UNE (named Crystal) for the building of a dam for the storage of waste after the extraction of useful components from ore. However two UNEs, Crystal (2 kt, –100 m, 1974) and Kraton-3 (20 kt, –525 m, 1978) failed, with radioactive releases to the environment. The government made some countermeasures. A

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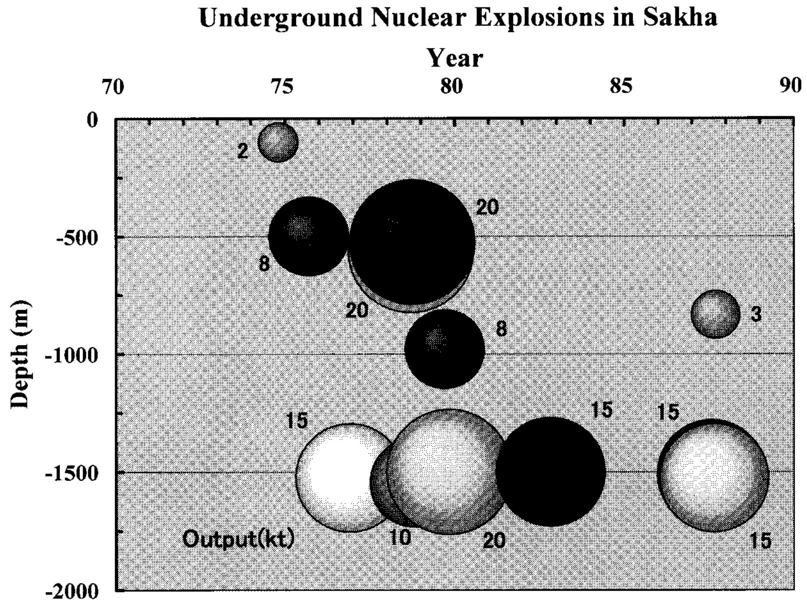

Fig. 1. Twelve underground nuclear explosions in Sakha republic from 1974 to 1987. Data of the UNEs are taken from Yakimets (1996)[1]. The radius of the balloon is proportional to the output of the explosion.

sanitary zone with a rocky embankment 15 m high and 150 m in diameter was formed over the explosion site of Crystal in 1992[2]. The ground surface 500 m^2 around K-3 was recultivated and covered with clean soil in 1990. The Institute of Radiation Hygiene carried out field investigations on the two sites in autumn 1996, and reported severe radioactive contamination and doses[2,3]. In March 1998 we conducted a radiological survey (gamma-survey and in-situ spectroscopy in the field and for local foodstuffs) of the Kraton-4 (K-4) area in response to requests from The Ministry of Nature Protection of the Sakha Republic made to Japan (The Japan-Russia Trade Association and The Nippon Foundation).

The K-4 explosion with an output of 20 kt proceeded without accident at a depth of 560 m on August 9, 1978. However, as a result of the explosion, multiple cracks in the ground surface appeared, three new islands emerged in nearby Lake Nijili, and water and sand banks appeared at a radius of 500–600 m from the bare hole[1]. A rise in the water level of the lake resulted in a shoreline shift of 8–10 m.

The surface contamination due to a deep UNE is not well known since nuclear test sites always include ground and atmospheric explosions resulting in radioactive contamination of the ground surface[4–6]. Nuclear explosions in Sakha were done generally underground. The K-4 site is more than 200 km from the other UNE sites, making it suitable for the study of leakage of radioactivity from the epicenter to the ground surface.

The environmental radiation dose was measured in the present study by using a pocket survey meter (Aloka PDR-101) in which a CsI(Tl) (20 × 25 × 15 mm) detector is installed. The range is 0.001 ~ 19.99 μSv/h. With this meter, the environmental dose rate was measured with an error of 15%. The in-situ measurement of gamma ray spectra was carried out to detect Cs-137 contamination on the ground surface and in local foodstuffs by using a portable NaI spectrometer (Hamamatsu C-3475) which has an NaI scintillator (2.5 cm$\phi \times$5.1 cm) and a multi-channel analyzer with 128 channels. The surface density of Cs-137 activity on the ground was calculated with a converting constant from the counting rate to surface density of Cs-137 which was calibrated to contaminated territory near Chernobyl[7]. Moreover the detector which had been calibrated for whole-body counting of Cs-137 was applied for detection of activity in a piece of raw meat.

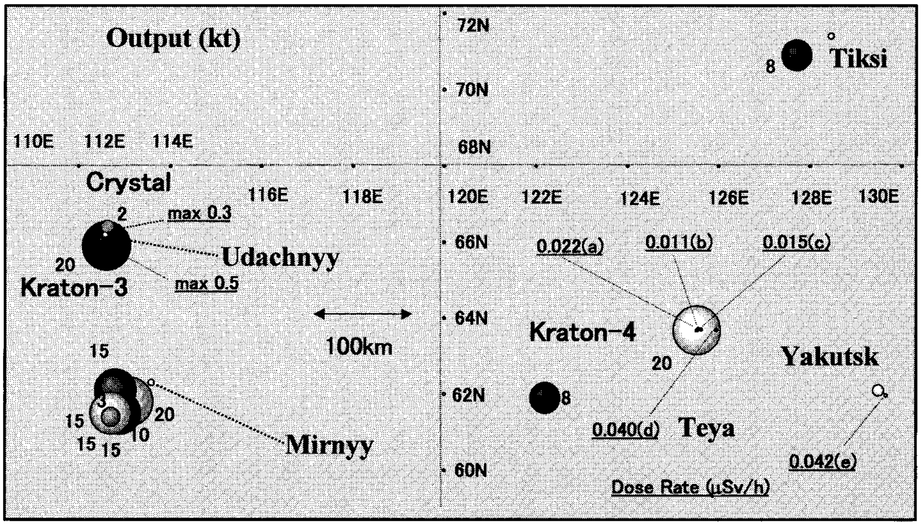

Fig. 2. Results of dose rate measurements made around K-4 and other sites are shown in a map with coordinates (E, N). Coordinates: (a) Hypocenter; 63.68N, 125.53E, (b) On iced Lake Dukayan; 63.71N, 125.56E, (c) Near Lake Dukayan; 63.70N, 125.62E, (d) Teya village; 63.69N, 125.96E, (e) Yakutsk; 61.96N, 129.66E. The values of 0.011 and 0.015 μSv/h were taken on iced Lake Dukayan and at 100m from the lakeside. The lake is 4km from the epicenter of K-4. The data for Crystal and K-3 in 1996 are from Miretsky et al (1997)[2].

Figure 2 shows the map of K-4 and other UNE test sites together with radiation dose rates measured at 5 different places, (a) K-4 hypocenter, (b) in the middle of Lake Dukayan which is about 4 km from the hypocenter, (c) a place on the ground 100 m from the shore of Lake Dukayan, (d) Teya village 21 km from the hypocenter and (e) Yakutsk 280 km from the hypocenter. The dose rate at each place is expressed as an average of those measured at 3 points within 10 m. The dose rate at the K-4 hypocenter (0.022 μSv/h) was much lower than that at Teya village, and more than 10 times lower than those at Crystal and Kraton-3 hypocenters reported by Miretsky et al[2]. The low dose rate for iced Lake Dukayan suggested little radioactive contamination of the water. Therefore, the dose rates at these 5 places as determined by the present measurements were in the normal range.

This was confirmed by measuring the environmental dose rates just around the K-4 hypocenter. Figure 3 shows dose rate as a function of distance from the hypocenter of K-4.

Although the ground surface was covered with snow of about 40 cm thickness, the measured dose rates were very low; ranging from 0.014 to 0.028 μSv/h comparing with natural background values in other countries such as Japan and Kazakhstan[5]. The mean value around the hypocenter was 0.022 ± 0.004 μSv/h for 9 spots within a 1 km range. We did not observe a high level of radiation around the hypocenter.

Figure 4 shows the results of in-situ measurements of gamma ray spectra at the K-4 hypocenter, Lake Dukayan and Yakutsk. The spectrum at the K-4 hypocenter did not show any remarkable gamma ray peak from fission products such as Cs-137 with a half-life of 30 y. The effective surface contamination of Cs-137 at the hypocenter was estimated to be less than the detectable limit of 1.1 kBq/m^2, which makes a marked contrast to that reported at the K-3 hypocenter (Cs-137: 82 kBq/m^2 and Pu-239, 240: 4.3 kBq/m^2)[2]. Since reported values of Cs-137 contamination due to nuclear tests world-wide are in the range of 2.7–4.6 kBq/m^2 in areas located between 50 and 70 degrees of north latitude[2], we concluded that the amount of Cs-137 surface contamination above the K-4 epicenter was normal, at least when measurements were done in March 1998.

Spectroscopy was done on elk flesh (15 kg in weight) as a local foodstuff of Teya village. The elk, which is a herbivorous animal, eats water grass, tree bark and lichen. Therefore this measurement would reflect radioactive transfer among soil, plant and animal[9]. However the spectrum did not show a peak of Cs-137 gamma ray for 25 min. This indicates that Cs-137 contamination of the flesh was less than the detectable limit of 20 Bq/kg. This result also supports a low level of Cs-137 contamination on the ground around the K-4 hypocenter.

The present results of the radiological survey around the K-4 hypocenter confirmed that the surface of the ground was normal in 1998. In other words, the data suggested that there

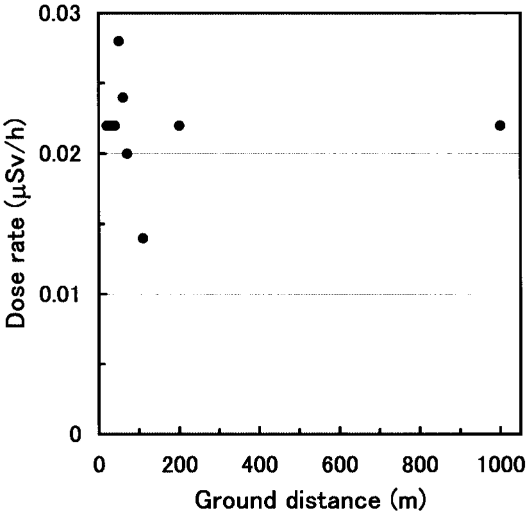

Fig. 3. Dose rate as a function of distance from the hypocenter of K-4 in March 1998. The ground surface was covered with snow 40 cm thick.

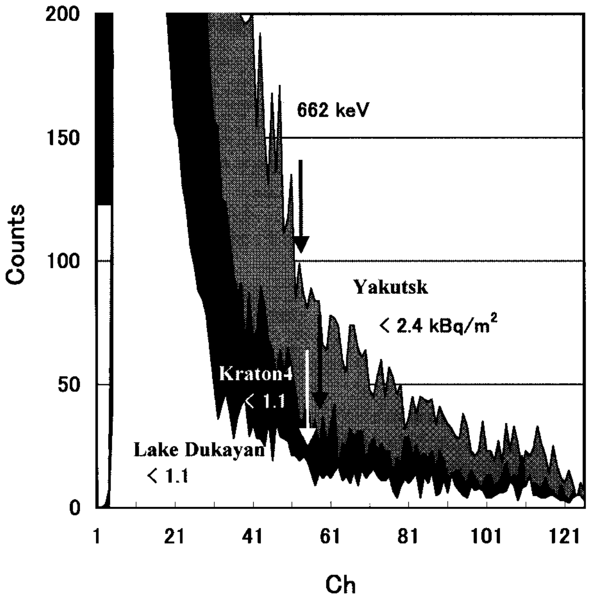

Fig. 4. In-situ gamma ray spectra around K-4 and in Yakutsk City for 30 ~ 60 min. The spectrum for Lake Dukayan was taken 100 m from the lakeside. Cs-137 contamination of the ground surface was below the detectable limits, which are shown in the figure.

had been no remarkable leakage of radioactivity from the epicenter (560 m in depth) to the surface at least for non-rare gas elements as of 1998. The plutonium, fission products and induced radioactivity due to the explosion are likely stored in perennially frozen rocks with a thickness of more than 500 m in this area[10].

In summary, a radiological survey around the hypocenter of K-4 (Yield of 20 kt, depth of 560 m, 1978), an underground nuclear explosion, and at the nearest settlement in Sakha was carried out in March 1998. The results of gamma survey and in-situ spectroscopy on the ground surface and on elk flesh were quite normal, indicating no remarkable amount of radioactivity on the ground surface in 1998.

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