Statens strålevern
Norwegian Radiation Protection Authority

NRPABulletin 8•07

The Kyshtym accident, 29th September 1957

The Kyshtym accident on the 29th of September 1957 resulted in the contamination of a large area of land with radioactive materials and, along with the Windscale accident a short time later, constitutes one of the first major accidents at a nuclear facility involving dispersal of radioactivity to the wider environment. Large areas with agriculture and rural settlements were contaminated to a high degree necessitating the development and implementation of various countermeasures to mitigate the consequences of the accident.

Figure 1. Mayak Production Association location map

Background to the accident

Kyshtym, located in the Chelyabinsk Oblast of Russia, near the southern Ural Mountains, is a small town that lies some ninety kilometres from Chelyabinsk. The town lies near the Mayak Production Association (Fig. 1) which served as the location for the emerging Soviet nuclear program in the years immediately following World War II. Then known as Chelyabinsk 40, the facility produced plutonium for Soviet nuclear weapons from 1948 onwards and activities at the facility have resulted in significant contamination problems for both the surrounding area and more distant regions due to long range transport of the radioactive contamination via river systems. In the early to mid 1950's, waste repositories for radioactive materials generated at the Mayak site were developed. High level radioactive waste was stored in composite steel-concrete tanks at the Mayak site under cooling conditions for periods of approximately 1 year.

Summary of the accident

On the 29th September the cooling systems of one of the waste storage tanks failed and the temperature began to rise inside the tank. Evaporation of the cooling liquid in the tank and the rise in temperature of the 70 to 80 tonnes of radioactive waste present resulted in a chemical explosion within the tank at around 4:20 pm in the afternoon, which later became known as the Kyshtym accident. This explosion resulted in a considerable loss of the tank's integrity and the ejection of radioactive material into the surrounding environment. The resultant aerosol plume attained an altitude of some 1000 m and resulted in wide ranging dispersal of the ejected material. Approximately 90% of the 740 PBq of mixed fission products released (see Table 1) were deposited as particulate material within 5 km of the tank whilst the remaining 74 PBq of radioactive material was deposited as dry fallout over an area some 30-50 km in width and some 300 km in length stretching north-north east of the Mayak facility (see Figure 2).

Isotope	Released Activity – Outside the Mayak Boundary (PBq)
$^{90}Sr + ^{90}Y$	4.0
$^{95}Zr + ^{95}Nb$	18.4
$^{106}Ru + ^{106}Rh$	2.7
^{137}Cs	0.03
$^{144}Ce + ^{144}Pr$	48.8
Pu-isotopes	trace amounts

Table 1. Radionuclide composition of the material released in the Kyshtym accident outside the Mayak boundaries (JNREG, 1997).

Aftermath of the accident

Some 15,000 to 20,000 km^2 received contamination levels higher than 3.7 kBq/m^2 of ^{90}Sr. A contamination density of 74 kBq/m^2 of ^{90}Sr was established as the intervention level for evacuation of the population. This delineated an area of approximately 1000 km^2 that became known as the East Urals Radioactive Trace (EURT). The maximum contamination density was found to be close to the site of the explosion itself and attained levels of 150 MBq/m^2 ^{90}Sr.

A quite rapid decline in levels of radioactivity within the EURT occurred as short lived isotopes decayed away. Within two years, isotopes such as ^{95}Zr, ^{95}Nb and ^{144}Ce had ceased to constitute a significant proportion of the contaminant load and the main isotope of concern was ^{90}Sr due to its relatively long half-life of 28.8 years.

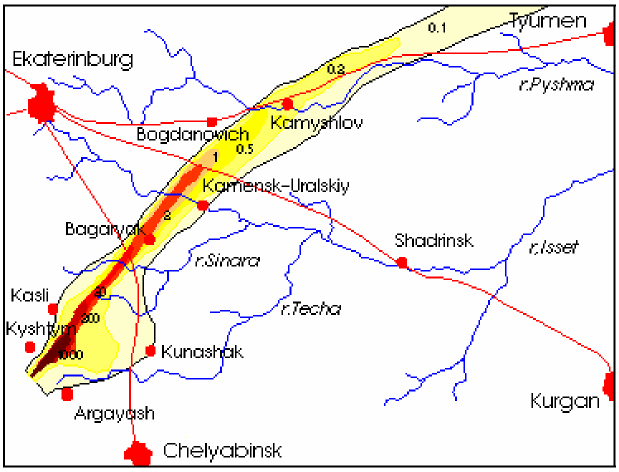

Figure 2: The East Urals Radioactive Trace (EURT): Initial contamination densities of ^{90}Sr (Ci km^{-2}).

At the time of the accident, 63% of the area was used for agricultural purposes, 20% was forested and 23 rural communities existed in the area. These populations were evacuated, amounting to some 10,700 people in total over a 22 month period after the accident. Further utilisation of the area was temporarily banned but in 1961 reclamation of the area was initiated. As of today, some 180 km^2 near the site of the explosion are still officially off-limits.

Immediately after the accident, activity levels in various environmental compartments increased as did levels in agricultural produce. The increases in these products were of the order of 10-1000 in peripheral regions of the EURT and by up to 100,000 near the explosion site itself. After 9-12 days, cases of acute radiation disease were observed in farm animals with a subsequent lethal outcome.

One year after the accident, surface contamination levels had decreased due to radioactive decay but resuspension of contaminated soil particles by wind and rain was observed resulting in the continued contamination of vegetation and agricultural products.

Impacts on the population

In the early phase of the accident aftermath, the external dose to humans from gamma radiation was greater than the dose received internally from ingested radioactivity. Some 270 days after the accident, the external and internal doses had equalised and thereafter the external dose began to decrease relative to the internal. Internal dose was delivered to the gastrointestinal tract via the consumption of contaminated foodstuffs and agricultural products. A radiation dose to bone was also delivered via the incorporation of ^{90}Sr into bone tissue as strontium functions as a chemical analogue to calcium within the body. In the period immediately after the accident, the main pathway for contamination to humans was via bread made from fallout contaminated grain harvested in the area. As time progressed, the soil-plant transfer system became more important and contamination of humans with ^{90}Sr was primarily as a result of ingestion of the isotope in milk, bread and from potable water from small reservoirs.

For the first time in history, food intervention limits were introduced concerning the content of radionuclides (^{90}Sr) in foodstuffs to protect the public from radiation exposure at a dangerous level.

Eight years after the accident, milk continued to be a main pathway for contamination into the human diet, constituting up to 50% of ingested radioactivity. By 1987, the intake of ^{90}Sr to humans had decreased by a factor of 1300 relative to the intake in the period immediately after the accident and by a factor of 200 relative to one year after the accident. Reduction of the levels of contamination in the human diet was due to a combination of

- radioactive decay of contaminants;
- natural environmental processes that reduce the availability of contaminants; and
- implementation of a wide range of countermeasures designed to limit the uptake of contaminants in the food chain and humans.

By 1989-1990, the annual intake of ^{90}Sr was 3% of the maximum permissible level for a person living in a zone that was contaminated with this isotope to a density of 37 kBq/m^2. Over a 30 year residence period in an area contaminated to this level, the committed effective dose amounted to 12 mSv, the equivalent doses to red bone marrow and bone amounting to 25 and 80 mSv, respectively. Doses would have been significantly higher if no countermeasures had been introduced.

Impacts on the environment

The intense radioactive contamination of the EURT territory resulted in a variety of biological effects being observed, primarily in the first 12-18 months after the accident. Exposure during this period was characterised by the presence of short lived beta and gamma emitting isotopes. During subsequent periods the exposure of biological systems to longer lived isotopes such as strontium and yttrium was comparatively low.

The earliest impacts of radiation in pine forests of the area were being observed in 1958 with significant damage to the trees being evident including yellowing of pine needles, defects in tissue development and morphological changes in tissue structures. In areas with contamination greater than 18 MBq/m^2, death of vegetation was evident and such effects were sustained for up to 3-4 years after the accident.

Figure 3. A birch forest in the EURT (picture from the mid 1990s).

Knowledge gained

Whilst the Kyshtym accident was a tragic event on many levels with serious consequences for both the population and the environment, the accident served as an important impetus for a number of initiatives and developments fundamental to our understanding of radioprotection today. The aftermath of the accident witnessed concerted efforts to decontaminate and remediate the affected area and the methods developed to deal with the consequences of the accident are still in use today. Between 1957 and 1959 over 10,000 tonnes of agricultural products were deemed unfit for human consumption and destroyed. Over 6000 hectares of agricultural land were subjected to deep ploughing decontamination, the surface layer of heavily contaminated soil being buried to a depth of over 50 cm, lower than the penetration depth of the roots of many crops. This served to reduce uptake via root systems. In 1958-1959 over 20,000 hectares of the EURT was ploughed to reduce uptake of contamination by plants and to decrease the exposure to gamma radiation. In the Chelyabinsk region, 59,000 hectares of land were removed from agricultural use as were 47,000 hectares in the Sverdlovsk region. As of 1990, the vast majority of this land was back in agricultural production. A range of methods to reduce the transfer of contamination to animals via feed crops were developed and implemented. These included the removal of contaminated soil layers, deep ploughing, the addition of fertilisers and ameliorants designed to reduce the uptake of contaminants, the use of crops which exhibit low uptake of strontium and the addition of nutrient supplements, mainly calcium, to animal feeds to ensure low assimilation of contaminants in body tissues. The implementation of these methods served to reduce uptake in plant species by factors between 5 and 15.

Further reading

Joint Norwegian-Russian Expert Group. Sources contributing to radioactive contamination of the Techa River and areas surrounding the “Mayak” Production Association, Urals, Russia. Østerås, Norway: Norwegian Radiation Protection Authority. 1997.

Trabalka, J.R., Auerbach, S.E. and Eyman, L.D. (1980). Technical Note: The 1957-1958 Soviet nuclear accident in the Urals. Nuclear Safety, 21, 94-9.

Joint Russian-Norwegian Expert Group. A survey of artificial radionuclides in the Kara Sea. Results from the Russian-Norwegian 1992 expedition to the Barents and Kara Seas. Østerås, Norway: Norwegian Radiation Protection Authority, 1993.