Incident

The 1957 Kyshtym disaster

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Summary

The Kyshtym disaster was a radioactive contamination accident that occurred on 29 September 1957 at Mayak, a plutonium production site for nuclear weapons and nuclear fuel reprocessing plant in the Soviet Union. Large quantities of radioactive material were released affecting an area of around 20,000 km², home to approximately 270,000 people. In terms of quantity of radioactivity released, only the Chernobyl and Fukushima disasters were greater in magnitude.

This paper describes the event itself, its causes and consequences, and also considers what knowledge, in particular with regard to emergency planning, has been gained from the accident.

Keywords: Kyshtym, nuclear, plutonium, release

Introduction

The Kyshtym disaster was a radioactive contamination accident that occurred on 29 September 1957 at Mayak, a plutonium production site for nuclear weapons and nuclear fuel reprocessing plant in the Soviet Union. It released large quantities of radioactive material affecting an area of around 20,000 km², home to approximately 270,000 people[1]. The event occurred in the town of Ozyorsk, Chelyabinsk Oblast (see Figure 1), a closed city built around the Mayak plant. Since Ozyorsk/Mayak (named Chelyabinsk-40, then Chelyabinsk-65, until 1994) was not marked on maps, the disaster was named after Kyshtym, the nearest known town. Viewed simply in terms of quantity of radioactivity released, only the Chernobyl and Fukushima disasters were greater in magnitude. On the International Nuclear Event Scale[a], it would be classed as level 6 – a serious accident (Chernobyl and Fukushima both being classed as 7 – the highest level on the scale). Despite this, for many years, details of the accident were, to say the least, very limited. Indeed, the Soviet authorities at the time did their utmost to hide the fact that an accident had happened at all. Vague reports of a catastrophic accident involving massive radioactive fallout began to appear in the western press in 1958, but it was not until Zhores Medvedev, a Soviet dissident, in his book *The Nuclear Disaster in the Urals* (1979)[2], provided the West with the first details of the disaster. It took until 1989 for the Soviet authorities to finally acknowledge that an accident had occurred.

[a] *The International Nuclear and Radiological Event Scale (INES) is a tool for communicating the safety significance of nuclear and radiological events to the public*

Besides describing the event itself, its causes and consequences, this article examines the geo-politcal tensions which existed at the time, namely the rush by the world's superpowers to develop nuclear weapons. It also considers what knowledge has been gained from the accident.

Background

Twelve years prior to the Kyshtym disaster, during the conflict between the US and Japan, many people died as the US detonated atomic bombs in Nagasaki and Hiroshima. The USSR leader, Josef Stalin, realised that the USSR's nuclear program lagged significantly behind that of the US and needed to be accelerated. First, a secret location was needed. A mountainous region in the Urals around 1800 km from Moscow was chosen, and very soon the first-ever plutonium plant was created and named Mayak. Around 40,000 inmates from GULAG, or Axis prisoner of war camps were forced into carrying out its construction. Soon after, six reactors lined Lake Kyzaltash, and because cold war tensions were raised this was done in a hurry and in the utmost secrecy. Almost immediately the plant was producing plutonium, and the first nuclear weapon was detonated in 1949.

The situation which led up to the disaster

Research and information were gathered from Soviet spies working on the Manhattan project. However, despite this, the nuclear industry was in its infancy, and there were serious gaps in understanding of the nuclear safety risks involved. Little thought was given to the issue of nuclear waste, which rapidly caused massive environmental contamination.

Water from the Lake Kyzaltash and Techa River was used to cool the nuclear reactors. The reactors used an open cycle cooling system, where water circulated directly through the reactor core. The highly contaminated water was initially discharged without any treatment back into Lake Kyzaltash and the Techa river, in which children played and was also the main source of drinking water for about 20 villages. The practice of discharging the waste into the Techa river, and Lake Kyzaltash was eventually stopped, and instead dumped into Lake Karachay, soon making it 'the most contaminated spot on earth'.

The accident

By 1953, a storage facility for the highly active liquid nuclear waste was added. This consisted of stainless-steel tanks mounted on a concrete base, 8.2m underground. The accident involved waste which was from the sodium uranyl acetate process used by the early Soviet nuclear industry to recover plutonium from irradiated fuel. The acetate process was a special process which was never used in the West — the idea was to dissolve the fuel in nitric acid, alter the oxidation state of the plutonium, and then

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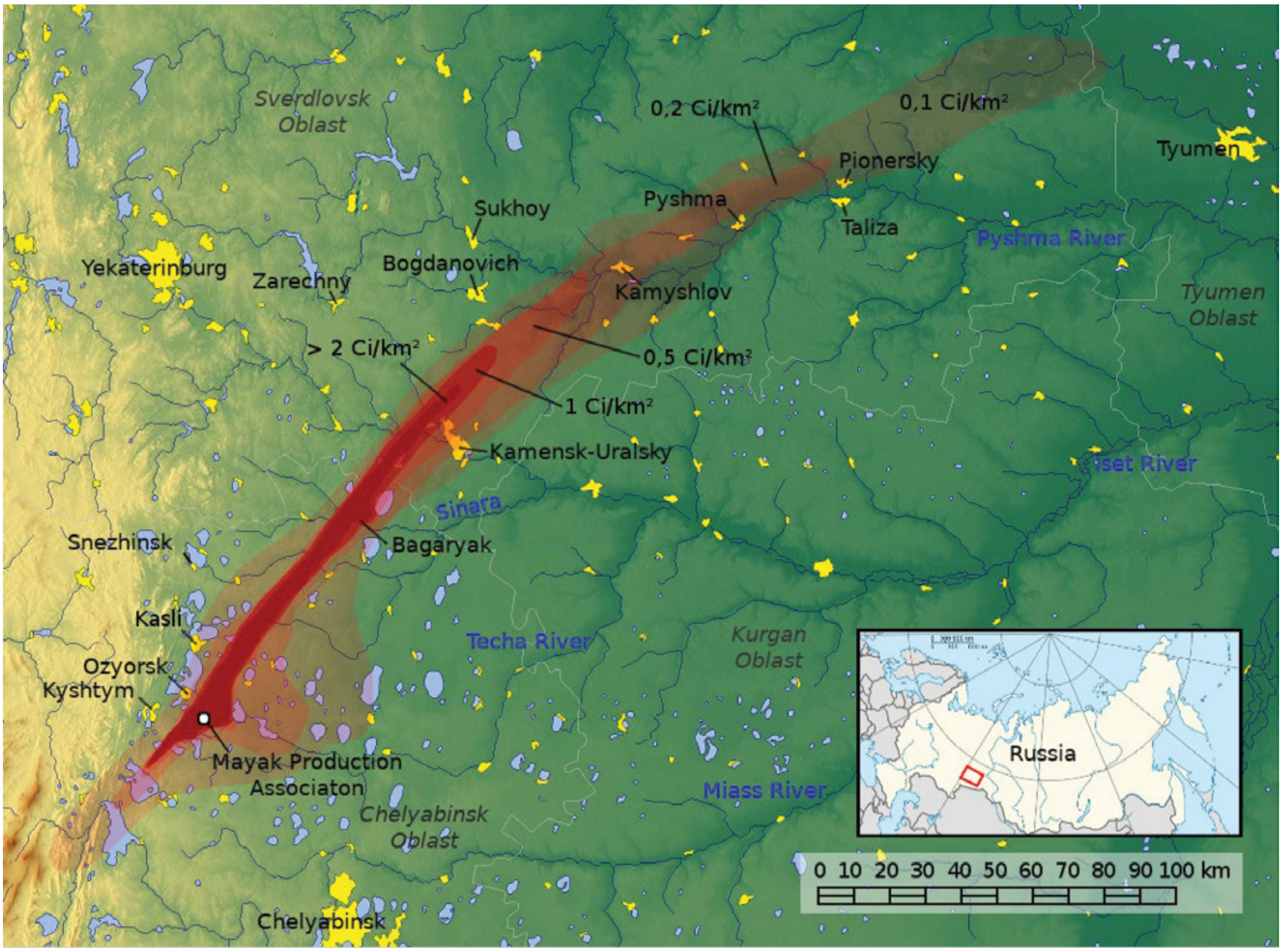

Figure 1 – Location of Mayak nuclear facility

add acetic acid and base. This would convert the uranium and plutonium into a solid acetate salt. The heat generated by the radioactive decay of the high-level nuclear waste stored in the tanks was removed by a water-cooling system. However, the cooling systems was inadequately maintained. A cooling system on one of the tanks, which contained 70-80 tonnes of highly radioactive waste had failed, and had been left unrepaired for a considerable period of time. During this period the temperature of the tank had risen to around 350ºC causing the water in the tank to evaporate, leaving behind a radioactive mix of ammonium nitrate and acetates. On 29 September 1957 the tank exploded with the force of approximately 70-100 tonnes of TNT[3]. The lid of the tank, approximately 160 tonnes of concrete, was blown free. A brick wall was destroyed in a building located 200m from the explosion site.

The workers at Ozyorsk and the Mayak plant did not immediately notice the polluted streets, canteens, shops, schools, and kindergartens. In the first hours after the explosion, radioactive substances were brought into the city on the wheels of cars and buses, as well as on the clothes and shoes of industrial workers. After the blast at the facilities of the chemical plant, dosimetrists noted a sharp increase in the background radiation.

It has been estimated that approximately 20 MCi (800 PBq) of radioactivity was released across the region. Most of this contamination (about 90%) settled out near the site of the accident and contributed to the pollution of the Techa River, but a plume containing 2 MCi (80 PBq) of radionuclides spread out over hundreds of kilometres.

Consequences

Over the next 10-11 hours the radioactive cloud drifted northeast to a distance of 300-350 km, causing widespread contamination. The contamination, consisting predominately of caesium 137 and strontium 90, was spread over an area of 800-20,000 km^2 depending on what contamination level is considered significant. A contamination density of Ci km^{-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). 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.

It was not until a week after the explosion that evacuation of 10,000 local people began. Even then, no reason for the evacuations was given. The evacuations were carried out over a period of nearly two years.

Effects on the population

An assessment of the consequences of the accident was carried out in 2017[3]. Of those people who were involved in the study, no case of acute radiation syndrome was found.[b]

The actual radiological consequences[4] for local inhabitants from

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the disaster is difficult to estimate. This is because their overall exposure is made up of that from the disaster itself, and that from the enormous quantities of radioactive material dumped into the Techa river and Lake Karachay. The populations living along the Techa River were chronically exposed to radiation, both externally and internally. Villagers were exposed via many different pathways, of which potable water from the Techa River was one of the most significant. External irradiation from the Techa River bottom sediments and shoreline was also an important factor. The radionuclides believed to contribute most to the dose commitment are ^{90}Sr and ^{137}Cs. Studies have been carried out in an attempt to determine the overall health effects of residents in the Techa river area and the EURT. It is worth noting, however, that 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.

An epidemiological study in the 1990s showed an increase in the incidence of leukaemia and solid cancers in the exposed population[3]. The number of excess deaths is difficult to determine because the cancer caused by radiation is clinically indistinguishable from other causes, but this study estimated the number of excess deaths to be between 49 and 55.

Environmental effects

The intense radioactive contamination of the EURT territory resulted in a variety of environmental effects being observed, primarily in the first 12-18 months after the accident. 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 5×10^{2}Cikm^{-2}, death of vegetation was evident and such effects were sustained for up to 3-4 years after the accident.

Radiation protection and monitoring

A program of emergency activities to mitigate the consequences of the explosion was approved on 2 October 1957. It included evacuation of the population from the nearest settlements, quality inspection of food products and fodder, and provision of 'clean' products, determination of the ^{90}Sr concentration per unit area and borders of the contaminated territory, and establishment of the Sanitary Protected Zone. Unfortunately, these measures were not taken in due time or to an adequate extent. The residents of three settlements located in closest proximity to the site of the explosion (1100 persons), were evacuated within 7–14 days after the accident, essentially because of high levels of external exposure. From autumn 1957, in the rest of the territory, quality inspection of food products and fodder with partial replacement of contaminated products was started to decrease the absorbed dose from internal exposure sources.

The first schematic map of contamination levels and borders of contaminated territory was obtained after three months (25 January 1958) based on the results of radiological analysis of the contaminated area. In early 1958, a sanitary protection zone (SPZ) was established with a restrictive regime (residence and economic activities were prohibited). The area of the SPZ was 700 km^2. Although the territory of the SPZ was taken under protection by the police, the population continued to use part of the SPZ area due to the lack of 'clean' pastures and hayfields, and lack of official information about radioactive contamination.

^{90}Sr soil deposition equal to 2 Ci km^{-2} was recognised as a maximum permissible level for safe living of the population and was used as the official boundary of the EURT (see Figure 1). Scheduled activities to reduce external radiation to residents included further relocation of the residents, decontamination of settlements and agricultural areas, development of a radiation monitoring system, including quality inspection of foodstuffs and fodder, as well as reorganisation and reorientation of commercial farms. In total, 22 settlements with a population over 10 000 people were relocated as a result of emergency and scheduled activities. Beyond this SPZ, it was established during the first year after the accident that the total contaminated area bounded by 0.1 Ci km^{-2} for ^{90}Sr (see Figure 1) (a reliably detectable level equal to double the value of global background contamination as of the date of the accident) comprised 23,000 km^2. 217 settlements with a population of about 270,000 people were located in this territory. Within the bounds of 2 Ci km^{-2} for ^{90}Sr, the contaminated area amounted to 1000 km^2. This territory acquired the official status of a Contaminated Area, and it is in this territory that the implementation of radiation protection measures for the population was considered indispensable. The territory of radioactive fallout also covered the facilities of the Mayak complex which had to continue its activities together with the implementation of countermeasures.

Whilst the Kyshtym accident was a tragic event on many levels with serious consequences for both the population and the environment, the accident, as can be seen from the above, served as an important impetus for a number of initiatives which form a significant part of emergency response planning today. An example of this is the use of dose or contamination intervention levels which are used to decide on actions such as sheltering or evacuation, and decontamination/remediation of affected areas following an accident.

[b] *Acute radiation Syndrome is an illness caused by exposure to large dose of ionising radiation in a short duration of time. The severity of symptoms such as nausea, vomiting or diarrhoea, depends on the type and amount of radiation, and duration of exposure.*

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