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USSR: Nuclear Accident Near Kyshtym in 1957-58

An Intelligence Assessment

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SOV 81-10102
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USSR: Nuclear Accident Near Kyshtym in 1957-58

Overview

Media reporting of a nuclear accident near Kyshtym has appeared occasionally since 1958. It was not until 1976, when the writings of Dr. Zhores Medvedev began to appear, however, that worldwide attention was focused on this subject. Medvedev, an exiled Soviet geneticist, claimed in several articles and books that a "disaster" occurred near Kyshtym in 1957-58. He alleged that thousands of casualties and widespread, long-term radioactive contamination occurred as the result of an explosion involving nuclear waste stored in underground shelters.

There is growing interest in both the United States and abroad in establishing whether this so-called accident or disaster was only a historical event in the development of nuclear energy or is, in fact, relevant to the current debate over nuclear technology safety

We believe that a significant radioactive contamination problem exists in the Kyshtym area of the southern Ural Mountains and that the origin of this contamination is the Kyshtym nuclear energy complex. We believe that this contamination problem is the result of a combination of events rather than a single isolated incident. We do not know the actual extent of the contamination zone, but we believe that an area about 1,000 square kilometers is affected; as much as 100 square kilometers contain high levels of radioactivity; the rest is contaminated with hazardous levels of radioactivity. A contributing factor in creating the contamination may have been the pressure to produce large quantities of nuclear materials quickly

There is evidence of five accidents or events in the Kyshtym area during the 1950s. The five events are listed in decreasing order of the amount of contamination they could have caused:

- A major release of high-level radioactive waste produced from early years of spent reactor fuel reprocessing probably occurred at a large waste pit and also possibly at a waste-filled ravine near the main production facility. We believe that a single major accident and/or a series of incidents at one or both of these sites created serious contamination conditions.

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- Early reactor operations at the Kyshtym complex clearly created a chronic contamination problem of significant proportions in the Techa River drainage area. Radioactive products, which resulted from reactor fuel failures and irradiation of coolant impurities, flowed into the river after they were discharged to the lake that provides cooling water (intake and discharge) for the reactors. In the late 1950s bypass canals were constructed, isolating the lake from the river, to prevent further contamination of the river.

- An incident occurred in one of the reactor areas during the late 1950s and probably was the cause of the shutdown of the area during the 1960s and 1970s. The most likely cause of the incident was a failure of the core-cooling system or a sudden reactor power surge. This incident probably produced only intense, short-lived contamination near the reactor. But it also may have caused radiation injuries to maintenance and cleanup personnel at the facility as well as to inhabitants of the affected off-site areas.

- An accident in the fuel reprocessing area, either a fire or chemical explosion within the area, probably was responsible for the shutdown of the area in 1957-58. Such an accident probably would cause local radioactive contamination and possibly radiation injuries to maintenance and cleanup personnel. An accident external to the area, such as a waste-pit explosion, also may have been responsible.

- A large explosion of stored chemicals may have occurred within the Kyshtym complex. Such an explosion and the subsequent fire could explain some of the events described in several reports. A large chemical explosion would not necessarily have had a direct impact on any of the facilities within the complex containing radioactive materials. At most, only minor, localized contamination would have resulted.

The events at Kyshtym have little relevance to current nuclear technology safety issues. The nuclear waste storage practices and technology, the fuel reprocessing technology, and the reactor technology now available are significantly different and/or improved relative to those in use at Kyshtym during the 1950s.

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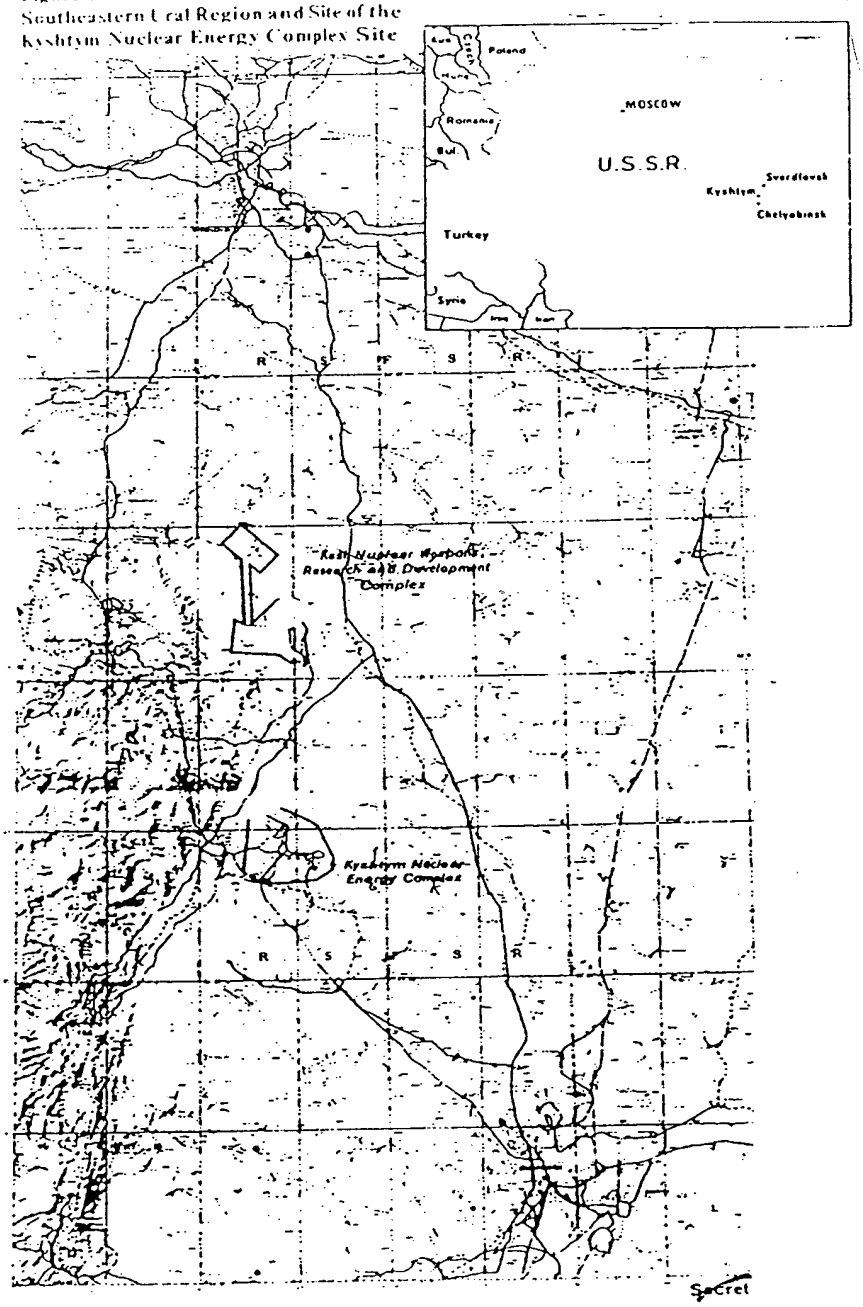
Figure 1
Southeastern Ural Region and Site of the Kyshtym Nuclear Energy Complex Site



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USSR: Nuclear Accident Near Kyshtym in 1957-58 [1]

Introduction

Since 1958 reports have indicated that a nuclear accident occurred in the southern Ural Mountains during the mid-to-late 1950s. Information in a majority of these reports points toward the involvement of the Kyshtym nuclear energy complex. It was not until September 1961, however, that satellite photography of the Kyshtym area provided our first look at the facility that had been associated with the reported accident.

The complex is approximately 15 kilometers (km) east of the city of Kyshtym in the eastern foothills of the south-central Urals (see figure 1). The complex includes the oldest plutonium production facility in the USSR. Construction of the complex is believed to have been well under way as early as 1946. The outer perimeter security fence encloses an area roughly 140 square kilometers (km²). The complex includes two major production facilities, a number of associated facilities for support and auxiliary functions, and housing areas.

The main production facility consists of three production reactor areas, a spent fuel reprocessing and waste disposal area, and various support areas. This production facility is separately secured and is located on the southern shore of Lake Kyzyltash. This lake serves as the source of cooling water for the reactors (see figure 2).

The second large secured area within the complex boundary is the Tatysh production facility located southwest of the main production facility on the shore of Lake Tatysh. This Tatysh facility has a number of laboratory-type buildings, a steam plant, two electrical substations, and a railroad siding (see figure 3).

[redacted]

[1] A Technical Intelligence Report to be published in late 1981 will present an in-depth analysis of the Kyshtym accident.

The absence of photography of the Kyshtym area during the crucial period between the late 1950s and September 1961 has been the most serious intelligence gap in our understanding of events surrounding the reported "accident." Over the last three years, however, new information has become available from in-depth analysis of Soviet radioecology literature.

[redacted] and satellite imagery. This information has provided new insight into possible accident events and radioactive contamination associated with the Ural "disaster."

Indicators of Radioactive Contamination Events

[redacted] reports on the Ural nuclear accident suffer from the lack of any firsthand or even secondhand accounts of the event(s), the absence of scientific qualifications [redacted] describing certain effects (for example, radiation burns), significant differences in the reported dates of an event (1956-65), and widely varying accounts of events and their aftermath. The reports, however, present a reasonably consistent localization of these events to the southern Ural area.

Roughly half of the reports indicate that an event occurred during 1957-58. Information in a majority of them clearly points toward the Kyshtym nuclear energy complex as the location of one or more events. Most of the reports refer to an explosive-type event. Some of the dramatic citations concerning the type of event are as follows:

- Explosion at the Kyshtym plant
- Atomic test . . . in Kyshtym.
- Atomic explosion in the (Chelyabinsk) area
- Large areas north of Chelyabinsk contaminated by radioactive waste from a nuclear plant
- Tremendous explosion . . . in one of the sections of the closed zone for the atomic center near Chelyabinsk.

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Figure 2

Main Production Facility, Kyshtym Complex

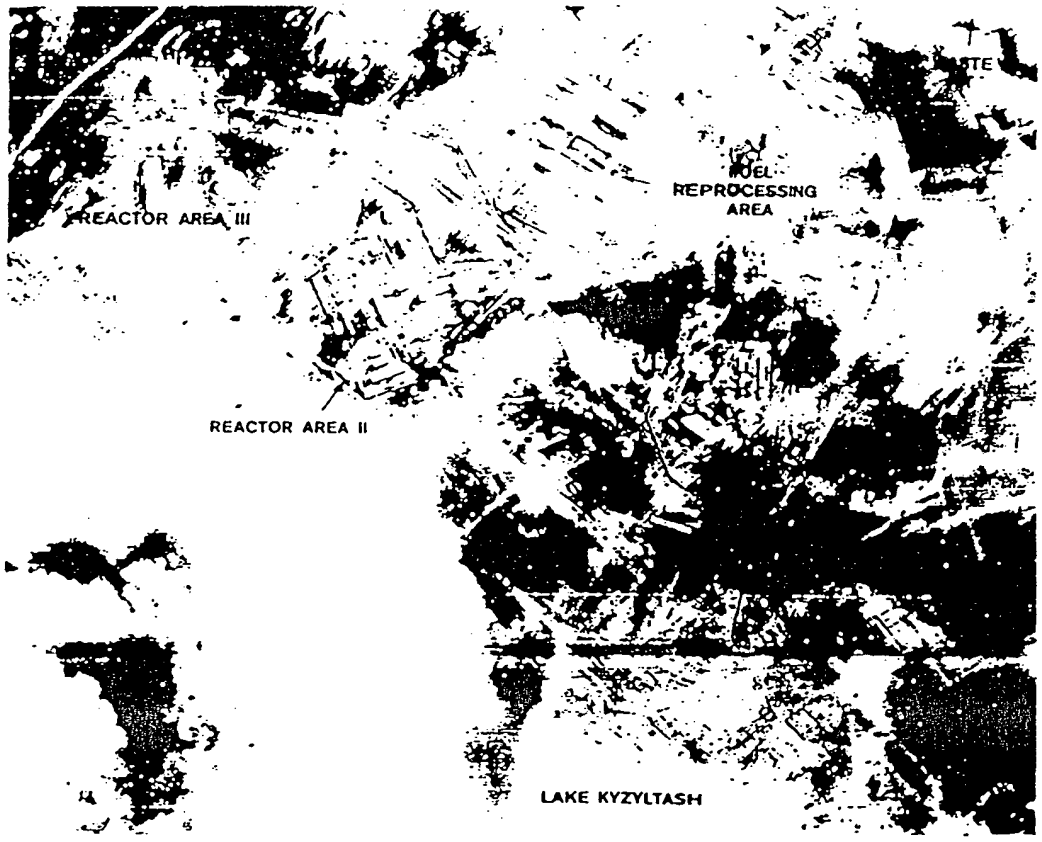

Figure 3

Tatysh Production Facility, Kyshtym Complex

- Explosion at the atomic installation known as Chelyabinsk-40.
- Terrific explosion . . . somewhere in Chelyabinsk Oblast.
- Atomic factory exploded in vicinity of Sverdlovsk.
- Enormous explosion occurred in a plant called Chelyabinsk-100.
- Nuclear test . . . occurred in an unspecified region of the Ural Mountains.
- Disaster, as SU1

Most of the reports also indicate an extensively affected area lying east of Kyshtym and between the cities of Sverdlovsk and Chelyabinsk.

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None pro-
vides any indication of the radioactivity levels or range of isotopes present in areas that are reported contaminated

Photography. In July 1959 a U-2 aircraft photographed the Kyshtym area for the first time, but the key areas of interest were almost entirely obscured by cloud cover. Satellite photography of the area obtained in September 1961 provided our first look at the nuclear facilities in the vicinity of Kyshtym. This absence of photography of the Kyshtym complex during the crucial period between the late 1950s and September 1961 has been the most serious intelligence gap in our understanding of events surrounding the accident. The 1961 photography reveals, however, several areas at or near the Kyshtym nuclear energy complex that are suspected of having a direct connection to the radioactive contamination that exists in the Ural Mountains. Among these are (1) the large retention basins east of the complex and the associated Techa River bypass canals, (2) the shutdown Reactor Area III, (3) the large waste pit and dammed ravine near the fuel reprocessing area, and (4) a long, narrow off-site "corridor," running from the complex perimeter in a northeasterly direction that appears to have been evacuated and declared off limits for the populace

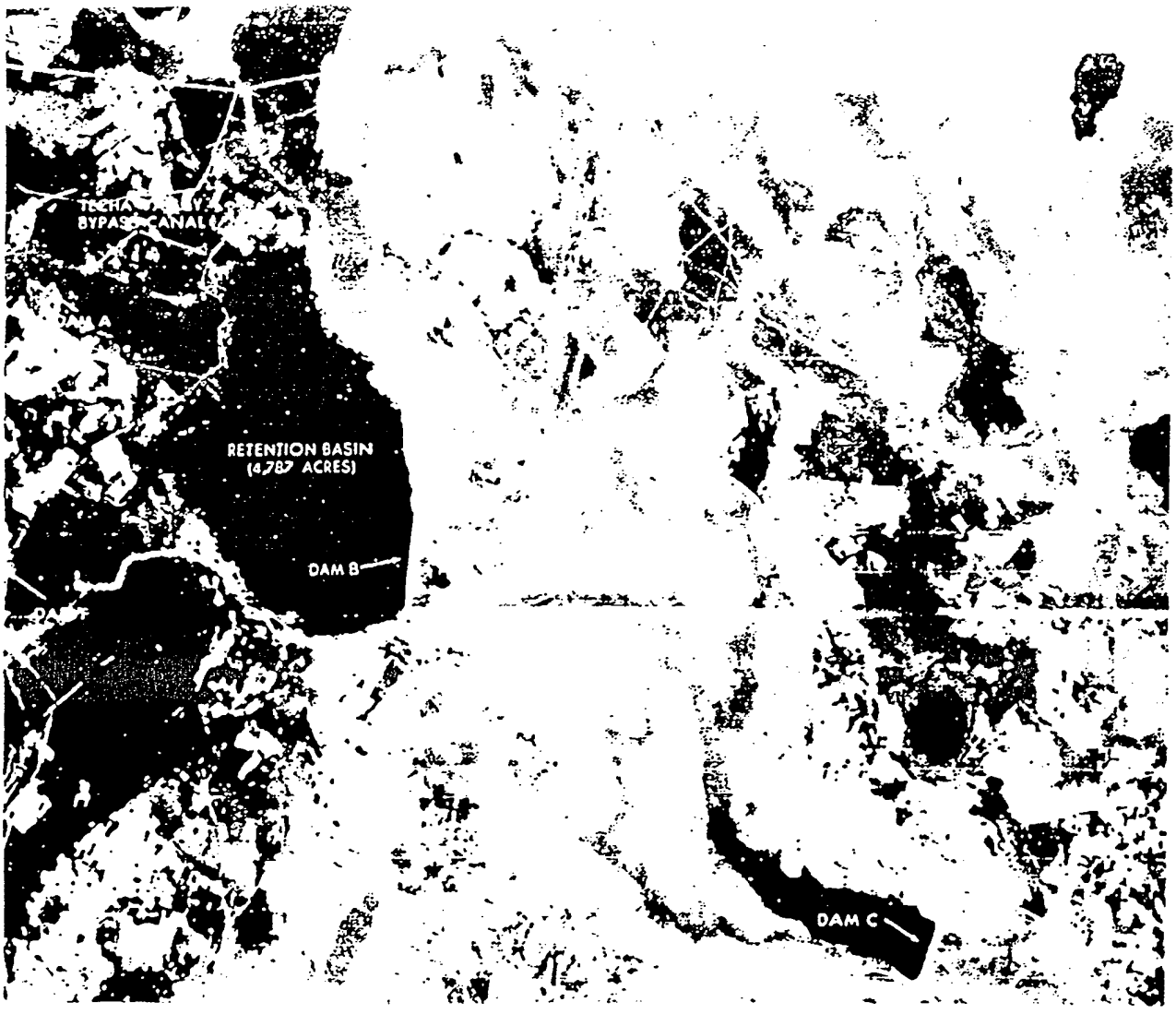
The 1961 photography of the Kyshtym area showed that canals had been constructed to route the Techa River around Lake Kyzyltash. Also, two large cascaded basins whose combined area of approximately 49 km^2 had been created for retention and evaporation of drainage from the lake (see figure 4). The creation of these retention basins and construction of the bypass canals may have been necessitated by the continuing chronic release of significant fission and activation products from reactor operations (and from site runoff). Also, construction of the basins and canals may have been precipitated by a single major accident that resulted in substantial ground and/or water contamination in the vicinity of the site. Given the absence of any holdup cribs in the reactor areas to confine the majority of products released through fuel failures, it is probable that these continuing releases eventually forced the Soviets to isolate the water bodies associated with reactor operations in order to reduce the radiation hazard to the populace downstream

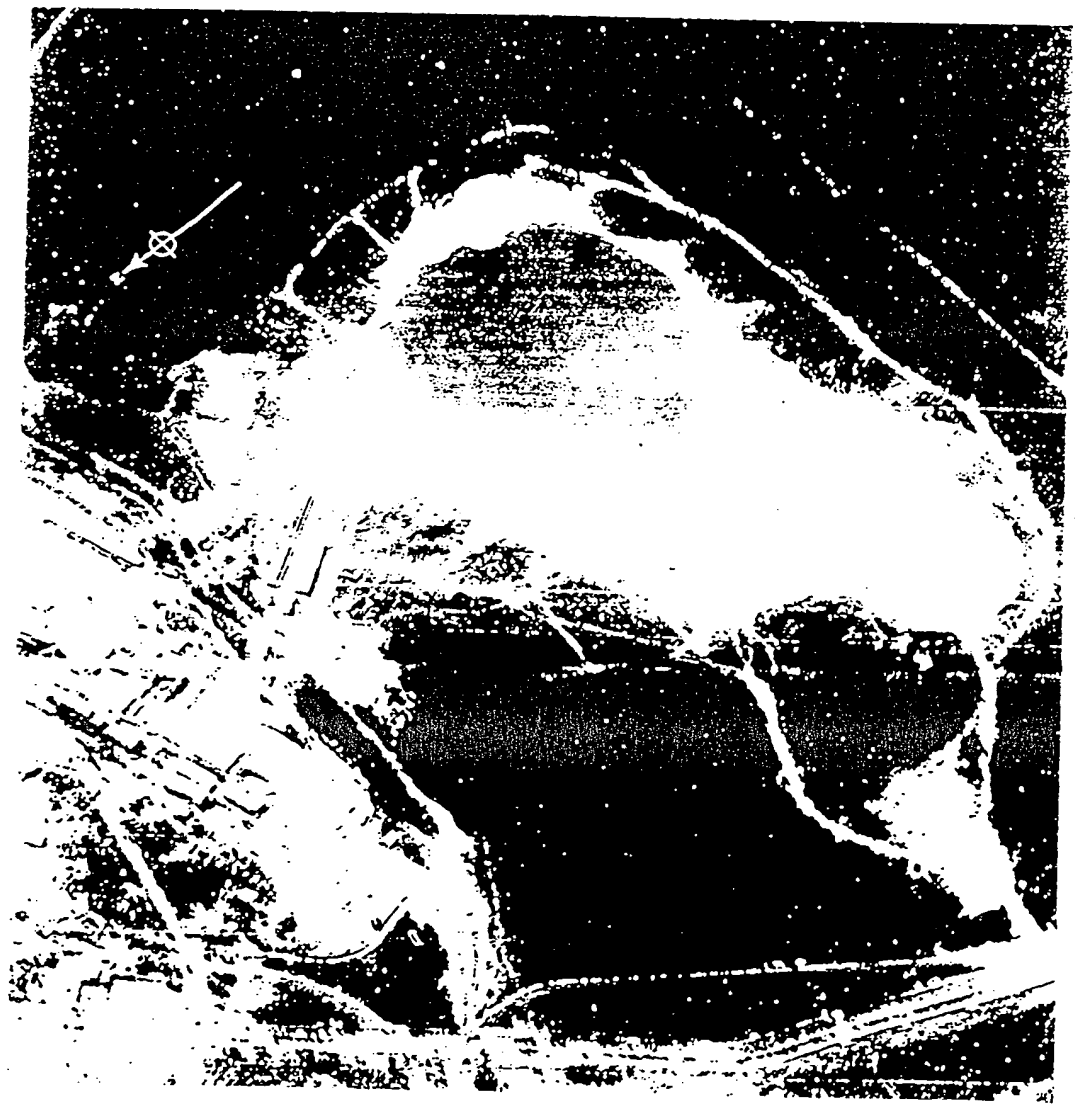
The photographic history of Reactor Area III indicates that a serious incident occurred at this site some time before 1961, probably in the late 1950s. From September 1961 until mid-1972, very little activity occurred within the area, and no reactor operations were under way. In mid-1972 a major decontamination and modification program was begun. After almost eight years, reactor operations at the renovated facility commenced in early 1980. It is difficult to reconcile the extended period of shutdown at Area III with anything less than a serious incident that precluded the resumption of reactor operations. Such a long cessation of operations is inconsistent with demonstrated Soviet practice in the operation of production reactors, if indeed there had not been an incident or one having a relatively short-term impact. If a serious incident had not occurred at Area III, it is likely that the Soviets would have made the effort necessary to repair and reactivate the reactor(s) in Area III as soon as possible after shutdown. The shutdown occurred at a time when there was a heavy demand for reactor products (plutonium and tritium) for the Soviet nuclear weapons program

A comparison of the estimated volume of high-level radioactive waste generated at the Kyshtym complex during its first eight to 10 years of operation and the known capacity of the tank storage at the site has led us to conclude that most of the high-level waste generated by early fuel reprocessing at the Kyshtym complex has been discharged to the large open pit south of the fuel reprocessing area (see figure 5). Lesser amounts of high-level waste appear to have been discharged to the dammed ravine east of the fuel reprocessing area (see figure 6). This conclusion is further supported by information obtained through an examination of the photographic history of activity at these two sites


OZERO
KYZYLTASH
MAIN
PRODUCTION
TATYSH
TATYSH
PRODUCTION
FACILITY
WASTE
ARGAYASH TETS
OZERO


OZERO
KYZYLTASH
RETENTION
BASIN
RETENTION BASIN
(4,787 ACRES)
MAIN
PRODUCTION
FACILITY
RETENTION BASIN
DAM B
DAM E
WASTE PIT
AYASH TETS
OZERO


RETENTION BASIN
(4787 ACRES)
DAM B
DAM C



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During the early-to-mid-1960s the Soviets began a massive earth-moving effort (still under way) to create a completely new, clean embankment for both the large pit and the dammed ravine. The liquid level in the pit and the ravine is kept fairly constant, and the discharge of high-level waste to these areas has ceased. Thus, the earth-moving operation would reduce the amount of high-level waste products transported into surrounding areas from the exposed banks, which were contaminated as a result of earlier waste additions and evaporation. The manner in which the Soviets are depositing the earthen material (presumably sand or gypsum) to create the new embankments is also rather revealing of the radiation hazard in the vicinity of these two sites. It is also apparent from the winter photography that the pit and the ravine generate heat, which is consistent with a site for high-level waste disposal

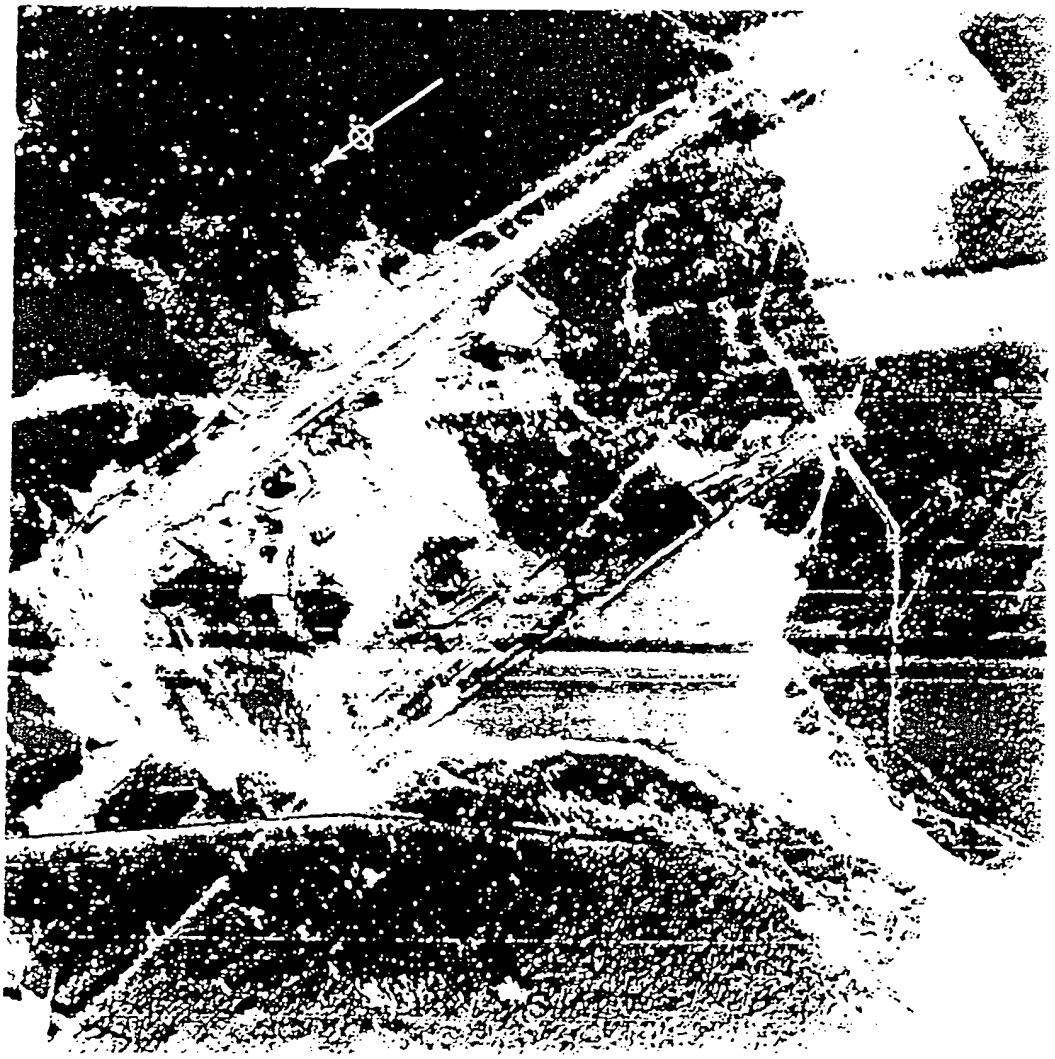
The inhabitants have been evacuated from an area roughly 5 to 10 km wide and about 70 to 80 km long northeast from the Kyshtym complex. The villages within the area have been razed, and large-scale cultivation of crops has been abandoned (see figure 7). Long narrow corridors of this type are typically the result of an airborne radiological release following an accident. Single events of this type tend to produce a narrow deposition plume with sharp boundaries. This is in contrast to the more widely affected area resulting from chronic operational releases, which tend to produce more diffuse, widespread depositions

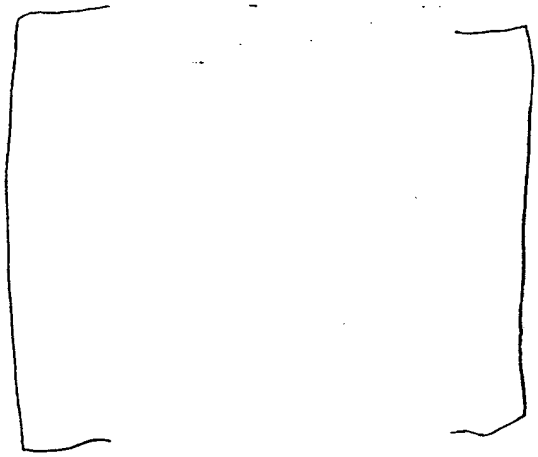
Soviet Radioecology Literature. Analysis of unclassified Soviet radioecology literature indicates that an accident occurred in the Kasli-Kyshtym area during 1957-58 and involved the atmospheric release of reprocessed fission wastes. This analysis indicates the following:

- A major airborne release of radioactivity occurred within a 50-km radius of Kasli in the winter of 1957-58, involving moderate- to long-lived fission products having little cesium-137.
- An extensive area (at least 25 to 100 km^2) was contaminated with high levels of radioactivity—roughly 1 milliCurie per square meter of strontium-90. The total area estimated to have contamination levels significantly above fallout background may exceed 1,000 km^2.
- The incident appears to have involved the release of 10^7 to 10^8 Curies of strontium-90, with a minimum airborne contribution probably on the order of $(0.3\text{-}1) \times 10^7$ Curies of strontium-90.
- It is impossible to determine from the radioecology literature alone whether the contaminated zone was created by a single event, several events (involving permutations and combinations of accidents and nonaccidents), or complex releases associated with a single accident

Figure 9

Waste-Filled Ravine East of the Fuel Reprocessing Area





Dispersal of wind- and water-borne waste products from the pit area probably has been a chronic source of contamination in the vicinity whatever the number and severity of individual accidents. Clearly, the fission product inventory and isotopic characteristics of the high-level waste residing in the open pit (and dammed ravine), however dispersed, offer the best match to the Soviet radioecology data.

We conclude, therefore, that a major release of high-level radioactive waste products probably occurred at the large waste pit and possibly also at the dammed, waste-filled ravine. We further conclude that serious contamination conditions may have been created in the vicinity of the complex as the result of a single major accident, a series of incidents, and/or chronic releases associated with one or both of these waste disposal sites.

Accident Hypotheses

The accident hypotheses suggested by the evidence from the five categories of information discussed above encompass (1) nuclear waste events, (2) production reactor events, (3) fuel reprocessing events, (4) nuclear weapon-related events, and (5) chemical shipment/storage detonation.

Nuclear Waste Events. It has been established that large volumes of high-level waste generated in the first several years (possibly 10 years or more) of operations at the Kyshtym complex were discharged to the large open pit (or pond) south of the fuel reprocessing area. A lesser amount apparently was discharged into the dammed ravine east of the chemical separations area.

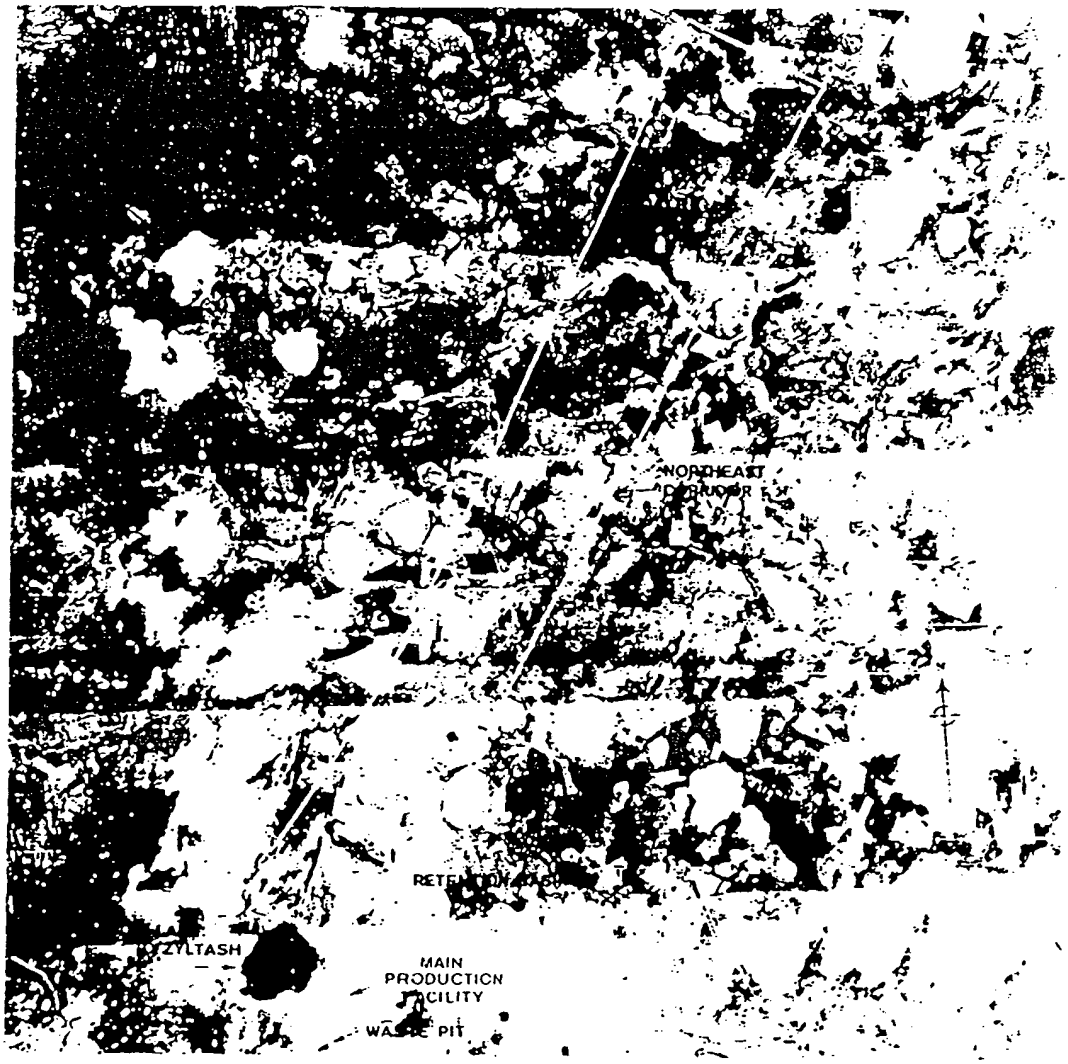
The accidents that possibly could result from using open pit reservoirs for storing high-level waste are chemical explosion, nuclear criticality, and dispersal of waste products from other causes (for example, wind and water transport). Detonation of dried waste is considered the most credible single major accident event for the open pit. Criticality (with a potential for supercriticality in an unlined earthen pit) theoretically has a great energy potential given reasonably high plutonium losses in separations. The neutron poisoning effect of various fission products in the waste solution and the severe demands on plutonium mass and configuration make a criticality or supercriticality event highly unlikely.

With respect to the few sites used for waste tank storage at the Kyshtym complex, accident categories considered were chemical explosion (hydrogen detonation, dried waste detonation), nuclear criticality, and tank rupture from other causes (bumping, corrosion, lifting from water table rise, and earthquakes). Dried waste detonation clearly has the greatest potential for producing widespread, high-level contamination. If the cesium-137 had been separated from the waste stream as a consequence of the separations chemistry or largely removed from the stored waste by, for example, tank rupture, then the contents of one large waste tank could provide both the inventory and isotopic characteristics consistent with the Soviet radioecology data. A viable set of conditions necessary to cause an explosion in the contents of a waste tank can be achieved, but photographic evidence does not support such an event at the Kyshtym complex.

Production Reactor Events. The types of production reactors considered in the analysis of events at the Kyshtym complex were heavy-water reactors (HWRs), single-pass (open cycle) graphite-moderated reactors (GMRs), and recirculating (closed cycle)

Figure

The Northeast Corridor



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GMRs. HWRs and recirculating GMRs were considered the most likely reactor candidates for the initial system(s) in Area III, with single-pass GMRs clearly being the type of systems present in reactor areas I and I'

The photographic history of Area III and nearby offsite areas indicates the occurrence of some type of reactor incident at this facility before the first satellite photography of September 1961. Types of accidents considered were reactor power surges, loss of control, overpower operation, power-coolant mismatch, cooling failure, and nonnuclear energy release in the core. Reactor power surges and cooling failure are the two types of reactor events that appear to be most consistent with observations about Area III, particularly with respect to the types of events required to preclude relatively quick repair and reactivation of a reactor facility. Release of fission products resulting from power surges and cooling failures could be quite severe, especially in terms of short-lived activity, and most likely would produce a long, relatively narrow plume deposition pattern that is reasonably consistent with the shape of the northeast corridor. It should be noted, however, that this type of event would not produce quite the magnitude of release nor the isotopic characteristics indicated in the radioecology literature

In addition to the Area III incident, it is clear from certain [redacted] reports and site photography that chronic releases of fission products and activation products from the single-pass GMRs during early operations at the site created a serious contamination problem in the Techa River by the early-to-mid-1950s. Before the late 1950s, the radioactive products resulting from reactor fuel failures and irradiation of coolant impurities were free to flow into the Techa River after being discharged to Lake Kyzyltash. It was not until the late 1950s that Lake Kyzyltash was finally isolated from the Techa River flow by a system of bypass canals

Fuel Reprocessing Events. Accident hypotheses considered for the fuel reprocessing facilities include explosions and fires, criticality, radioactivity spills, and chronic releases. A fire and/or explosion, particularly in connection with the possible operation of a solvent extraction pilot plant, are the most likely causes of a serious incident within the fuel reprocessing area that would cause the shutdown noted in the [redacted] data. Such an event could cause severe contamination in the vicinity of the affected facilities. The magnitude of release even in this type of event would be relatively small because of the limited reactor fuel inventory in a fuel reprocessing plant operation. A major radioactivity spill, if occurring at a strategic location in the plant, would produce relatively little contamination away from the facility but could result in an extended downtime for cleanup. Criticality and chronic releases are considered much less serious in an accident sense, although injuries to plant personnel could result. It is possible that some reports of accident casualties being treated in Chelyabinsk hospitals were the result of overexposure and injury to maintenance and cleanup crews brought in to repair and reactivate a damaged fuel reprocessing facilit

It is likely, therefore, that either a fire and/or explosion or a major radioactivity spill caused the 1957-58 shutdown of fuel reprocessing at Kyshtym if, in fact, this shutdown was caused by an incident internal to the fuel reprocessing area. The evidence is insufficient to establish conclusively whether this shutdown was caused by an incident inside the fuel reprocessing area or an incident somewhere outside this area (for example, waste pit explosion

Nuclear Weapons-Related Events. Accident hypotheses considered for nuclear weapons-related events are (1) fallout from atmospheric tests, (2) accidental detonation of a device, and (3) releases from a weapon component fabrication plant. None of these events is a credible candidate for a major event and subsequent high-level contamination in the Kyshtym area. The low-level global fallout activity found in the environmental samples and the features of high-altitude meteorological phenomena argue against any significant contamination problem in the Kyshtym area

being created by fallout from high-yield atmospheric tests at Novaya Zemlya or Semipalatinsk. There is no evidence for an accidental detonation of a device, nor do we believe that the Soviets would risk having an assembled device in the vicinity of the Kyshtym complex during the time frame of interest. The consideration of releases from a fabrication plant for weapon components was prompted by the suspected presence of such a facility in the Tatysh area of the Kyshtym complex. Neither chronic nor accidental single releases from such a plant are consistent with either the magnitude or the isotopic characteristics indicated by the Soviet radioecology data nor with the nature of the event as described in much of the reporting.

Chemical Shipment/Storage Detonation. Events relating to shipping, storage, and detonation of chemicals were considered as a possible explanation for some of the reporting of explosive events. One highly explosive chemical, ammonium nitrate, may have been stored in reasonably large quantities somewhere within the complex during the 1950s.[2] If the Soviets had been experimenting with an early Hanford-type solvent extraction separation process [3] during this time period, it is likely that ammonium nitrate (which is used as a process chemical) would have been stored on the site.

[2] Several disasters involving explosions of stored or in-transit ammonium nitrate have been documented
[3] REDOX-type process.