**Russian/Soviet Nuclear Warhead Production.** Thomas B. Cochran and Robert S Norris. NWD 92-4, June 12, 1992. Natural Resources Defense Council, Washington, DC., p. 116.

This Working Paper from the US Natural Resources Defense Council adds significantly to the knowledge of Soviet nuclear weapons production. Following the discovery of nuclear fission by Otto Hahn and Fritz Strassman in Berlin in December 1938, Leningrad became a leading centre for nuclear fission research, with Igor V. Kurchatov at the Leningrad Physico-Technical Institute (LFTI), an important centre. Georgiy Flerov wrote to Stalin, in April 1942, alerting him to the urgency of solving the 'uranium problem'. Meanwhile, Igor Kurchatov drew up a plan of research with three main goals: to achieve a chain reaction in an experimental reactor using natural uranium; to develop methods of isotope separation; and to study the designs of both U-235 and plutonium bombs.

Following the bombings of Hiroshima and Nagasaki, Stalin is said to have ordered his deputies and Kurchatov to 'provide us with atomic weapons in the shortest possible time'. The initiative to create a Soviet hydrogen bomb project appeared in 1946, in a special report to the government by Isai Gurevich, Ya B. Zeldovich, Isaak Pomeranchuk and Y. B. Khariton.

Cochran and Norris comment that the Soviet progress on the hydrogen bomb closely parallels developments in the United States. The initial Soviet concept, being pursued by Zeldovich's group, was to install a layer of liquid deuterium in an ordinary atomic bomb between the fissile material (the hollow sphere made of uranium-235 or plutonium-239) and the surrounding chemical high explosive. It was noted, however, the authors write, that the lack of heat and compression of the deuterium resulted in practically no thermonuclear reaction in the deuterium. To increase the reaction rate, two improvements in the design were proposed in 1948, one by Sakharov and the second by Vitaly Ginzburg. Sakharov proposed to increase the reaction rate of deuterium by surrounding it with a shell of natural uranium, effectively increasing the deuterium concentration at the deuterium–uranium boundary. Sakharov's variant has been described as a heterogeneous construction made of alternating layers of thermonuclear fuel, eg. deuterium, tritium, or their chemical compounds, and a heavy substance, e g. uranium-238. Sakharov called it 'sloyka' ('layer cake'). Ginzburg proposed substituting lithium-6 for some of the deuterium, as a means of generating tritium in the weapon itself These two ideas were incorporated into the first Soviet thermonuclear test on August 12, 1953. Identified as 'Joe 4' by the US, this test was a single-stage boosted fission weapon with a yield in the 200–300 kiloton range.

Sakharov and his colleagues used an idea ('Third Idea') of using radiation implosion to compress and ignite a physically separate thermonuclear secondary (also developed by Teller and Ulam in the US in the spring of 1951). The first Soviet test of a device of this type occurred on 22 November 1955.

The first Soviet atomic bomb was designed at Arzamas-16 at Sarova, assembled at Chelyabinsk-65 (formerly, Chelyabinsk-40), and tested on 29 August 1949 at the Semipalatinsk test site. This test site was closed in August 1991 by Kazakh President Nursultan Nazarbayev. The other weapon design laboratory is at Chelyabinsk-70 in the Urals region. One of the two principal nuclear warhead assembly (and disassembly) plants is Sverdlovsk-45 at Nizhnyaya Tura (58° 40′ N, 59° 48′ E) in the Urals. There were thought to be some 29 nuclear weapons production/storage sites in the Soviet Union prior to its breakup. The locations of most of these are not publicly known (Table 1).

The authors state that the Soviet Union followed a pattern of nuclear weapons materials production similar to that of the United States. Each began with the construction of natural uranium-fuelled, graphite-moderated thermal reactors for plutonium production and the development of gaseous diffusion technology for the enrichment of uranium. Today, according to Cochran and Norris, Russia relies on graphite-moderated reactors for plutonium and tritium production, and primarily on gas-centrifuge technology for uranium enrichment. The Soviet Government announced in October 1989 that 'this year it is ceasing the production of highly enriched uranium'.

### Location of plutonium production sites

The three plutonium (and tritium) production sites are Mayak Chemical Combine (Chelyabinsk-65; formerly Chelyabinsk-40) near Kyshtym in the Urals, the Siberian Chemical Combine (Tomsk-7) in Siberia, and the Mining and Chemical Combine (Krasnoyarsk-26) near Dodonovo in Siberia. There is no tritium production at Krasnoyarsk-26. Plutonium and tritium production at Chelyabinsk-65 has now ceased. Prior to 1987, there were as many as 14 production reactors at these three sites—six at Kyshtym, five at Tomsk, and three at Dodonovo.

The five water-cooled, graphite-moderated production reactors, all now decommissioned, at Chelyabinsk-65 are located in separate buildings in two separate production areas. The first reactor, 'A' reactor, was graphite-moderated with 1,168 channels. It was originally designed to operate at 100 megawatts thermal (MWt), but was later upgraded to 500 MWt. The 'A' reactor began operating on 19 June 1948 and shut down in 1987. Its plutonium was used to fabricate a ball almost 10 cm in diameter, which was used in the first Soviet bomb tested on 29 August 1949. It used aluminum-clad natural uranium fuel in vertical fuel tubes and gravity fuel discharge. The core diameter was 9.4 m and height was 9.2 m. The core was located within a concrete well with walls 3 m thick. Outside the walls were large tanks of water. A confinement system was used to control radioactive releases in the event of an accident, the authors state.

The Soviets relied on gaseous diffusion technology for enrichment and production of uranium. Most of their weapon-grade uranium production to date has been produced using this technology. More recently, they have shifted to the more efficient gas centrifuge technology. Currently (early-1992) the Russians have a total of just over 14 million kg separative work units per year (kg SWU/y, often shortened to SWU/y) of centrifuge capacity at its four plants. The plants are currently operating at one-half capacity (about 7 m SWU/y), producing primarily low enriched product for power reactor fuel, and using as feed material, enrich-

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**Table 1.** Principal nuclear weapon research, test and production facilities

**DESIGN LABORATORIES**

- All-Russian Scientific Research Institute of Experimental Physics (VNIIEF)
  - Arzamas-16
    - at Sarova, Nizhegorod Oblast
- All-Russian Scientific Research Institute of Technical Physics (VNIITF)
  - Chelyabinsk-70
    - 20 km north of Kasli, Urals region

**TEST SITES**

- Novaya Zemlya.
  - Northern and Southern Test Areas
    - two islands north of the Arctic Circle
- Semipalatinsk (or Kazakh) Test Site (permanently closed in 1991)
  - Semipalatinsk-21
  - Shagan River, Degelen Mountain, and Konyastan test areas
    - South of Semipalatinsk, Kazakhstan

**WARHEAD PRODUCTION (ASSEMBLY) FACILITIES**

- Sverdlovsk-45
  - at Nizhnyaya Tura, Urals region
- Either Zlatoust-36 or Penza-19
  - near Zlatoust, Urals region near Penza

**BALLISTIC MISSILE RE-ENTRY VEHICLE ASSEMBLY PLANT**

- Zlatoust-36
  - near Zlatoust, Urals region

**PLUTONIUM AND TRITIUM PRODUCTION REACTORS**

- Mayak Chemical Combine
  - Chelyabinsk-65 (formerly Chelyabinsk-40)
    - at Lake Kyzylash, near Kasli and Kyshtym, Chelyabinsk Oblast, Urals region
- Siberian Chemical Combine
  - Tomsk-7
    - on the Tom River 15 km northwest of Tomsk in Siberia
- Mining and Chemical Combine
  - Krasnoyarsk-26
    - on the Yenisey River 10 km north of Dodonovo near Krasnoyarsk in Siberia

**URANIUM ENRICHMENT FACILITIES**

- Urals' Electromechanical Plant (Urals' Electrochemical Combine)
  - Sverdlovsk-44
    - at Verkh-Neyvinsk, near Yakaterinburg (formerly Sverdlovsk), Urals region
- Siberian Chemical Combine
  - Tomsk-7
    - on the Tom river 15 km northwest of Tomsk in Siberia
- Electrochemistry Plant
  - Krasnoyarsk-45
    - on the Kan River between Krasnoyarsk and Kansk, Siberia
- Electrolyzing Chemical Combine
  - at Angarsk, 30 km northwest of Irkutsk in Siberia

*Source* Thomas B Cochran and Robert Standish Norris

ment tailing (0.24–0.4% U-235), rather than natural uranium. There is possibly some gaseous diffusion capacity (about five per cent of the total) still operating. (This was to have been shut down by the end of 1992, report the authors.)

As of the beginning of 1992, six of 14 production reactors remained operational Three of these were scheduled to be shut down in the last half of 1992, leaving three operational. These last three are dual purpose reactors producing heat and/or electricity. The Russian President Boris N. Yeltsin says, that reactors for weapons-grade plutonium production are to be shut down by the year 2000, and some of them even as early as in 1993.

## State of weapons grade material stockpile

According to Academician Yuri Trutnev, Russia (and formerly the Soviet Union) has about 100 metric tons (MT) of weapon-grade plutonium, 30 kg of tritium, and about 500 MT of highly enriched uranium in nuclear weapons, with the amount of inventory of these materials available for, but not in, weapons, a small fraction of the total The four operating uranium-enrichment plants are at Sverdlovsk-44, Tomsk-7, Krasnoyarsk-45 and at Angarsk near Lake Baikal. Mr Viktor N. Mikhailov, head of Russia's Ministry of Atomic Energy, reveals, as quoted in *The New York Times*, that the Soviet nuclear arsenal peaked at 45,000 warheads some seven years back; 12,000 more than the western estimates then. This was twice the number of warheads in the possession of US at that time, the US analysts say. The Russian inventory of bomb-grade enriched uranium is now said to be more than 1200 metric tonnes (K. Subrahamanyam, *The Economic Times*, New Delhi, p. 10, November 24, 1993).

Since Russia will continue to produce plutonium at least for a few more years, the authors surmise, that the current inventory of plutonium will grow at a rate of 1-2 MT per year. According to Evgeniy V. Mikerin, in the event of a negotiated cut-off in the production of plutonium and highly enriched uranium for weapons, Russia would have a continued requirement for 'two to three tritium production reactors'. The Soviet Union stopped production of highly enriched uranium for weapons in 1989.

In addition to major events, such as the dumping of radioactive wastes in the Techa River (1949–56) and the Kyshtym accident, a major radiation event occurred in 1967. Lake Karachay, near the Mayak complex (Chelyabinsk-65) dried up during a warm and dry spring. An estimated 2,700 sq km containing a population of about 41,500 people, were affected by contaminated dust and soil carried by the wind. Fallout consisted mainly of cesium-137 and strontium-90 [Bruce Amundson, *The PSR Quarterly*, Dec. 1992, 2(4)].

The breeder programme in Russia is plagued by safety concerns, write the authors—leaks in the sodium-water heat exchangers and the possibility of a runaway chain reaction during an overheating accident—and by problems encountered in the development of 'mixed-oxide' (MOX) plutonium fuel. The BN-600 breeder at Beloyarskiy continues to operate at half power, and until recently operated with highly-enriched uranium rather than plutonium. The Russian breeder is increasingly vulnerable to charges that it is uneconomical. Scientists at Chelyabinsk-70 are seeking funding support to develop and test a lead-cooled fast breeder that is said to be much safer than the sodium-cooled fast breeders. Such claims could further erode support for the BN-800.

The construction of the South Urals Nuclear Power Station, which originally was intended to consist of three 800 MWe liquid metal fast breeder reactors, was begun in 1984. Only the concrete footings for the first two reactors were put in place before construction was suspended in 1987. The third reactor did not advance beyond the planning stage.

It is reported that radioactivity in the reservoir Lake Karachay, near Chelyabinsk-65, amounts to 118.4 MCi (million curies). Of this, 110 MCi is in ground deposit and 8.4 MCi is in the reservoir. In the early years, radioactive waste management was non-existent. The Hanford tank farm in US currently contains an estimated 446 million Ci of high-level liquid wastes. Mayak scientists (Sayfer, Degteva, Kossenko and Akleeve) reported, in 1990, an estimated 823 million Ci of high-level liquid wastes in tanks stored at the site. In addition, at least, 150 million Ci have been spread off-site, into the environment, over an area of about 26,700 sq km, by both air and surface water pathways (A Penyagin, speech before USSR Supreme Council, subcommittee on nuclear energetics and nuclear ecology, 11 February 1990). In comparison, the Chernobyl accident on 26 April 1986 is estimated to have released approximately 100 million Ci of radioactivity into the environment*.

### Release of radioactive pollutants

During the first several years at Hanford in US, under the condition of urgent push for plutonium production, more than 725,000 Ci of Iodine-131 were released to the atmosphere. No data on Iodine-131 releases from the Soviet facilities have been made public, but it is presumed to be substantial. Cochran and Norris estimate that, since 1949 Mayak has discharged in excess of 154 MCi of long-lived radionuclides (Sr-90 and Cs-135) into the environment, contaminating in excess of 26,700 sq km, and exposing more than 437,000 people, making Chelyabinsk-65 environs arguably the most polluted spot on the planet. Parts of the Chelyabinsk-65 site have a dose rate of up to 15 MilliR (roentgen) per hour. The average value for the remainder of the site has a dose rate of up to 15 milliR/h. Fish in Reservoir No. 10 (some 6 km east of Lake Karachay) are reported to be '100 times more radioactive than normal'.

There was more than one incident of massive radioactive environmental contamination from the secret military nuclear plant in Chelyabinsk region affecting people living in the area. The first incident resulted from the disposal of radioactive wastes into the Techa River from 1949 to 1956. The second incident occurred on 29 September 1957, when there was a chemical explosion due to cooling system failure in the waste storage facility, near Kyshtym, known as 'Kyshtym disaster'.

The areas most affected by these incidents include parts of Chelyabinsk, Kurgan, and Sverdlovsk regions (Figure 1). Approximately three million Ci of radioactivity was released from wastes disposed in the Techa River from 1949 to 1956 (Figure 2) Kossenko's purpose was to study how to moderate radiation doses, delivered at low dose rates in a relatively large and stable population. Table 2 from

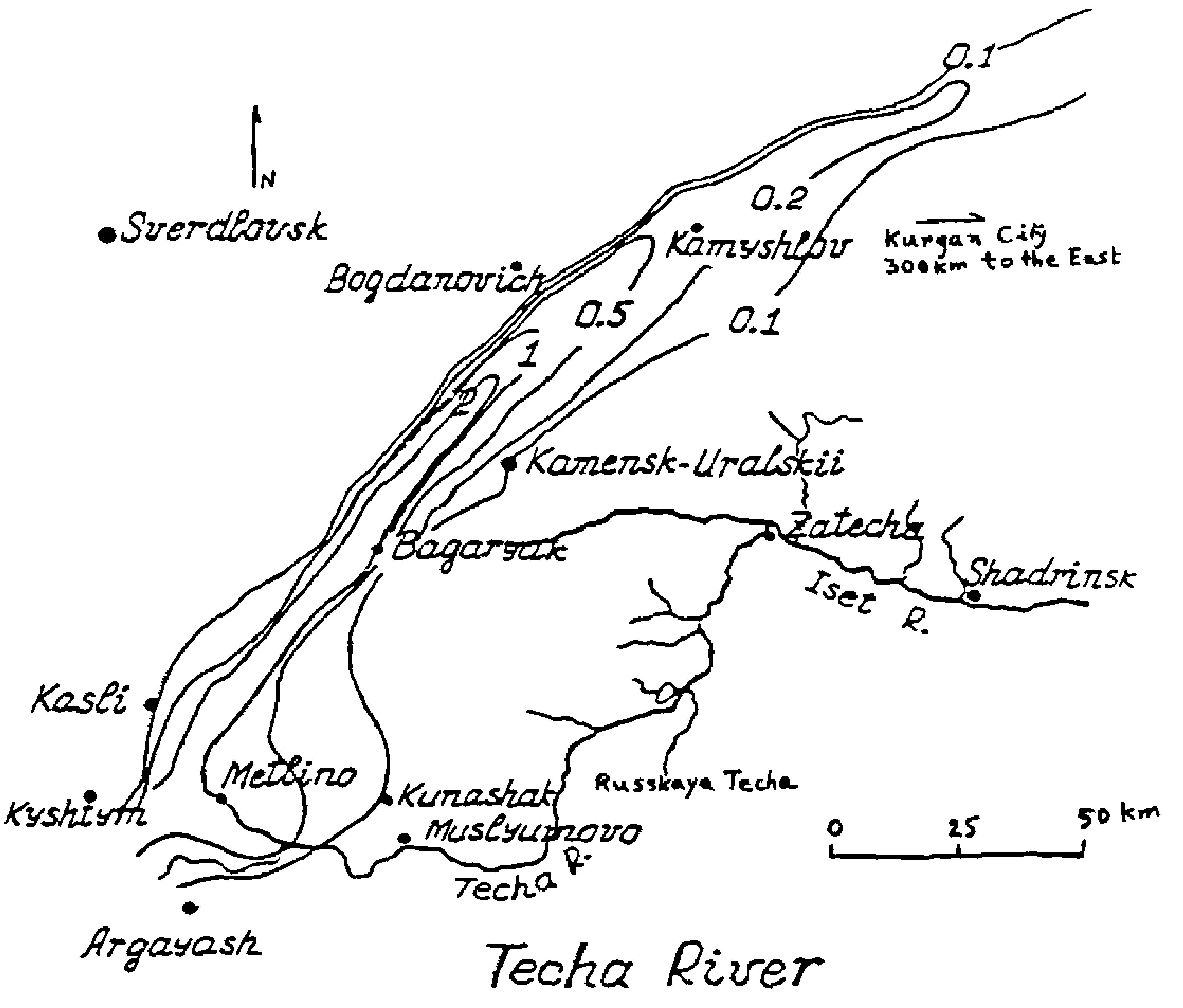

**Figure 1.** Radioactive fallout from the 1957 accident at Chelyabinsk-65 Contamination lines indicate the levels for strontium-90 in curies per square kilometre in 1957 and 1958, shortly after the Kyshtym accident The Techa River is traced from its source near the secret nuclear plant to where it feeds into the Islet River *Source* M M Kossenko, M. O. Degteva and N A. Petrushova, *The PSR Quarterly*, Dec 1992, 2(4).

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*These pollution sources, with an overall activity of more than one billion curies, represent a constant threat of contamination from the radionuclides to the large basin of the river Ob and the waters of the northern Arctic; it is a threat growing over time, observes V G Merezhko [Conference on 'Assessment of Land-based Sources of Marine Pollution in the Sea adjacent to the Commonwealth of Independent States (CIS)', Sevastopol, 6–10 April 1992, IMO, London, Pub. 274/94, p 250]

Irrespective of a whole series of hydrotechnological measures the cumulative transport of Strontium-90 by the waters of river Techa (Urals) ultimately into the Kara Sea was about 160 TBq (1959–89) In contrast, the introduction of Sr-90 from the Chernobyl Nuclear Power Station along the Pripyat and Dnieper rivers and into the Black Sea cumulatively amounted to about 54 TBq during 1986–91, according to Academician Gennady Polikarpov (IMO, Pub 274/94, pp 23–31)

As of January 1992 the total number of nuclear weapons in the Commonwealth of Independent States is about 27,000 (Table 5)

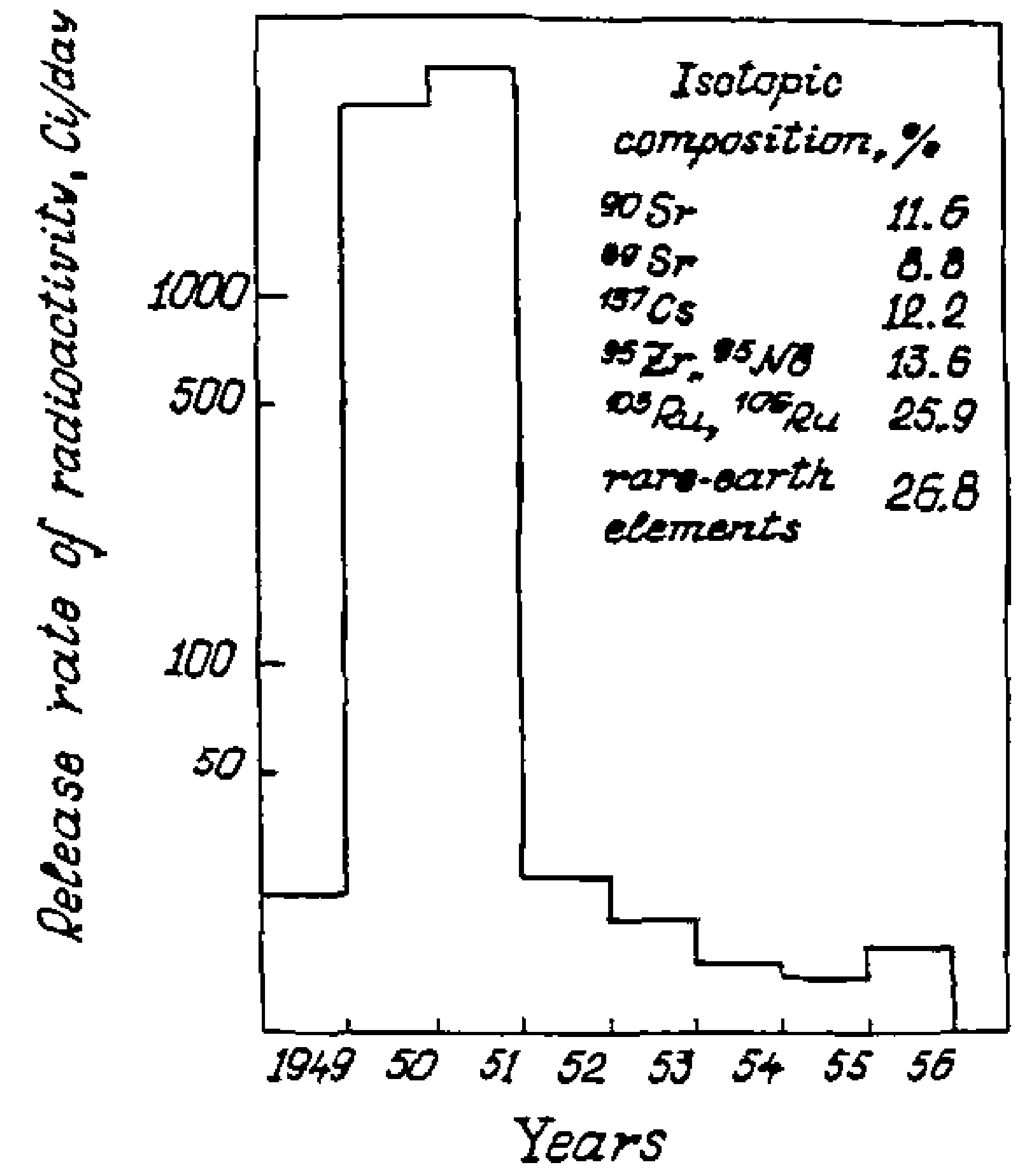

**Figure 2.** The average amount of radioactivity released per day into the Techa River from 1949 through 1956 and the isotopic composition of the release. Ci = curie. *Source* Mira M Kossenko, Marina O Degteva and Nelly A. Petrushova in *The PSR Quarterly*, Dec. 1992, 2(4)

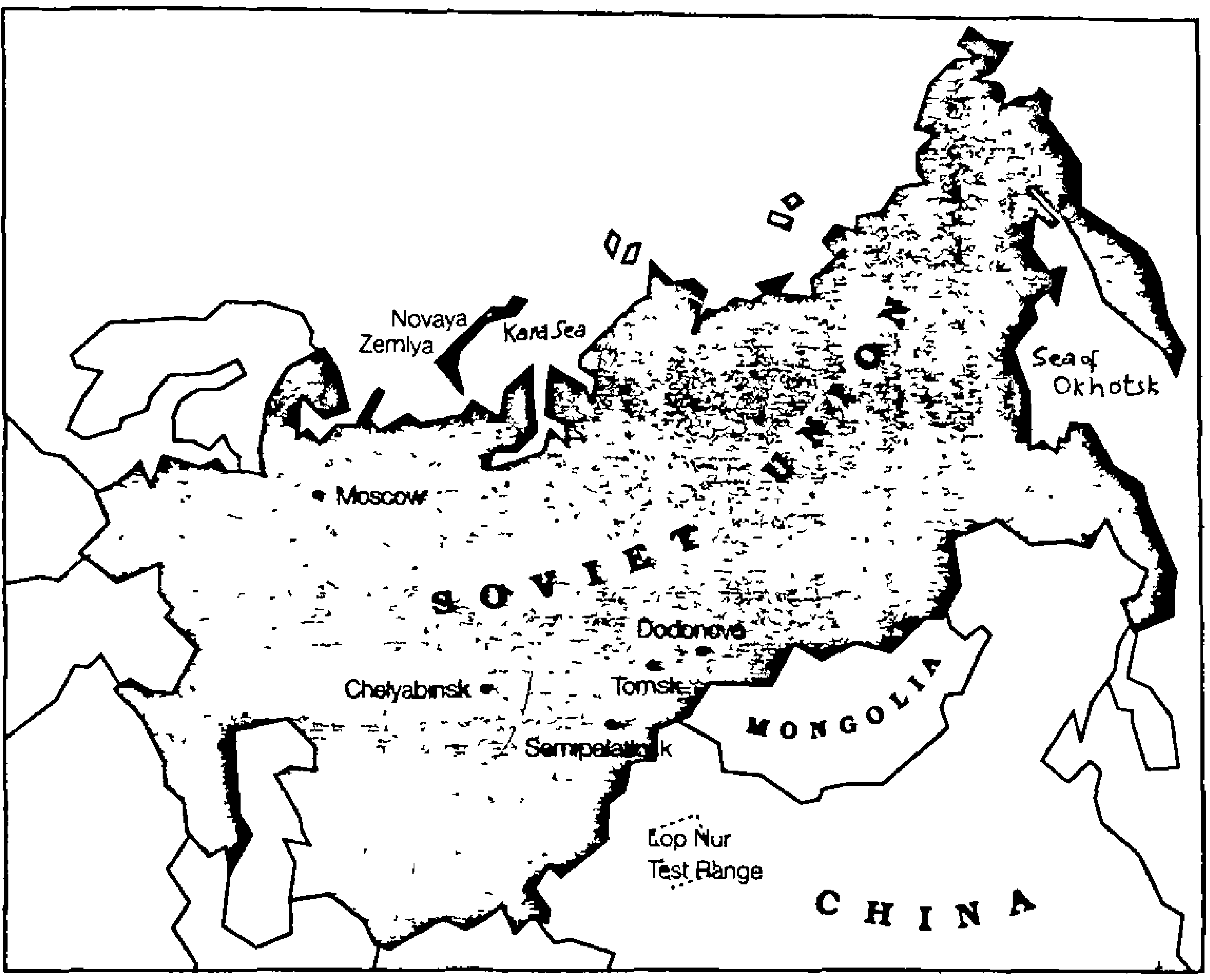

**Figure 3.** Soviet test sites are at Novaya Zemlya and Semipalatinsk, reactors are at Chelyabinsk, Tomsk and Dodonovo. Also shown, China's nuclear test site. Krasnoyarsk-26 is situated on the Yenisey River, 10 km north of Dodonovo. *Source* Thomas B. Cochran and Robert S Norris, *Bull Atom. Sci*, May 1991.

Kossenko's study describes organ dose estimates for the inhabitants of some villages along the Techa River. It was found that the risks of leukemia, in the Techa River study by Kossenko, are smaller than the risks to atomic bomb survivors and those irradiated for treatment of analysing spondylitis and cervical cancer.

In the second incident, nitrates and acetates in the waste began to dry out with the failure of the cooling system in one of the unmonitored tanks. These heated up to 350 degree Celsius and exploded with a force equivalent to 5 to 10 tonnes of TNT. Some 70–80 metric tonnes of waste containing some 20 million Ci were ejected (Table 3). There were 217 towns and villages with a combined population of 270,000 inside the 15,000–23,000 sq km (6000–9000 sq mile) area contaminated to 0.1 Ci/sq km (Sr-90) or greater, 10,000 people within 1000 sq. km contaminated to greater than 2Ci/sq km (Sr-90); and 2100 people within 120 sq km contaminated to greater than 100 Ci/sq km (Sr-90). A comparison of nuclear incidents in the South Urals is given in Table 4 (Kossenko *et al* 1992).

In the aftermath of the Kyshtym disaster, the combined collective effective dose commitment of the evacuated population, prior to evacuation, was approximately 130,000 person-rem; and the collective effective dose commitment of those persons that were not evacuated was 450,000 person-rem, reports V. N. Chykanov *et al.* Over their lifetime, reports the Commission formed by the order of the then President, Gorbachev, to investigate the ecological situation in the Chelyabinsk region, the collective radiation exposure from this accidental release could result in as many as 1000 additional cancers in the population.

The closed society in the former USSR

**Table 2.** Organ dose estimates (external and internal) for inhabitants in some villages along the Techa River

| Villages | Distance from point of release (km) | Mean doses, Gy | | | |
|---|---|---|---|---|---|
| | | Red bone marrow | Bone surfaces | Large intestine | Other tissues |
| Metlino | 7 | 1.64 | 2.28 | 1.40 | 1.27 |
| Muslyumovo | 78 | 0.61 | 1.43 | 0.29 | 0.12 |
| Russkaya Techa | 138 | 0.22 | 0.53 | 0.10 | 0.04 |
| Zatecha | 237 | 0.17 | 0.40 | 0.08 | 0.03 |

(1 Gy = 100 rads)

*Source* M M Kossenko, M. O Degteva and N A Petrushova, in *The PSR Quarterly*, Dec 1992, 2(4)

**Table 3.** Land contaminated by the 1957 accident at Chelyabinsk-65

| Contamination level (Ci/km$^2$) | Area (km$^2$) |
|---|---|
| 0.1–2 | 15,000–23,000 |
| 2–20 | 600 |
| 20–100 | 280 |
| 100–1000 | 100 |
| 1000–4000 | 17 |

*Source*: G N Romanov and A S Vorovov (quoted in the report)

Table 4. Comparison of nuclear incidents in the southern urals

| Main characteristics | Techa River | | Kyshtym accident | |
|---|---|---|---|---|
| Released activity (Ci) | $3 \times 10^6$ | | $2 \times 10^7$ | |
| Type of release | Aquatic | | Atmospheric | |
| Isotopic composition as percentage of release | $^{89}$Sr, $^{90}$Sr | 20.4 | $^{90}$Sr | 5.4 |
| | $^{137}$Cs | 12.2 | $^{144}$Ce | 66.0 |
| | $^{95}$Zr, $^{95}$Nb | 13.6 | $^{95}$Zr, $^{95}$Nb | 24.9 |
| | $^{103}$Ru, $^{106}$Ru | 25.9 | $^{106}$Ru | 3.7 |
| | Rare-earth elements | 26.9 | | |
| Type of irradiation | | | | |
| External | From contaminated sediments and soils | | From deposited radionuclides | |
| Internal | From intake of river water and milk ($^{90}$Sr, $^{89}$Sr, $^{137}$Cs) | | From intake with contaminated foodstuffs ($^{90}$Sr, rare-earth elements) | |
| Size of exposed population | 28,000 This is the number of people who lived in the Techa riverside villages in 1949–1952. The whole population is under observation. | | 34,000. This is the part of the population exposed as a result of the Kyshtym accident These people lived on the most contaminated territories and are under observation | |
| Distribution of doses to red bone marrow | | | | |
| Mean (Gy) | 0.4 | | 0.02 | |
| Range of individual doses (Gy) | 0–4.0 | | 0–0.9 | |

*Source*: M. M. Kossenko, M. O. Degteva and N. A. Petrushova, in *The PSR Quarterly*, Dec. 1992, 2(4).

Table 5. Nuclear weapons in the Commonwealth of Independent States

| State | Strategic offensive | Ground forces | Air defence forces | Air force | Navy | Total | (%) |
|---|---|---|---|---|---|---|---|
| Russia | 8,750 | 4,200 | 2,675 | 2,375 | 2,750 | 20,750 | 77 |
| Ukraine | 1,750 | 600 | 125 | 1,050 | 500 | 4,025 | 15 |
| Kazakhstan | 1,400 | 0 | 0 | 0 | 0 | 1,400 | 5 |
| Belarus | 100 | 0 | 0 | 575 | 150 | 825 | 3 |
| TOTAL | 12,000 | 4,800 | 2,800 | 4,000 | 3,400 | 27,000 | 100 |

Estimate as of January 1992.
*Source*: Robert S. Norris, *Arms Control Today*, January/February 1992

willingly, with immunity, carried out extensive environmental and health monitoring. This they did with the certain knowledge that there would be no public disclosure. On the other hand, in the 'open' society of USA, the prospect of scientific openness caused its nuclear establishment to refrain from conducting radiation health studies on off-site populations near nuclear production testing sites (Bruce Amundson, *The PSR Quarterly*, December 1992, 2(4), pp. 210–215). The department of Energy and the Atomic Energy Commission in the US have refused to let health concerns interfere with their weapons-making mission (George Perkovich, *Foreign Policy*, n. 85, Winter 1991–92, pp. 83–105). We should not forget the thousands of hapless victims of radiation-related diseases and sufferings, while counting the costs of the arms race.

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The views expressed here are those of the author, and not of the Institute where he works