The Nuclear Threat to the Environment in Russia

The catastrophe at the Chernobyl nuclear power plant ten years ago provided graphic illustration of the risks associated with the operation of nuclear facilities in the successor states to the Soviet Union. In Russia, in particular, the potential dangers are extremely high, as it is here that the largest number of civilian and military nuclear facilities are concentrated. A total of more than 13 000 enterprises deal with radioactive material. Security is seriously deficient in many facilities, a problem that has been exacerbated in recent years by the financial constraints facing nuclear facilities, the inadequate supplies of technical equipment and spare parts, and the increasing shortage of skilled labour. Nuclear power stations of the WWER-440 and RBMK-1000 (the model in operation at Chernobyl) types suffer from serious design faults. An equally serious potential risk emanates from its plutonium-producing and fuel-reprocessing facilities. Major risks are also involved in the storage of radioactive waste and spent fuel. Their total radioactivity amounts to around 7 billion curie. Most nuclear waste is stored in temporary sites, many of which fail to meet the prevailing safety standards. No decision has been taken on the decommissioning of the reactors in the nuclear submarines that have been taken out of service. In light of the environmental risks posed by nuclear waste, in October 1995 the Russian government adopted a Programme of Action, the prime focus of which is the creation of new storage capacity. The law on the use of nuclear energy, which came into force at the end of November 1995, is designed to improve state supervision of nuclear activities.

The potential risk from nuclear plants as a whole

The most important areas of the nuclear complex in the Russian Federation are: the nuclear power stations, firms involved in the nuclear fuel cycle, uranium mining and hydro-metallurgy firms, the armed forces, and the armaments industry, scientific research institutes and various enterprises in other sectors of the economy. The total number of enterprises and facilities dealing with nuclear material and thus potentially posing a threat to nuclear safety amounts to over 13 000. It is evident that in a large proportion of these enterprises the prevailing safety regulations are not being consistently adhered to. Thus the operation of nuclear facilities is associated with substantial environmental risks. Safety standards in virtually all the research reactors, for instance, are considered to be unsatisfactory. In 1993 alone the government nuclear supervisory body identified around 20 000 infringements of safety regulations. The financial problems facing nuclear facilities, inadequate supplies of technical equipment and spare parts and the increasing shortage of skilled labour have all served to exacerbate the safety deficiencies yet further in recent years.[1]

Radioactive pollution of the environment by nuclear facilities is considerable even in the course of normal operations. According to the Russian environment ministry, in 1993 the enterprises supervised by the nuclear energy ministry emitted 6.5 million m^3 of radioactive effluent into the water system, releasing radionuclides with a radioactivity of 31 000 curies. Total radioactive emissions by nuclear firms in 1993 were given as 437 000 curies (414 000 curies inert radioactive gases, 12 500 curies radon-222 and 10 500 curies tritium). In 1994 the discharge of polluted effluent by the nuclear sector rose to 6.9 million m^3; the emissions of inert radioactive gases, though, fell by 30%, of radon-222 by 36% and of tritium by 34%. Emissions of radionuclides with a long half-life, however, increased by 41%. Of the nuclear power plants it is those with the Chernobyl-type reactors (RBMK-1000) in Kursk, Smolensk and Sosnoviy Bor that emit by far the greatest quantities of radioactive substances. In 1994 they accounted for 91% of inert radioactive gases, 95% of radionuclides with a long half life and 94% of iodine-131 (cf. table 1).

Inadequate safety standards in nuclear power stations

Russia is currently operating nine nuclear power stations with 29 reactor blocks and a gross capacity of 21 242 MW; in 1995 they accounted for 11.5% of electricity output. The nuclear power stations are located as follows:

- Balakovo: 4 reactor blocks of the WWER-1000 type;
- Beloyarsk: one reactor block of the BN-600 type (fast breeder);
- Bilibino: 4 reactor blocks of the GLWR type;
- Kalinin: 2 reactor blocks of the WWER-1000 type;
- Kola: 4 reactor blocks of the WWER-440 type;

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[1] Cf. *CIS Environmental Watch,* no. 7, Monterey 1995, pp. 18.

Table 1

Radioactive Emissions from Russian Nuclear Power Stations, 1993 and 1994

Nuclear power station	Inert radioactive gases (Ci/day)		Radionuclides with long half life (mCi/day)		Iodine-131 (mCi/day)	
	1993	1994	1993	1994	1993	1994
Belakovo	4.45	1.2	0.3	0.018	0.11	0.009
Beloyarsk	0.6	1.0	–	–	–	–
Bilibino	24.1	31.0	–	–	–	–
Kalinin	2.36	2.0	0.01	0.01	0.03	0.04
Kola	13.20	6.1	0.24	0.22	0.41	0.23
Kursk	465.26	223.0	0.67	0.63	0.54	0.27
Sosnovyi Bor (near Leningrad)	102.80	136.3	6.00	4.87	6.57	3.87
Novovoronezh	2.83	1.8	0.08	0.05	0.009	0.02
Smolensk	167.0	83.0	0.64	0.2	1.20	0.9

Sources: Reports of the Russian Ministry of Environment for 1993 and 1994.

– Kursk: 4 reactor blocks of the Chernobyl-type RBMK-1000;
– Novovoronezh: 2 reactor blocks of the WWER-440 type and 1 of the WWER-1000 type;
– Smolensk: 3 reactor blocks of the RBMK-1000 type;
– Sosnovyi Bor: (near Leningrad): 4 reactor blocks of the RBMK-1000 type.

The following are currently under construction: three reactor blocks of the WWER-1000 type (Balakovo-5, Kalinin-3 and Rostov-1), one reactor block of the RBMK type (Kursk-5), two fast-breeder blocks of the BN-800 type (Beloyarsk-4 and Ural-1) and one nuclear heat plant (Voronezh-1).

Russia's nuclear power stations report annually to the International Atomic Energy Organisation in Vienna on their operating results. However, the data published refer only to those events which affect the operational status of the plant. These data suggest that operational disturbances are twice to three times as common in Russian as in German nuclear power stations. This is largely due to inadequate quality control and an outdated piloting system.

A safety study conducted by the German organisation responsible for reactor safety *(the Gesellschaft für Anlagen- und Reaktorsicherheit)* of the reactor types WWER-440 and WWER-1000 commissioned by the German government came to the conclusion that it would be practically impossible to install additional modern safety equipment in the older reactors of the WWER-440 type. These reactors have no containment, the capacity of their emergency cooling equipment is quantitatively and qualitatively insufficient, and their safety measures against fire and flooding are under-developed. Because the pressure-water reactors are frequently sited in close proximity to one another in order to economise on space, in the event of an emergency there is the likelihood that other reactors will become involved in such a way as to pose an additional security risk. Although it is in principle possible to re-equip reactors of the more modern WWER-440 type and the WWER-1000 power stations so as to bring them in line with international safety requirements, deficiencies remain in certain areas. In the case of reactors of the RBMK-1000 type, as with the older WWER-440 reactors, western experts take the view that they fail to meet the prevailing minimum international standards of reactor safety. This reactor type was built primarily with a view to its military utility. It enables plutonium to be generated for armaments production with a relatively modest input in terms of technology and construction time, and offers uninterrupted operation and high availability. The safety drawbacks, such as the lack of a containment, a leakage observation system, and adequate protection against fire were considered acceptable in the light of these advantages.

127 incidents affecting plant operation occurred in Russian nuclear power stations in 1994 (1993: 159 incidents). In February 1994, for example, the first block of the power station at Sosnovyi Bor had to be closed down due to a leak in the cooling system along a welded seam. The third reactor block of the power station on the Kola Peninsula had to be closed in March 1994 due to a leak in the cooling system. Fire broke out during a major overhaul of the third reactor block of the Beloyarsk power station in May 1994. Only in the last-mentioned case was radioactivity – according to the official reports – released into the environment. Between 1991 and 1993 12 major incidents occurred in which the site of the power station itself suffered radioactive pollution or radioactivity was emitted into the environment.

The risk to the environment posed by the plutonium-producing and nuclear fuel reprocessing plants

An environmental risk of at least equal proportions to that posed by the nuclear power stations emanates from the "nuclear fuel cycle" plants that form part of the military-industrial complex, i.e. those plants in which plutonium is produced and spent nuclear fuel is reprocessed. Three of the firms active in the nuclear fuel cycle, and in which numerous serious accidents have already occurred, are particularly important in this context:

- the "Mayak" production combine, whose plants are located in Ozersk (formerly known as Chelyabinsk-65);
- the Siberian chemicals combine located in Seversk (formerly called Tomsk-7);
- the Krasnojarsk mining and chemicals combine with its nuclear plants in Zheleznogorsk (formerly called Krasnoyarsk-26).

The production combine "Mayak" commenced operations in 1948. It was the first enterprise in the former Soviet Union in which weapons-grade plutonium was produced. For this purpose five graphite-moderated reactors were built, all of which have since been shut down (cf. table 2). Currently plutonium is being produced there in one light-water reactor and one heavy-water reactor. Since 1977 spent fuel rods from WWER-440 and fast breeder reactors as well as spent nuclear fuel from the Soviet/Russian navy have been reprocessed there. Numerous serious incidents have occurred in the Mayak nuclear plants since the complex entered service. In the course of operations so far this enterprise has released into the environment radioactive substances with a cumulative radioactivity of 150 million curies, three times the volume emitted during the Chernobyl disaster. By 1956 76 million m^3 of liquid nuclear waste and radioactive effluent had been dumped in the river Tetsha. Levels of strontium-90 of more than 1 000 times the natural level have been recorded in places. In spite of the closure of the five graphite-moderated reactors, the nuclear plants still in operation at the site pose a serious threat to the environment. Measurements conducted in 1992, for instance, indicated that the incidence of plutonium pollution in the environment has increased sharply since the reprocessing plant was commissioned. At the edge of the sanitary protection zone of the site, the concentration of plutonium in the soil reaches 28 000 Bq/m^2 and up to 6 000 Bq/m^2 within a radius of 40 km: the maximum permissible level is 3 700 Bq. Moreover, small-scale incidents have occurred repeatedly over recent years. In just two years (1993 and 1994) the environment ministry reports list four occasions on which radioactivity was released into the environment.

The nuclear complex of the Siberian chemical combine in Seversk (Tomsk-7), which commenced operations in 1953, is currently the largest site in Russia for the production of weapons-grade plutonium and enriched uranium. Of the five graphite-moderated reactors constructed here, two are still operational, producing weapons-grade plutonium and providing the city of Tomsk with electricity and district heat. Radioactive pollution of the environment by the Tomsk-7 plants is substantially lower than that in the environs of Chelyabinsk-65, although here, too, certain areas suffer from high plutonium concentrations. Moreover, in the bed of the River Tom high levels of Cobalt-58, Chromium-51 and zinc-65 pollution have been recorded. On 6 April 1993 the most serious accident since the reactor catastrophe at Chernobyl occurred in this nuclear complex. In the course of a process to separate plutonium and uranium from spent nuclear fuel rods, a tank containing almost 9 000 kg of uranium and 310 g of plutonium exploded, following the failure of the safety system, due to excessive pressure and temperature. As a result of the accident various radionuclides with a short half life (in particular ruthenium-106, niobium-95 and zirconium-95) with a total radioactivity of between 40 and 50 curies were released into the environment. An area of 100 km^2 was contaminated with radioactivity.[2]

Weapons-grade plutonium is also still being produced on the site of the Krasnoyarsk mining and chemicals combine (Krasnoyarsk-26) in one of a total of three graphite-moderated reactors. The construction of a

[2] E. Kayukov, W. Wallace, Anatomy of an Accident, in: *CIS Environmental Watch,* no. 4, Summer 1993, pp. 57.

Table 2

Plutonium Production in Russia

City	Reactor	Last year of operation	Plutonium output
Ozersk Ozersk (Chelyabinsk-65)	Graphite-moderated reactors		
	A	1987	Total plutonium output to 1990: 58.3 t
	IR	1987	
	AV 1	1989	
	AV 2	1990	
	AV 3	1990	
	Other reactor types		
	Light water reactor	Still in operation	Total plutonium output to the end of 1992: 14.7 t
	Heavy water reactor	Still in operation	
Zheleznogorsk (Krasnoyarsk-26)	Graphite-moderated reactors		
	AD	1992	Total plutonium output to 1990: 44.7 t
	ADE-1	1992	
	ADE-2	Still in operation	
Seversk (Tomsk-7)	Graphite-moderated reactors		
	I 1	1990	Total plutonium output to 1990: 73.7 t
	I 2	1990	
	ADE-3	1992	
	ADE-4	Still in operation	
	ADE-5	Still in operation	

Source: A. V. Yablokov (Ed.): Plutonij v Rossii. Ekologija, ekonomika, politika. Moscow 1994, p. 50.

reprocessing plant for the spent fuel rods of the WWER-1000 reactors and a production plant for MOX fuel is planned for the site. Emissions of effluent by the plant have contaminated the River Yenisei with numerous radioactive materials, among them chromium-51 and caesium-137. In 1993 a pollution level of up to 1.4 curies/km^2 was measured in the earth on the banks of the Yenisei. At various points the river water and the banks are polluted with plutonium-238 and -239. In the area around the combine the earth was found to be polluted with cobalt-60, europium-152 and zinc-65.[3]

Despite the enormous potential dangers, the safety provisions in the "fuel cycle" enterprises are consistently inadequate. The machinery used to monitor technical processes is outdated and unreliable. Automatic systems to test for radioactive pollution in the area around the plants are lacking.

The threat to the environment from radioactive waste

The storage of radioactive waste poses a considerable threat to the environment. The risks pertain both to the possibility of serious accidents (e.g. due to explosions) and to the long-term release of radioactivity. The total radioactivity of dumped nuclear waste and spent fuel amounts to around 7 billion curies (nuclear waste: 2.3 billion; spent fuel 4.65 billion curies; cf. tables 3 and 4). This represents around 100 times the radioactivity released during the Chernobyl disaster.

The largest nuclear waste disposal site is located at the "Mayak" production combine near Chelyabinsk. According to figures published by the Russian environment ministry the nuclear waste stored here has a radioactivity of 1.5 billion curies. To a significant extent this waste consists of high-level sediments and solutions stored in special containers. Medium-level liquid nuclear waste with a radioactivity of 120 million curies has been dumped in Lake Karatschai.

An underground storage site is located on the premises of the Siberian chemical combine in Seversk (Tomsk-7). It contains around 40 million m^3 of radioactive sediments, the total radioactivity of which is put at up to 1 billion curies. Some of this waste is high-level and contains plutonium; according to estimates this sediment contains several dozen kilogrammes of plutonium. In addition radioactive sediments and solid nuclear waste with a radioactivity of 125 million curies are deposited in some 50 places on the site of this combine, in some cases in open dumps.

The third large nuclear waste dump is situated on the site of the Krasnoyarsk mining and chemical combine near Zheleznogorsk (Krasnoyarsk-26). According to official figures 1 000 t of spent fuel rods from WWER-1000 type reactors with a radioactivity of 500 million curies are stored here. In 1993 the nuclear inspectorate put the volume of nuclear waste stored at the Krasnoyarsk-26 site at 4 million m^3, with a radioactivity of 700 million curies.

Even in the eyes of Russian experts, the safety standards in the disposal sites for nuclear waste run by "fuel cycle enterprises" are inadequate to preclude the risk of serious radioactive accidents. The greater part of the radioactive waste is located in temporary storage facilities on the site of the various enterprises. Many of the storage sites were constructed in the 1950s and 1960s, and most of them fail to meet the prevailing safety standards. Environmental analyses were not conducted when the dumps were constructed. The dumps were often taken into service and operated without technologically based security measures, detailed construction plans and without the approval of supervisory institutions. In some enterprises radioactively contaminated waste is being stored in the open air, allowing radioactivity to be released into the environment. Nuclear waste with a radioactivity of 700 million curies has been dumped in open special basins or in rivers and lakes, so that there can be no guarantee that radioactive particles are not released into the environment.

The temporary storage facilities located at Russian nuclear power stations hold 6 100 t of spent fuel from RBMK reactors (radioactivity: 3 billion curies) and 1 100 t from WWER reactors (radioactivity: 900 million curies). No concept for the final storage of spent fuel has as yet been developed. Also stored at the power stations are 286 000 m^3 of liquid and solid radioactive waste (radioactivity: 44 000 curies), most of which is low-level and medium-level in nature. High-level nuclear waste accounts for less than 1% of the total. Over the next 15 years the nuclear power stations are calculated to produce 700 000 m^3 of liquid and 500 000 m^3 of solid nuclear waste; no comprehensive plan for its storage and processing exists at present. A number of temporary storage facilities in certain power stations have already virtually reached capacity (cf. table 5), so that in the event of an accident it would not be possible to store large quantities of contaminated material. Moreover, full use cannot be made of the storage facilities for solid nuclear waste at present because in most cases the waste is not sorted by type and material.

The prevailing security requirements and health and safety directives are particularly frequently infringed in the treatment of radioactive sediments from nuclear power stations. Frequently this leads to an increased radioactive contamination of the buildings and the earth on the site and to the release of radioactivity into the environment. The inadequate safety standards and the failure to adhere to safety regulations have been revealed by a number of accidents in connection with the storage of radioactive waste in Russian nuclear power stations.

[3] A. Bolsunovsky, Broken Swords: Military Pollution in Krasnoyarsk, in: *CIS Environmental Watch,* Number 4, Summer 1993, pp. 4.

Table 3

Nuclear Waste (excl. spent fuel) in Russia

Source of radioactive waste	Type of radioactive waste	Quantity	Activity in curies	Location and nature of storage
Ore mining and processing	Sediments and slack Low-level waste	100 mill. m^3	180 000	Various disposal sites
Uranium enrichment and production of fuel rods	Liquid and solid nuclear waste Low-level waste	1.6 mill. m^3	4 000	Storage on company premises
Nuclear power stations	Low- and medium-level liquid and solid nuclear waste	286 000 m^3	44 000	Temporary storage facilities at the power stations
Nuclear-chemical complex (reprocessing of spent fuel, production of weapons-grade plutonium)	Liquid high-level waste	25 000 m^3	570 mill.	Steel containers. Storage at the "Mayak" production combine in Ozersk (Chelyabinsk-65)
	Liquid radioactive waste	46 mill. m^3	800 mill.	Underground storage at the mining and chemical combine in Zhelznorgosk (Krasnoyarsk-26) and the Siberian chemical combine in Seversk (Tomsk-7)
	High-level waste enclosed in glass	9 500 m^3	200 mill.	Storage at the "Mayak" production combine
	Low- and medium-level liquid waste	400 mill. m^3	700 mill.	Special containers, special basins, water system
	Low- and medium-level solid waste	100 mill. m^3	12 mill.	Storage facilities sealed in concrete on company premises
Navy	Low-level liquid waste	14 000 m^3	180	Ships and naval bases
	Low-level solid waste	13 000 m^3	800	Storage facilities sealed in concrete
Shipbuilding industry	Low-level liquid waste	2 500 m^3	500	Ships and naval bases
	Low-level solid waste	1 500 m^3	100	Storage facilities on company premises
Merchant navy fleet	Low-level solid and liquid waste	1 790 m^3	211	Coastal sites
	High-level solid waste	100 m^3	20 000	Coastal sites
Other radioactive waste	Liquid and solid nuclear waste	200 000 m^3	2 mill.	16 storage facilities of the "Radon" special combine
Total radioactive waste (excl. spent nuclear fuel)		More than 600 mill. m^3	Approx. 2.3 bill.	

Sources: Report of the Russian Ministry of Environment for 1994. Moscow 1995, pp. 89. Sobranie zakonodatel'stva Rossijskoj Federacii no. 44/1995, pp. 7812.

Table 4

Storage of Spent Nuclear Fuel in Russia

Organisation responsible	Origin of the spent nuclear fuel	Quantity	Activity in curies	Location and nature of storage
		Spent nuclear fuel		
Minatom Rossii	Spent fuel from RBMK-1000 reactors	6 100 t	3.1 bill.	Temporary storage sites at the Sosnovyi Bor, Kursk and Smolensk nuclear power stations
	Temporarily stored spent fuel from WWER-440 and WWER-1000 reactors	1 100 t	900 mill.	Temporary storage facilities at various nuclear power stations
	of which:			
	Spent fuel from WWER-1000 reactors	486 t	380 mill.	Temporary sites at the Kalinin and Balakovo nuclear power stations
	Finally stored spent fuel from WWER-1000 reactors	1 000 t	500 mill.	Storage facilities at the Zheleznogorsk mining and chemical combine (Krasnoyarsk-26)
	Finally stored spent fuel from WWER-440 reactors	212 t	67 mill.	Storage facilities at the "Mayak" production combine
	Spent fuel from BN 350/600 reactors	67 t	20 mill.	ditto
	Spent fuel from AMB reactors	116 t	10 mill.	ditto
	Spent fuel from KS-150 reactors	64.5 t	5 mill.	ditto
	Spent fuel from JaEU reactors	5.5 t	3 mill.	ditto
	Spent fuel from research reactors	.	1 mill.	Storage facilities at the research institutes and on company premises
Navy	Spent fuel from JaEU reactors	30 t	15 mill.	Naval bases and ships
Mintrans Rossii	Spent fuel from JaEU reactors	10 t	17 mill.	Coastal storage facilities and ships
Total spent fuel		Approx. 8 000 t	4.65 bill.	

Sources: Report of the Russian Ministry of Environment for 1994. Moscow 1995, p. 89. Sobranie zakonodatel'stva Rossijskoj Federacii no. 44/1995, pp. 7812.

Table 5

Radioactive Waste (excl. spent fuel) Stored at Russian Nuclear Power Stations

Nuclear power station	Type of radioactive waste	Storage capacity in m^3		Quantity of stored waste at year's end in m^3		Capacity utilisation in %	
		1993	1994	1993	1994	1993	1994
Balakovo	Radioactive sediments	3 600	3 600	2 846	2 570	79.0	71.4
	Solid nuclear waste	18 684	18 684	4 587	4 587	24.5	24.5
Beloyarsk	Radioactive sediments	6 400	6 400	5 231	5 339	81.7	83.4
	Solid nuclear waste	18 800	18 800	14 601	14 601	77.6	77.6
Bilibino	Radioactive sediments	1 000	1 000	828	763.5	82.8	76.3
	Solid nuclear waste	3 000	3 000	1 854	1 854	61.8	61.8
Kalinin	Radioactive sediments	3 600	3 410	3 500	2 690	97.2	78.9
	Solid nuclear waste	6 000	6 000	3 881	3 881	64.6	64.6
Kola	Radioactive sediments	7 806	8 526	6 397	6 782	81.9	79.5
	Solid nuclear waste	19 473	19 473	5 881	5 881	30.2	30.2
Kursk	Radioactive sediments	63 000	63 000	29 500	30 395	46.8	48.2
	Solid nuclear waste	27 800	27 800	27 570	27 570	99.1	99.1
Sosnovyi Bor (near Leningrad)	Radioactive sediments	21 400	17 020	18 445	11 519	86.2	67.7
	Solid nuclear waste	24 000	24 000	14 145	14 145	58.9	58.9
Novovoronezh	Radioactive sediments	18 591	17 331	6 548	5 813	35.2	33.5
	Solid nuclear waste	39 783	39 783	27 619	27 619	69.4	69.4
Smolensk	Radioactive sediments	19 500	19 400	12 100	11 110	62.0	57.3
	Solid nuclear waste	14 800	14 800	9 500	9 500	64.1	64.1

Sources: Report of the Russian Ministry of Environment for 1993. Moscow 1994, p. 69. Report of the Russian Ministry of Environment for 1994. Moscow 1995, p. 92.

In 1985, for instance, radioactively contaminated water entered the water table over an extended period from the storage site for radioactive sediments at the Novovoronezh nuclear power station. In 1991 radioactive waste on the site of the same power station contaminated the environment with strontium-90 and caesium-137. Due to a leak in a dump for nuclear sediment at the Kola nuclear power station in 1989, the water table was polluted with cobalt-60. In September 1992 the site of the Kola power station was contaminated with radioactive water that leaked out of a defective tank. The defect was caused by the poor quality of the welding and material fatigue, which led to deformation of the tank, gaps along the welded seams and in the metal plates of the tank. In July 1992 the removal of earth on the site of the Kalinin power station revealed an area contaminated with radiation. In December 1992 a building was flooded with radioactive water during an operation to pump radioactive sediment due to the negligence of the operating personnel. Due to leaks in the building's foundations, the water entered the earth underneath the storage site.

Large quantities of contaminated waste (slack) are produced during the mining and processing of uranium and thorium ore. While the storage of such waste poses little risk of accidents, qualitatively inadequate storage facilities mean that the risk of negative effects on the groundwater and for public health cannot be precluded. The total area required for the storage of the waste generated by uranium and thorium mining is reckoned to amount to 60 000 hectares. 100 million m^3 of waste with a radioactivity of 180 000 curies are stored here. Currently the only company involved in the hydrometallurgical processing of uranium ore is located in Priargunsk (in the Chita district). 43 million m^3 of waste have been dumped here; 60% of the storage capacity of the site has been exhausted.

The data on the volume and the location of the radioactive waste generated by research institutions and other facilities are patchy. Up until the 1960s, for example, nuclear waste was in some cases dumped on local authority household waste dumps; even now radioactive contamination of the earth can be identified at such sites. Given that such practices are unlikely to have been restricted to establishments in Moscow, it must be assumed that the statistics on the volume of nuclear waste deposited in the past are highly inaccurate.

The Kurchakov Institute for Atomic Energy in Moscow has been in existence since the 1940s. Nuclear waste with a radioactivity of 65 000 curies has been dumped on the Institute site. The dump fails to meet modern safety requirements. Since 1973 the radioactive waste produced by the Kurchakov Institute (100 to 150 t p.a.) has been transferred to a special deposit site of the scientific production combine "Radon" in Moscow. The high- and medium-level nuclear waste produced by the energy-physics institute in Obninsk (in the Kaluga district) is deposited on the Institute site. The low-level, liquid radioactive waste has until now been released into the River Protwa (a tributary of the Oka). A considerable volume of radioactive waste with a radioactivity of 1 million curies is located on the site of the scientific research institute for nuclear reactors in Dimitrovgrad (in the Ulyanovsk district).

As the financial situation of these institutes has deteriorated, the safety risks inherent in the storage of the waste produced have increased, because investment projects to improve safety standards and to construct new storage capacities have in many cases been postponed. A central problem lies in the fact that the atomic energy ministry has as yet failed to reach a decision on the reprocessing and utilisation of the spent fuel elements stored by the institutes. Between 80 and 90% of the storage capacity at the three institutes mentioned above is required for storing fuel rods, technology for the further utilisation of which does not exist at present.

Most of the radioactive waste produced by the remaining sectors of the Russian economy is transported to the storage sites run by 16 regional waste treatment combines. The volume of nuclear waste stored here is given as 200 000 m^3, with a combined radioactivity of 2 million curies. The waste treatment combines are responsible for collecting, transporting and storing the radioactive waste of their clients. They are required to guarantee radioactive safety at all stages of the waste treatment process. The largest of these combines is the "Radon" scientific production combine located in Moscow. Although the safety standards at the Moscow disposal site are classified as satisfactory, the Russian environment ministry takes the view that the other sites fail to meet the prevailing requirements. In some cases the capacity of the site has already been reached and in others only very limited capacity remains, so that new land must be made available for additional disposal sites.

Radioactive waste and the "nuclear legacy" of the Russian navy and deep-sea fleet

The nuclear facilities of the Russian navy and other ships pose a significant danger to the environment. In mid-1994 there were 235 Russian ships and submarines with a total of 407 nuclear reactors. The operation of these reactors generates about 20 000 m^3 of liquid and 6 000 m^3 of solid nuclear waste p.a. Nuclear waste with a radioactivity of 21 000 curies is stored in disposal sites, most of which were built in the 1960s and which are inadequate in technical terms. At least 6 500 containers, 17 ships or submarines and 155 other large containers containing solid nuclear waste (radioactivity 15 500 curies) and radioactive sediments and solutions with a radioactivity of 25 000 curies have been sunk in the seas north of Russia (Kara Sea, Barent Sea), particularly around the coast of the Novaya Zemlya Archipelago. A particularly serious risk is posed by the six nuclear submarine reactors and one reactor from the ice-breaker "Lenin" which lie at a depth of between 20 and 300 metres; these reactors still contain nuclear fuel and, at the time of sinking, contained 2.3 million curies of radioactivity. Liquid and solid nuclear waste was also transported to far-eastern waters, whereby the radioactivity of the liquid waste is reported to amount to more than 12 000 curies (cf. table 6).

In 1993 and 1994 121 nuclear submarines were decommissioned (Northern Fleet: 70; Pacific Fleet: 51). In the case of just 42 of these submarines were the reactors processed (Northern Fleet: 18; Pacific Fleet: 24). Reactors containing nuclear fuel remain in the other 79 submarines. Nine of these submarines are concentrated in the area around Severodvinsk (in the district of Archangelsk). The normal operating life of the reactors and their active zones has expired; technical monitoring with the appropriate meters is lacking; no provisions have been made for regular nuclear-chemical analyses of the fuel rods. The state of a number of reactors, in particular of their active zones, was described as unacceptable at the time the submarines were decommissioned. In view of the lack of supervision and maintenance and on-going corrosion, the state of these reactors has almost certainly deteriorated further since then. In the case of 40% of the decommissioned submarines, no repairs have been conducted for the last ten years; 4 submarines show signs of serious damage.

The waste treatment problems facing the Russian Navy go beyond those associated with the nuclear facilities of decommissioned submarines. Overall the fleet has a waste treatment requirement for spent fuel rods with a radioactivity of 32 million curies. Storage capacities have been exhausted. In technological terms the existing waste disposal sites meet neither the requirements of Russian law nor agreed international standards. In many cases containers containing solid nuclear waste are stored in the open. Many of the fuel rods are loaded on to ships, some of whose cargo holds are damaged. The waste contains high-level and toxic transuranium elements. Storage capacity is lacking to ensure the safe disposal of such waste. Moreover, the transport of such waste would pose substantial risks in the light of the frequent rail accidents and the obsolete containers used; the risk of a major accident with the release of radiation is extremely high.

The Russian government's nuclear policy

In order to reduce the environmental risks emanating from nuclear waste and spent nuclear fuel, in October 1995 the Russian government adopted a long-term programme to run from 1996 to 2005. The total budget for the programme runs to 8.7 trillion rouble (at 1996 prices), although for 1996 expenditure of just 162 billion rouble is planned. Among the measures to be implemented are the following:

- to develop new security guidelines for dealing with nuclear waste and spent nuclear fuel and to set up appropriate monitoring systems;
- to create the technical plant necessary to process and utilise nuclear waste produced by uranium mining and processing;
- to improve the safety standards in existing and to create new temporary storage sites for nuclear waste and spent fuel;
- to develop technology with which to treat the radioactive waste generated by decommissioned reactors from nuclear power stations, plutonium production, research institutes and the navy;
- to close and isolate unsafe disposal sites posing an environmental threat;
- to treat areas contaminated with radioactivity; and
- to set up final storage sites for radioactive waste, among others on the Novaya Zemlya Archipelago and on the sites of the nuclear complexes at Chelyabinsk and Krasnoyarsk.

A new law on the use of nuclear energy came into force at the end of November 1995. This law pertains to all activities linked to the civilian and military use of nuclear energy (including the storage of nuclear waste and spent fuel). The development and production of nuclear weapons, on the other hand, are not covered by the law.

Under the law all nuclear plants used for military purposes and all nuclear materials and radioactive waste are the property of the Russian Federation. In principle nuclear plants for civilian use are also owned by the state, although certain exceptions are provided for. The views of local authorities are to be considered in establishing nuclear plants on their territory. Citizens in the areas affected have the right of information on the safety of the nuclear plants and the extent to which their region is contaminated by radioactivity. The enterprises running nuclear plants are liable for any damage resulting from radiation. Safety analyses and environment compatibility studies are required before new plants are built. All nuclear plants have been put under government supervision. In the event of infringements of the

Table 6

Data on the Radioactive Pollution of the Seas by the Soviet Union/Russia Since the Start of the 1960s

Sea and region	Source of radioactive pollution	Nature and quantity of the source of radioactive pollution	Water depth in m	Total radioactivity in curies
Northern waters of the Atlantic Ocean	Liquid nuclear waste			25 000
of which:				
Barents Sea		190 000 m^3	50 to 300	12 150
Kara Sea				8 500
Other waters of the Arctic Sea				3 100
Kara Sea	Solid nuclear waste and other objects polluted with radiation	Almost 32 000 m^3. 6 508 containers with radioactive waste, 17 ships, 154 other objects	12 to 380	15 500
Northern Arctic Seas	Reactors with nuclear fuel	5 sunken vessels with a total of 7 reactors containing nuclear fuel	20 to 300	At the most 2.3 mill.
Northern Arctic Seas	Reactors without nuclear fuel	5 sunken vessels with a total of 10 reactors none of which contain nuclear fuel	20 to 50	Approx. 100 000
Pacific Ocean and Sea of Japan	Liquid nuclear waste	Approx. 125 000 m^3	1 400 to 3 700	Approx. 12 350
Pacific Ocean and Sea of Japan	Solid nuclear waste	Almost 22 000 m^3. 6 642 containers with radioactive waste, 38 ships, around 100 other objects		
Atlantic and Pacific Ocean	Sunken nuclear submarines			650 000
Northern Arctic Ocean	Discharges of radioactive waste vie the rivers Ob' and Yenisei			Several 1 000

Source: Zelenyj mir no. 13/1993, no. 15/1993 and no. 16/1993.

law on nuclear safety, the culprits can be held responsible through disciplinary, administrative or criminal proceedings.

Summary

Russian nuclear plants constitute a considerable danger to the environment and the population. Accidents on the scale of the Chernobyl disaster cannot be precluded given the still inadequate safety standards. The inadequacies in terms of safety are particularly acute in the WWER-440 and RBMK nuclear reactors, the "fuel cycle" enterprises and in research institutes operating outdated plants. In addition, large quantities of nuclear waste are being stored on sites that are inadequate in various ways. A large volume of nuclear waste has been dumped at sea and into rivers in an environmentally irresponsible fashion.

There are no grounds for expecting an improvement of the safety situation in the nuclear field in the short term. The older power stations cannot be re-equipped. Their closure is inevitable, but has met with stiff opposition. The construction of new nuclear power stations with satisfactory safety standards is only possible in the longer term and requires enormous capital expenditure. The environmental risks resulting from the operation of the existing plants for plutonium production and the reprocessing of fuel rods cannot be significantly reduced by simple re-equipment measures. No concept for the final storage of nuclear waste exists at present. Given the large quantity of nuclear waste in Russia, the creation of sufficient storage capacity for safe temporary storage would also require major investment. Although organisational measures, such as an improved nuclear inspectorate, could make some contribution to averting the nuclear danger, on their own they can make no impact on the serious potential risk caused by technological deficiencies.

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