Table 5 presents a summary radionuclide budget of the Barents and Kara Seas ecosystem. Despite the uncertainty in its precise assessment, referred to above, we believe that the order of values objectively reflects the situation existing at the time of RW disposal.

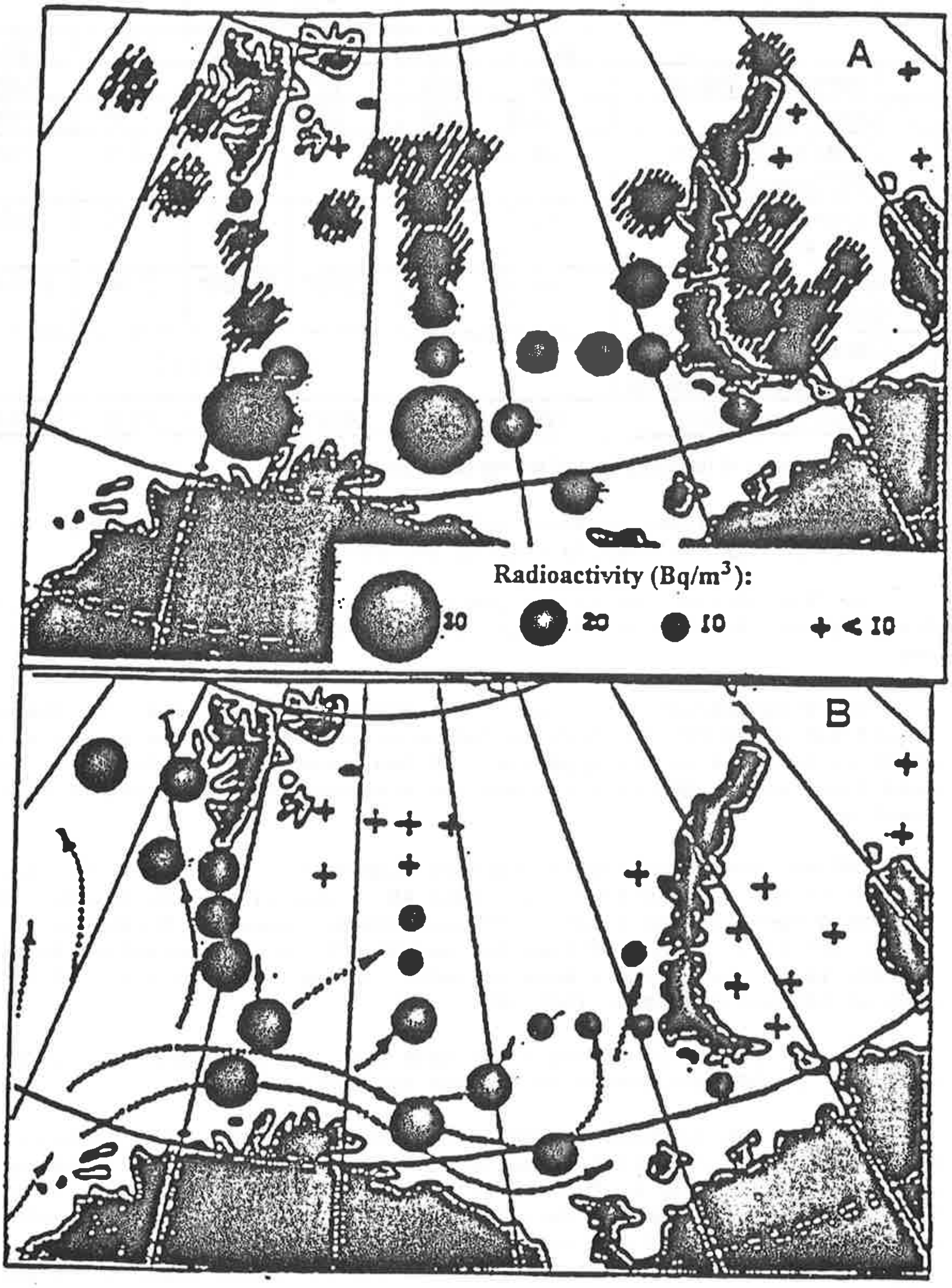


Figure 7. Distribution of Radioactivity in Surface Waters of the Barents, Kara and Greenland Seas. A: Distribution of radioactivity (^{137}Cs), based on 1982 data; B: Hypothetical distribution of radioactivity of surface waters of the Barents and Kara Seas if the source of the radioactivity had been transported by currents from the northern seas. Hatching indicates areas of high and low concentrations (near Spitzbergen Island) that cannot be explained by transport from the Arctic Sea alone. Arrows: directions of major currents.

Table 5. Anthropogenic Radionuclide Budget of the Barents and Kara Seas Ecosystem, 1961-1990

Source of Long-Lived Radionuclides	Barents Sea		Kara Sea		Ecosystem as a Whole		
	Activity		Activity		Activity		Contribution
	kCi	TBq	kCi	TBq	kCi	TBq	%
1. Atmospheric fallout	100	3700	70	2600	170	6300	6.2
2. River runoff	6.0	200	33.0	1200	39	1400	1.4
3. Contributions from Gulf Stream system	200	7400	—	—	200	7400	7.3
4. Dumping of solid and liquid RW	13	480	16	600	30	1100	0.7
5. Sinking of SRW with SNF	—	—	2300*	85300*	2300*	85100	84.4
6. Underwater and surface nuclear explosions	...(No data)...						
Total (upper limit)	319	11780	2419	89700	2739	101300	100

*—Expert estimate of the upper limit of activity at the time of disposal.

2.3.2 Disposal sites, volumes, and total activity of radioactive waste dumped by the USSR in the Far Eastern Seas

In this section, as in the previous one, we consider the data on the discharge and dumping of low- and intermediate-level liquid and solid RW at sea.

The geographical locations of officially designed areas for disposal of liquid and solid RW are shown in figure 8, and descriptions of the areas are given in table A4 of the Appendix. Of ten areas used for disposal, only Area 4 satisfied IAEA requirements for disposal of RW in terms of depth and location.

LRW was dumped in the far eastern seas by the USSR from 1966 through 1991 in five of the designated areas (table A6 of Appendix). By volume, most of LRW was dumped in Area 7 (near the southeastern coast of Kamchatka Peninsula), and by activity, in Area 9 (Sea of Japan). The annual variation in LRW dumping in the far eastern seas is shown in figure 9. In terms of activity, most of LRW was dumped in 1986-1987.

The available data demonstrate that a total of at least 12,335 Ci (456 TBq) of LRW was dumped in the far eastern seas.

Data on the disposal of low- and intermediate-level SRW in the far eastern seas are presented in table A7 of the Appendix. Such dumpings were carried out regularly in four of 10 designated areas from 1986. In volume of SRW dumped, Area 9 (Sea of Japan) is noteworthy, and in total activity of low- and intermediate-level SRW dumped Area 8 off the southeastern coast of Kamchatka should be noted. According to the available data, the total activity of intermediate- and low-level SRW dumped by the USSR in specially designated areas in the far eastern seas is 6,851 Ci (254 TBq). This activity is contained in 6,868 sunken containers, 38 sunken ships, and over 100 other individual sunken large objects.

The variation in dumping of low- and intermediate-level SRW in the far eastern seas is shown in figure 9. These data indicae that the maximum amount of such SRW (in terms of activity) was dumped in the far eastern seas in 1975 and 1985.

Table 6 presents all available data on the disposal of NS reactors in the far eastern seas.

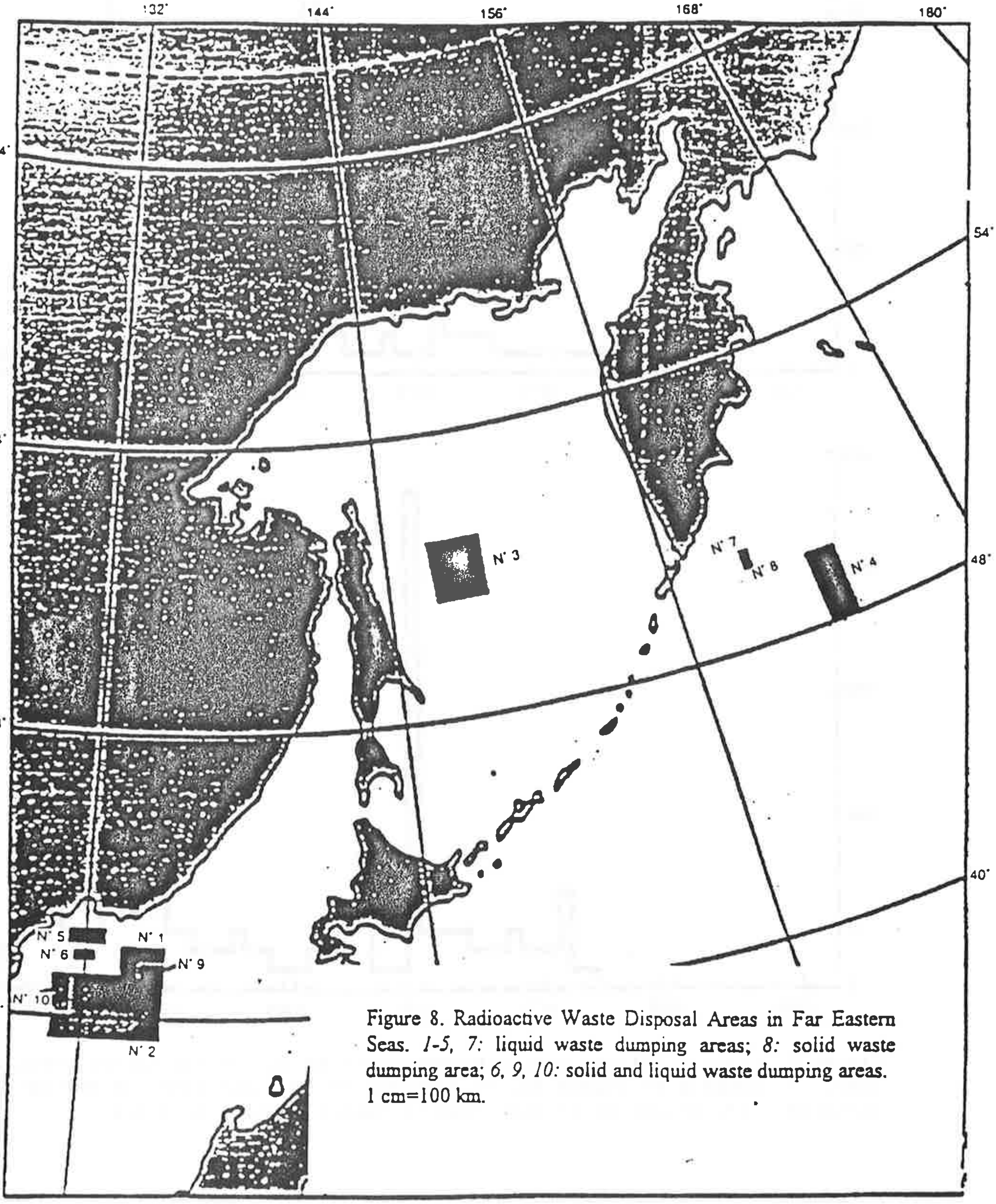
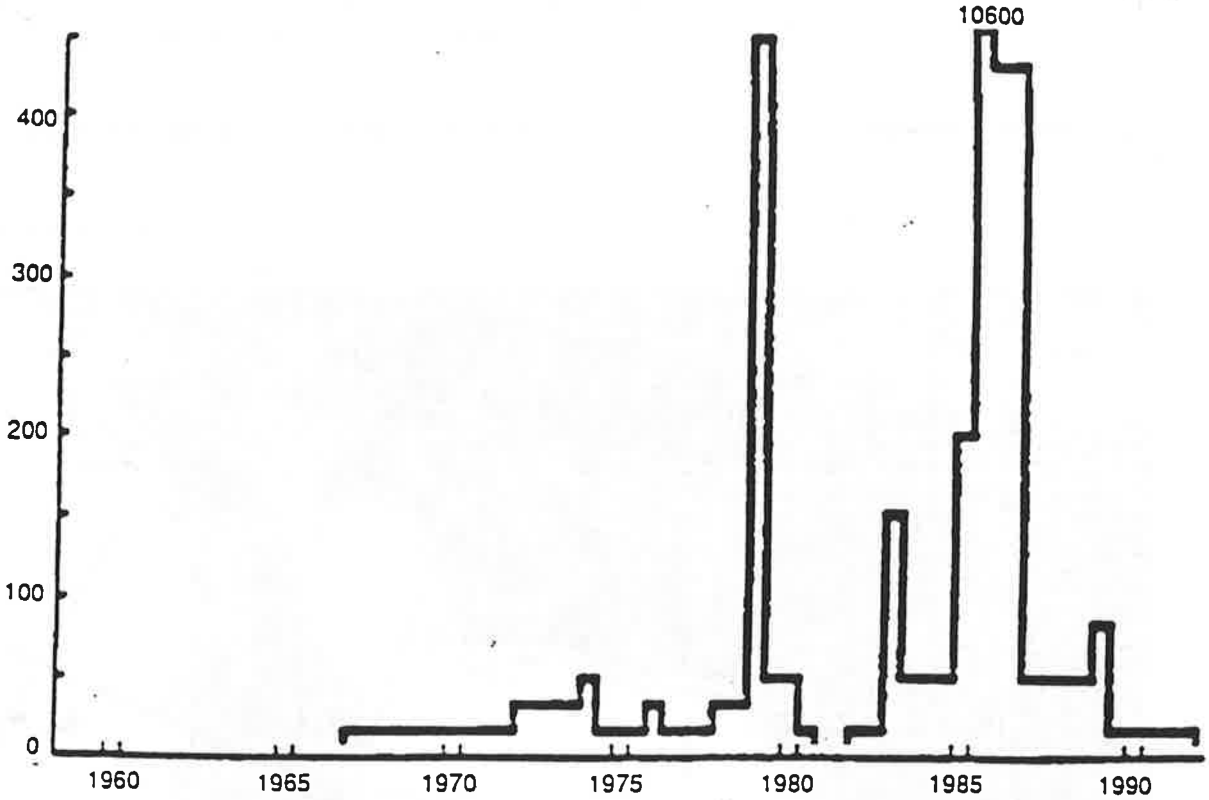


Figure 8. Radioactive Waste Disposal Areas in Far Eastern Seas. *1-5, 7:* liquid waste dumping areas; *8:* solid waste dumping area; *6, 9, 10:* solid and liquid waste dumping areas. 1 cm=100 km.



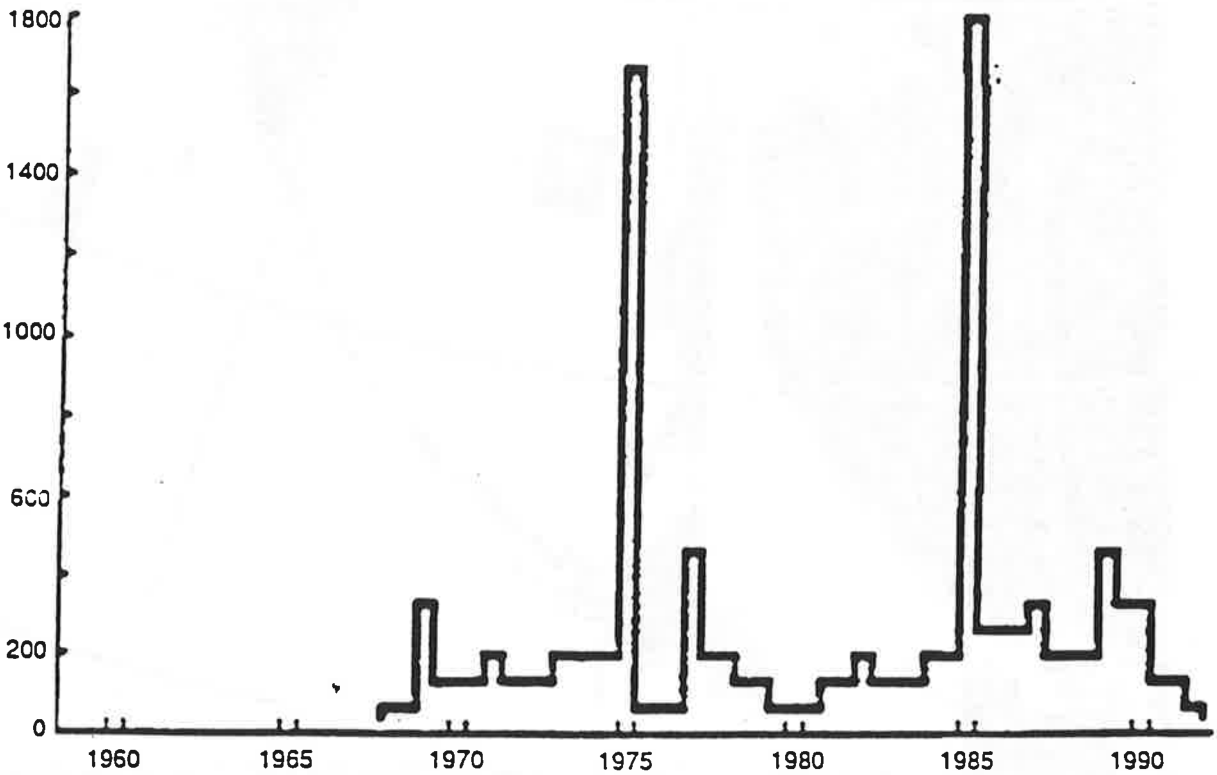


Figure 9. Rate of Disposal of Radioactive Waste in the Far Eastern Seas by Year. A: dumping of liquid RW; B: disposal of low- and intermediate-level solid RW. Bar height is proportional to annual dumping activity.

Table 6. Disposal of Reactors with Spent Nuclear Fuel in Place in the Far Eastern Seas

Object	Coordinates, Year	Depth, meters	Total Activity,* Ci (TBq)	Radio-nuclide Content	Description of Protective Barriers
Two NS reactors	40°10' N, 131°15' E, Sea of Japan (Area 10), 1978	3000	46.2 (1.7)	Unclear	Lead-lined metal container
Core plate from the reactor of NS No. 714	52°30' N, 159°9' E, east of Kamchatka, 1989	2500	70 (2.6)	Unclear	Lead-lined metal container
Total: 2 reactors and one shield assembly			116 (4.3)		

* At the time of disposal.

Thus, according to available data, the activity of RW dumped by the USSR in the far eastern seas is distributed as follows:

Liquid RW	12,337 Ci (456 TBq)
Intermediate- and Low-Level Solid RW	6,112 Ci (225 TBq)
Solid RW (induced activity in two reactors and one shield assembly without SNF)	116 Ci (4.3 TBq)
Total	18,565 Ci (685.3 TBq)

No dumpings of reactors with SNF in place were carried out in the far eastern seas. In addition to the above data, we should include information on RW that entered the waters of the Sea of Japan as a result of a radiation accident aboard an NS in Chazhma Bay (see section 3), the loss of a 350 kCi RTG radionuclide power supply during its transportation near Sakhalin Island, and radioactive contaminations resulting from the atmospheric fallout and river runoff.

Considering the vast areas of water of the far eastern region, the liquid and solid RW dumped by the Pacific Fleet do not appear to be more than several percent in the budget of man-made radioactive contamination.

2.3.3. Total amount of radioactive waste dumped by the USSR at sea

On the basis of the accumulated documentary data and expert findings, the total activity of all RW discharged and dumped by the USSR in the seas adjacent to the Russian territory may be estimated at 325 kCi (12 PBq). Experts estimate the upper limit of the activity of RW dumped at up to 2.5 MCi(92 PBq).

In addition to the data on RW dumped in the northern and far eastern seas (see tables 2-6), we should include information on radioactive materials that entered the marine environment incidentally. These materials include:

- radioactive materials aboard NSs that sank as a result of accidents (including nuclear reactors and NWHs);

- radioactive materials aboard other objects that suffered accidents and fell into the world's oceans (satellites, nuclear reactors, NWHs that fell into the sea due to aircraft accidents or failed launches);

- radiation sources that accidentally fell into the ocean;

- LRW that accidentally entered the sea from shore storage facilities as a result of leaks;

- products of underwater and surface nuclear explosions.

There is no adequate information with regard to any of the items listed above, so its collection is a priority matter. The available data on the above sources of radioactive contamination of the world's oceans are shown in table 7.

Table 7. Information on Radioactive Objects that entered the World's Oceans due to Accidents with Soviet Submarines

Object	Location, Date	Depth, meters	Maximum Reactor Activity, kCi	NWH Activity at Time of Accident, Ci	Notes**
Diesel submarine	Pacific Ocean, Hawaiian Islands, April 1968	6,000	None	1.0	Bow section with NWH's raised in August 1974 by *Glomar Explorer* (activity 0.4 kCi)
Nuclear submarine	Bay of Biscay, 4/8/1970	4,000	250*	0.8	2 nuclear power plants
Nuclear submarine	Bermuda Islands, 10/6/1986	5,500	250*	3.8	2 nuclear power plants
NS *Komsomolets*	Norwegian Sea, 4/7/1989	1,685	150*	0.43	1 nuclear power plant
Total			650	6.03	5 nuclear power plants

* Expert estimate (at time of sinking).

** The world's oceans contain a total of 50 NWHs belonging to various countries [22].

The total activity of all RW sources that entered the world's oceans from the USSR territory cannot be accurately determined at present as there is no certainty that every source of radioactive contamination of the ocean without exception was taken into account. Tentative data, largely of an expert nature, are presented in table 8.

2.4 Radioactive waste disposal in the seas of the Russian Federation

The disposal of RW at sea, long practised in the USSR, was continued in 1992 by the Navy in the far eastern and northern seas. Factual data obtained by the Commission on the matter are presented in table 9.

Despite the comparatively low values of activity of the dumped RW, it should be reiterated that this practice put the Russian Federation in the position of having violated the provisions of the London Convention, which it pledged itself to observe, and also led to violation of the Russian Federation Law, Protection of the Natural Environment.

Table 8. Summary Data on the Scale of Contamination of the World's Oceans by Radioactive Wastes from the USSR Territory, 1961-1990

Source of Contamination	Location and Date	Suspected Total Activity, kCi*
LRW from Navy and Murmansk Shipping Company	North Atlantic Ocean. Northwest Pacific Ocean. 1959-1991	About 25 Over 12
SRW from Navy and Murmansk Shipping Company, including sunken reactors	Same	About 300 (experts estimate not over 2,500)
Sunken NS's	Atlantic and Pacific Oceans	Under 650
Lost NWH's, RTG's, satellites, etc.	Atlantic, Indian and Pacific Oceans	Several thousand
Discharge of RW from Yenisey and Ob Rivers	Arctic Seas	Several thousand
Total	All the world's oceans	Not over 10,000

* At the time of disposal.

Table 9. Disposal of Radioactive Waste at Sea by the Russian Navy in 1992

Disposal Area (Coordinates)	Type of Dumping	Activity	
		Ci	GBq
Barents Sea			
Area 5 (coastal)	3,066 m^3 LRW	18	666
Far Eastern Seas			
Area 5, Sea of Japan	906 m^3 LRW	1.3	48
Area 7, east coast of Kamchatka	906 m^3 LRW	1.3	48
Area 9, Sea of Japan	1774 m^3 LRW	7.6	281
Area 8, 52°30' N, 159°9' E, east coast of Kamchatka	46 m^3 SRW, 41 containers	12	444
Area 9, 41°40' N, 133°30' E, Sea of Japan	2640 m^3 SRW, tanker *TNT-11*	14.5	534
Area 9, 41°40' N, 133°30' E, Sea of Japan	55 m^3 SRW, 41 containers	0.5	19
Total by type	6,652 m^3 LRW 2,741 m^3 SRW	28.2 27.0	1050 1000
Total Activity		55.2	2050

SECTION 3. RADIOLOGICAL CONDITIONS IN MARINE RADIOACTIVE WASTE DISPOSAL AREAS IN THE NORTH AND FAR EAST

Before reviewing the specifics of the radioecological situation in the seas adjacent to the northern and far eastern coasts of the Russian Federation, we should address the organization of radiation and sanitary-epidemiological monitoring in marine RW disposal areas.

3.1 Organization of radiation and sanitary-hygienic monitoring in marine radioactive waste disposal areas

Until 1983, monitoring of radiation conditions in marine RW disposal areas was performed by the forces and assets of the Northern and Pacific Fleets. The scope and frequency of monitoring was regulated by sanitary requirements for disposal of RW at sea, with special attention paid to investigation of levels of biologically hazardous radionuclides in seawater, bottom sediments, and commercial and marker species of water life in RW disposal areas.

Radiation hygiene surveys of RW disposal areas were performed by radiation monitoring ships, which were part of the Navy's support fleet and represented modified MRT class fishing trawlers. In technical condition and seaworthiness, the radiation monitoring ships did not fully meet the requirements for the ships designed to sail in open seas in heavy ice and weather conditions. For this reason, full monitoring could not always be completed.

More detailed radiological surveys of marine areas were carried out during scientific research on problems of RW disposal at sea in 1960, 1966, 1967, 1972, 1980, and 1984-1990 by the Maritime Branch, Twelfth Central Scientific Research Institute of the USSR Defence Ministry, 126th State Scientific Research Test Area of the USSR Defence Ministry, Roskomgidromet's Typhoon Scientific Research Institute, and the Navy's Central Medical Laboratory. The purpose of this research was to assess possible radioecological consequences and determine optimal conditions for discharge of liquid and dumping of solid RW by nuclear vessels and ships at sea at high latitudes with severe ice conditions, in coastal and non-coastal waters, and at naval bases.

Before performance of any operations in the areas designated for discharge and dumping of waste, pre-operational radiation inspections were conducted according to special programmes, including determination of radionuclide activity in seawater, commercial water life, and bottom sediments.

When the implementation of the PS-82 regulations specifying approval procedures for RW dumping at sea, monitoring of radiation conditions in RW discharge and dumping areas was performed by Goskomgidromet, and in water areas of bases, refuelling and repair stations for nuclear-powered ships, it was carried out by radiation safety services of a ship large command or task force.

Radiation inspection of seas used for RW disposal was performed by Goskomgidromet in a series of expeditions by research vessels. In 1975, the Navy hydrographic ship Abkhaziya performed a radiation inspection of the Sea of Japan. In 1982, the research icebreaker Otto Shmidt performed a radiation inspection of the Kara Sea. In 1992, a joint Russian-Norwegian expedition aboard R/V Viktor Buynitskiy of Roskomgidromet performed a radioecological inspection of the Barents and Kara Seas (figure 10).

An expedition planned for 1992 by Roskomgidromet and the Navy to inspect SRW disposal areas in the bays and inlets of the eastern coast of the islands of Novaya Zemlya was not held and the fault for this abortive action lies with the Navy.

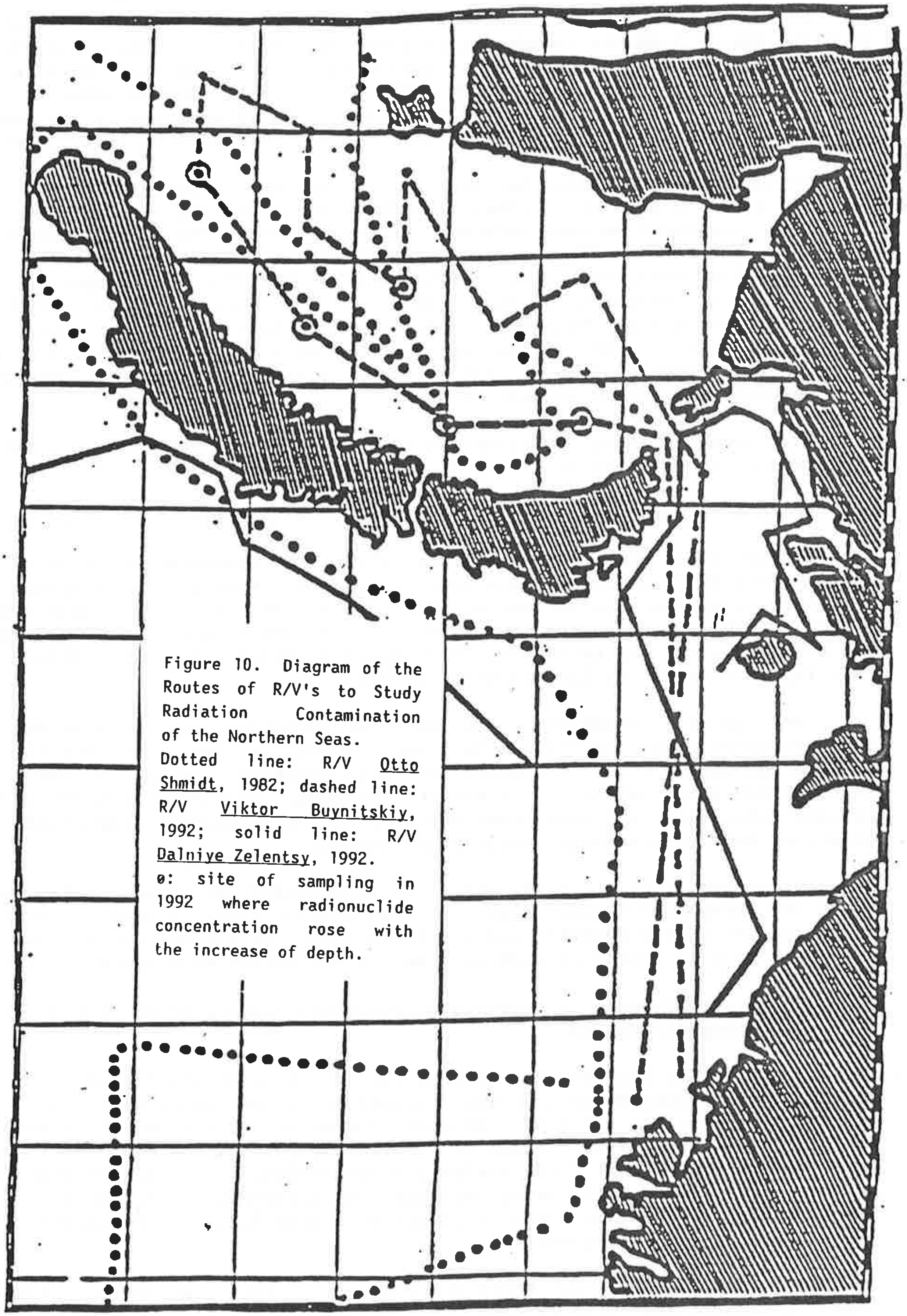


Figure 10. Diagram of the Routes of R/V's to Study Radiation Contamination of the Northern Seas. Dotted line: R/V Otto Shmidt, 1982; dashed line: R/V Viktor Buynitskiy, 1992; solid line: R/V Dalniye Zelentsy, 1992. ø: site of sampling in 1992 where radionuclide concentration rose with the increase of depth.

All studies of radiation conditions since 1967 were performed in water areas located 50-100 km from SRW disposal areas. Director monitoring of radiation conditions directly within the waste disposal areas has not been performed for 25 years.

It should be noted that the RW dumping in containers does not guarantee absolute safety from the standpoint of possible seawater contamination, since the container material is subject to corrosion. Metal containers fail in seawater after 10 years, and concrete ones in 30 years. The possible pollution of the marine environment by furfurol, which was used to seal many reactor compartments when they were sunk, has not been studied in full detail.

On the whole, the radiation and sanitary-hygienic monitoring at RW disposal sites in both the northern and far eastern seas in recent years should be considered as unsatisfactory. Despite the fleets' annual generation of a large quantity of RW requiring disposal and dumping at sea in the course of decades (including high-level and potentially hazardous RW), regular observation and monitoring of the condition of radioactive objects dumped at sea has practically not been performed, although the Russian Ministry of Defence, Ministry of Agriculture, and Ministry of Atomic Energy have numerous scientific research institutes that carry out research work on the development and operation of nuclear-powered vessels.

Development of a system of marine radioecological monitoring in disposal areas was started by the Navy only in 1992.

3.2 Radiation conditions in the seas used for radioactive waste disposal

In the course of radiation hygiene inspections conducted at SRW disposal sites before 1967 and before 1990 in areas of LRW discharge, not a single fact of hazardous radioactive contamination of the marine environment was elicited, either in the disposal areas themselves or in adjacent water areas, with the exception of brief (up to several days) local increases in radionuclide activity in seawater during discharge of LRW.

There is no information on the status of radiation conditions at SRW disposal sites proper in the northern and far eastern seas. The lack of information caused not only concern to the governmental agencies of the Russian Federation authorized to monitor the status of the environment in the Russian Federation, but also draws sharp criticism on Russian from other countries and international public organizations.

An assessment of the total radioactive contamination of sea surface waters where RW disposal took place requires more detailed data. Levels of radioactive contamination of the northern and far eastern seas determined so far show no dangerous rise in levels of radionuclides in the marine environment (table 10).

3.3 Anticipated changes in radioecological conditions at sites of radioactive waste disposal at sea

An assessment and forecast of possible radiation, hygienic and radioecological consequences of sea disposal of RW produced during the operation, refuelling and repair of nuclear-powered vessels and ships were performed on the basis of a study of documentary data on the quantitative and qualitative composition of RW, analysis of technology and radiation protection measures used in preparing RW for disposal and disposing of it, and a comparison of various sources of radioactive contamination of the Arctic and Pacific coastal seas of Russia.

The analysis shows that there are important differences in the estimated impact of liquid and solid RW dumped at sea.

Table 10. Average ^{90}Sr Concentration in Sea Surface Waters, 1990-1991, pCi/l [23]

Area	1990	1991	Number of Samples in 1991
Baltic Sea	0.53-0.57	0.44-0.46	15
Sea of Azov	0.85	0.83	5
White Sea	0.25	0.25	4
Barents Sea	0.21	0.16	6
Caspian Sea (northern part)	0.40	0.33-2.35	13
Sea of Okhotsk	0.09	0.10	4
Sea of Japan	0.17	0.10	4
Black Sea (Dnepr-Bug estuary)	—	2.1	14
Pacific Ocean (coastal waters of East Kamchatka)	0.08	0.09	12

Calculations performed using models of radionuclide migrations in marine systems demonstrate low levels of possible entry of radionuclides from LRW into the human body through food chains. Even with a conservative approach, exposure doses for possible critical population groups do not reach significant values and are not reliably different from doses caused by the natural and technogenically altered radiation background.

In the course of research on the subject, Summary Documents on the Disposal of Radioactive Waste from Naval Facilities in Special Areas of the Sea between 1960 and 1966, performed in 1967, no increase in radionuclide activity in seawater, plankton, or commercial water life was detected in areas of LRW discharges. Computations in the study called Documents on the Validation of the Draft "Sanitary Requirements for Disposal of Radioactive Waste at Sea" also showed that discharges of regulated amounts of LRW would not lead to a hygienically significant increase in the concentration of artificial radionuclides in seawater and commercial water life. Actual values of LRW discharges were, as a rule, significantly lower than regulatory standards.

Consequently, data from previous research allow us to draw a preliminary conclusion that the LRW discharged from facilities of the Northern and Pacific Fleets and the Murmansk Shipping Company poses no significant radiation hygiene danger, either to the population as a whole or to critical population groups (fishermen, residents of coastal areas). Further studies could adjust the above preliminary assessment of the effect of LRW, but are unlikely to substantially alter it.

It is more complicated to assess the effect of LRW disposal on the marine ecosystem and marine biocenoses. Our knowledge of the circulations of substances in northern and polar ecosystems is too fragmentary to draw final definite conclusions. For example, our knowledge is totally inadequate even in the area of hydrography. Recent discovery of powerful bottom currents that vary with the seasons and deep storms in which the rate of movement of water masses exceeds several knots show the extent of our ignorance, even of apparently well-studied parameters of the sea.

A conclusion on the effect of LRW disposal on shaping radioecological conditions at sea requires comprehensive comparative studies of marine water life over large water areas [24-27]. A comparison of various local populations of vertebrates, invertebrates, micro-organisms and algae is needed.

Such studies, even if they are energetically started in the near future, will take several years. Increasing number of cases of diseases and pathological changes (including those to the cardiovascular system) noted in pinnipeds inhabiting the Barents-White Sea ecosystem [27] has caused serious concern. The above changes cannot be directly linked to LRW dumping, but a theoretical possibility of such a link exists.

At the same time, budget calculations of the share of total anthropogenic radiation contamination of marine ecosystems due to LRW (2.5-5.0%) indicates with a fair degree of certainty that the effect of discharged LRW on marine ecosystems cannot be considered to be a determinant negative factor within the bounds of the northern and far eastern seas adjacent to the Russian territory.

The radiation hygienic and radioecological danger of SRW dumped at sea is determined by their radionuclide content and activity, the condition of their protective barriers (degree of water tightness of their packing containers, rate of the latter's corrosion, etc.).

A comparative analysis of the potential hazard of SRW dumped at sea from vessel and ship nuclear power plants allows to draw a conclusion that the greatest threat in terms of radiation hygienic and radioecological safety is posed by reactors with SNF in place in the Kara Sea. When reactor compartments and reactors with damaged cores in place dumped at sea were subject to special treatment including reinforcement of the protective barriers (filling internal cavities with furfurol or cement, additional sealing, etc.), it seems unlikely that there could be a substantial release of radionuclides in the near future.

However, this theoretical conclusion may be incorrect, since the actual course of corrosion processes and transformation of the constructed protective barriers is unknown. No full-scale experiments of sufficient duration and similarity to actual conditions were performed during the development of protective barriers and estimation of computed time to seal failure. And until all types of dumped SRW with high activity levels are inspected, no final conclusions can be drawn.

The computed design time to possible seal failure for the block of the first nuclear power plant of the icebreaker Lenin, which contains three reactors without nuclear fuel, is up to 500 years. No similar data for other sunken reactors were furnished to the Commission, and re-evaluation of all these calculations, if available, is an important task for the immediate future. Moreover, it should be kept in mind that a number of reactors with SNF removed were dumped at sea without any additional protective barriers to the release of radionuclides into the marine environment.

The aforesaid also applies to containerized SRW, and to RW dumped in the holds of the sunken vessels. According to the calculations, the container walls (3-4 mm of steel-3) could be subject to significant corrosion within 20-30 years after dumping at sea. Since the corrosion of steel-3 proceeds unevenly over the surface of the container, the flushing of its contents is not uniform. During that period, all radionuclides with half-lives shorter than 3 years will decay, and ^{90}Sr and ^{137}Cs activity in the waste will decline by half.

It seems impossible to estimate with certainty the rate of release of the remaining long-lived radionuclides, although there is no doubt that the process will inevitably take a long time.

Unfortunately, the above theoretical calculations could also be far from reality. We know from eyewitness evidence that during the disposal of low-level SRW, sometimes metal containers were shot at to accelerate their sinking. This means that without the slightest doubt, the release of radionuclides undoubtedly began immediately after disposal of the containers. The radioecological consequences of the release of large amounts of radionuclides in the shallow areas of the Kara Sea must have affected the ecosystems, but this effect can be assessed only after appropriate observations are carried out in the disposal areas.

So far, we have only some alarming data indicating that in some water areas in the western Kara Sea, the concentration of radionuclides (^{137}Cs) rises with the increase of depth (table 11; see also figure 10).

Table 11. ^{137}Cs Concentration (Bq/m^3) at Various Depths in the Southwestern Kara Sea at Five Sampling Points

Depth	Number of Sampling Points				
	1	2	3	4	5
Surface	6.9	2.9	3.2	3.5	3.4
7-80 metres	5.0	6.9	6.2	10.3	4.4
85-230 metres	10.9	11.1	19.5	11.6	9.8

When future analyses are made it should be taken into account that in a number of cases, the sunken vessels were loaded with highly toxic substances such as heptyl.

Most of non-containerized SRW dumped at sea is equipment manufactured of high alloy steels. Such steel is subject to corrosion at a rate of about 1 mm per 100 years. The thickness of the radioactive layer on articles made of this steel removed from a reactor is 0.1-0.5 mm. Consequently, all the activity from non-containerized SRW of this type must have passed into the marine environment within 10-12 years after disposal. The release (flushing) of radionuclides from other noncontainerized wastes proceeds even more rapidly. Consequently, a large portion of the radionuclides from non-containerized RW must have entered the environment. However, since the total activity of this RW is low, it is not expected to produce a noticeable effect on shaping of the overall radioecological conditions in the sea.

However, we should keep in mind that an accidental contact with individual radiologically rather hazardous objects is possible, for example due to removal of the objects during diving work, or when storms cast them ashore from the shallow bays and inlets of the islands of Novaya Zemlya, where a large portion of RW was dumped (figure 11).

To keep people from an accidental contact with the radiologically hazardous objects thrown ashore, the Novaya Zemlya Northern Test Site performs an annual visual inspection of the eastern coastline of the archipelago. In Primorski Kraj, aerial gamma-ray photography was performed in 1991 in the location of the NS accident at Chazhma and along the coast of the Sea of Japan. No radiologically hazardous objects or articles were found, with the exception of an unidentified metal object with high levels of radiation (over 100 r/hr: fragments of fuel rods) found in 1984 on the coast of Abrosimov Inlet, Novaya Zemlya.

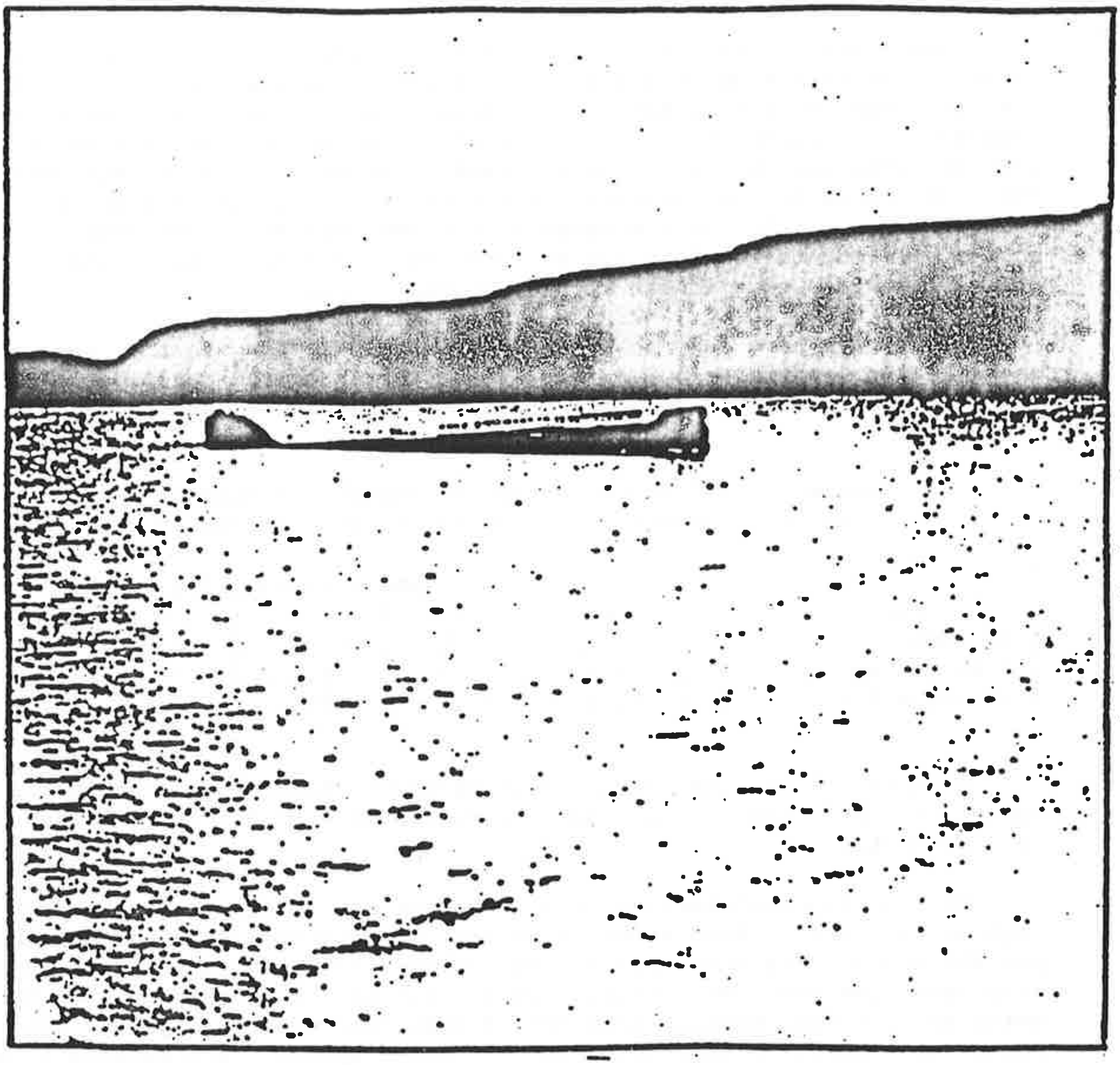


Figure 11. September 1, 1981, Stepovoy Inlet (Novaya Zemlya): Sinking of a damaged NS with two liquid metal reactors. Depth about 20 meters.

We should note two other factors that increase the potential radioecological hazard of dumped SRW. The first concerns the possibility of a significant acceleration of corrosion processes in seawater affecting RW composed of different metals (for example, steel with copper, zinc, titanium, etc.). In such cases, electrolytic reactions can be brought about in which the corrosion rate of metals can be increased many-fold. It is just a process that characterizes a rapid destruction of elements of the NS Komsomolets (the steel-titanium combination).

The second factor is a possibility of unauthorized disposal of RW at sea, or its disposal in violation of the approved standards.

Having in mind the above mentioned with regard to SRW the Commission was forced to refrain from drawing any final conclusions concerning the degree of SRW radioecological hazard until all disposal sites without exception are inspected.

Introducing reliable monitoring (observation, tracking and analysis) of the release of radionuclides from dumped SRW is a priority matter.

Since all dumpings of SRW in the northern seas (and most dumpings in the far eastern seas) were performed in gross violation of international standards, and considering their potential radioecological hazard, the only reliable solution to the problem can be raising of large high-level SRW from shallow disposal sites and its redisposal in specially equipped repositories on land. However, this solution can be adopted after comprehensive studies to assess the radiation risk of such SRW dumpings.

3.4 <u>Accident on a nuclear submarine in Chazhma Bay (Primorski Kraj), 1985</u>

On 10 August 1985, during completion of reactor refuelling work on an NS at a pier in a Navy shipyard in Primorski Kraj (Chazhma Bay, town of Shkotovo-22), due to violation of nuclear safety requirements and reactor lid raising technology, an uncontrolled spontaneous uranium fission chain reaction was brought about in the port reactor.

The resulting thermal explosion of the reactor destroyed the forward and aft machine rooms and the forward compartment of the control and protection system. One assembly with a freshly loaded core was blown out of the reactor. The fuelling shack was also partially destroyed, and its roof was blown off to a distance of 70-80 metres, landing in the water 30 metres from shore. The NS sustained damage to its pressure hull in the aft section of the reactor compartment.

Immediately after the explosion in the reactor compartment, a fire broke out, which was brought under control after four hours. The combustion products, along with fission and activation products and particles of unreacted fuel compound in the form of fine particles and slurry, fell out within a radius of 50-100 metres around the damaged NS.

A radioactive plume was deposited with an axis intersecting Dunay peninsula in a northwesterly direction and extending seaward to the coast of Ussuri Inlet. The plume was 5.5 km long across on the peninsula (further fallout of aerosol particles took place on the water surface up to 30 km from the release site).

The release of radioactive substances into the atmosphere was calculated (neglecting radioactive noble gases) at about 185,000 TBq (5 MCi). The release of radioactive noble gases was estimated at approximately 81,000 TBq (2 MCi). The heaviest contamination was noted at the epicenter of the release and along the axis of the radioactive plume. Seven and one-half hours after the accident the exposure dose rate (EDR) of radiation in the area of the accident reached 250-500 mr/hr, and contamination of surfaces by beta-emitting nuclides was $0.5\text{-}4.0\times10^6$ decays/cm^2-min.

Significant radioactive contamination affected submarines and special service ships near the accident site, piers, and the shipyard territory and its structures.

A large part of the water area of Chazhma Bay was also radioactively contaminated, especially near the damaged NS. Contamination of the bay occurred at the time of the explosion and formation of the plume, and also when radioactive water from the damaged compartment entered the water through the hole formed in the pressure hull. One hour after the explosion, the activity of short-lived radionuclides in the seawater reached 74 kBq/l (2 μCi/l). Two months after the accident, radionuclide levels in the seawater had declined to original background values and remain at this point today.

The accident created a focus of radioactive contamination on the bottom of the water area of Chazhma Bay. The area of intense radioactive contamination is concentrated at the accident site and within the limits of EDR>240 μr/hr occupies an area of about 100,000 m^2. In the central part of the focus, the EDR is 20-40 mr/hr, with a maximum of 117 mr/hr as of 1992. Currents are gradually moving the radioactive contamination toward the entrance to Chazhma Bay. The radioactivity of bottom sediments is due mainly to ^{60}Co(96-99%) and partly to ^{137}Cs.

The maximum ^{60}Co unit activity in bottom sediments at the accident site is 78 kBq/kg (2.1 μCi/kg), and in marine water life 670 Bq/kg (18 μCi/kg). The total ^{60}Co activity in the bottom sediments of Chazhma Bay as of 1992 was approximately 185 GBq (5 Ci).

Contamination of bottom sediments by ^{137}Cs is recorded in local areas and in concentrations comparable to or slightly above background values.

Radioactive contamination of the water area affects the southeastern part of Chazhma Bay. The area of maximum contamination of the bay bottom is 0.08-0.1 km^2 (within limits of gamma-ray EDR>240 μr/hr). Contamination of bottom sediments can be observed moving from the accident area toward the western entrance to Strelki Inlet. Contamination of the water area of eastern Ussuri Inlet within a radius of 3-5 km from the explosion site of the shore radioactive plume creates and elevated gamma-ray EDR over background of between 1 and 8 μr/hr.

Radioactive contamination in the water area of Chazhma Bay, the western passage of Strelki Inlet, and the eastern part of Ussuri Inlet is caused by concentration of radionuclides, mainly ^{60}Co, by bottom sediments. The activity of radionuclides in the seawater in these areas is at the level of background values typical of other parts of the Pacific coast. All activity is concentrated in the bottom sludge and can be removed only with the sludge itself or with the surface mud layer.

The observed tendency for radioactive contamination in the bottom layer to move and disperse along the bottom of Chazhma Bay will entail no serious ecological consequences, since the total radionuclide activity in the bottom sediments is relatively low (about 5 Ci), and the leading radionuclide is ^{60}Co, with a half-life of 5.26 years.

During the accident and clean up, 290 persons were exposed to elevated radiation. At the time of the accident, 10 persons died of their injuries (eight officers and two enlisted men). Ten persons developed acute radiation sickness, and 39 displayed radiation reactions.

Continuous monitoring of radiation conditions in the accident area and in the radioactive plume has been performed by the yard's radiation safety service. Periodic monitoring of radioactive contamination of natural environmental systems is being performed by units of the Pacific Fleet's Chemical and Medical Services, the Flotilla of Primorski Kraj, the Sanitary and Epidemiological Service of Primorski Kraj, and the Maritime Hydrometerological Administration.

In the future, radioecological studies of the consequences of the NS accident in Chazhma Bay (including precise determining of the boundaries of the radioactive plume in the marine environment and its rate of dispersion along the bottom of the bay and inlet) must be continued.

3.5 N/S Komsomolets accident in the North Atlantic, 1989

On 7 April 1989, a fire broke out in the stern section of the Komsomolets, a nuclear submarine. The vessel surfaced, but after several hours' struggle for survival, it sank, killing 42 crew members. The NS reached bottom at a depth of 1,680 m at a point with co-ordinates 73°43'16" N by 13°15'52" E, near the island of Medvezhiy. The site is about 300 nautical miles from the Norwegian coast.

One difference between this accident and others, including those involving American NSs, is the threat of accelerated release of radionuclides into the marine environment. The reason is that the Komsomolets has a titanium pressure hull. The rate of corrosion is increased many-fold when a titanium hull reacts in seawater with the steel reactor parts and other ship components made of various metallic materials.

The reactor was switched to a stable cool down mode, ensuring nuclear safety, both at the time of sinking and when the vessel remained sunken.

From the time of sinking, engineering design features of its NWHs made a nuclear explosion absolutely impossible, so the problem of nuclear safety for the ship in its sunken position can be regarded as solved. However, the problem of ensuring radioecological safety remains.

From information on the power generated by the power plant of the Komsomolets, experts estimate that the reactor core contains approximately 42 kCi of ^{90}Sr and 55 kCi of ^{137}Cs. The radioactivity of its NWHs, resulting from their ^{239}Pu content, is about 430 Ci.

The area where the accident took place is among the most biologically productive in the world's oceans, and is of special economic importance. It falls within the sphere of interests of Russia, Norway, Sweden, Great Britain, and Iceland. Even minimal transport of radionuclides (fission products and transuranian elements) up the food chain from seawater to plankton to fish could have grave political and economic consequences.

The first expedition in the area of the NSs sinking was undertaken in May 1989 by the R/V Akademik Mstislav Keldysh. The results of the study were of a reconnaissance nature.

A full-scale research programme was carried out in a second expedition aboard several ships from April to September 1991. Two Mir deep-water manned submersibles were outfitted with standard dosimetric instruments and specially developed radiometric apparatus. The submersibles delivered special cartridges with selective sorbents to capture certain radionuclides to the NS and recovered them. Between 23 and 31 August 1991, both submersibles dived to the Komsomolets simultaneously for a total time of 66 hours 31 minutes. Thirty-two water and soil samples were taken in close vicinity to the NS's hull. The results of the analyses obtained by January 1992 showed that although the primary loop of the reactor was not watertight, the release of radionuclides was extremely low (^{137}Cs concentrations not over 10 pCi/l).

It was learned that the upper part of the pressure hull in the area of the forward compartments was damaged. It was also found out that the doors of the torpedo tubes were open and seawater was in contact with the bodies of the missile torpedoes. The casings of the NWHs lost their seals, and active warhead materials were in contact with seawater.

A third expedition to the Komsomolets was conducted from 7 to 18 May 1992 aboard the R/V Adademik Mstislav Keldysh and the R/V Ivan Kruzenshtern. Submersibles performed six dives to the Komsomolets and to a rescue chamber discovered to have surfaced 300 metres away.

Even the second expedition noted that the NS's hull had sunk into the mud relative to its base plane at least 2.5 metres at the bow and up to 4.5 metres at the stern. In 1992, no noticeable changes were detected as compared to the NS's condition in 1991. Hull encrustation by living organisms was less noticeable than in August 1991, evidently due to seasonal variation.

The pressure hull had been significantly more damaged in the bow as compared with the condition recorded in 1991 on videotapes. Along the port side in the area of the bulkhead between Compartments I and II, a transverse crack about 2 metres long and up to 50 mm wide was detected. Along the same port side of the pressure hull, a long longitudinal crack had appeared, approximately 30 mm wide along nearly its entire length, and in some areas the crack's opening had reached 400 mm. In the upper part of the pressure hull of Compartment II, along the port side near the attachment of an emergency flotation buoy, the damage comprises a crack at least three metres long and up to 300 mm wide. A noticeable increase in the amount of corrosion products (ferric oxide) within torpedo tube 2 was recorded.

The predicted entry of small quantities of ^{137}Cs into the seawater, first recorded in 1991, was confirmed. The maximum cesium concentration near the NS was 180 Bq/m^3, and it averaged - on the deck above the reactor compartment - 29.6 Bq/m^3 (the allowable concentration of ^{137}Cs in drinking water is 550,000 Bq/m^3). Although the official report states that analyses of water samples, bottom sediments and selective sorbents did not detect ^{239}Pu release from the NWHs into the environment in 1992, other data indicate that such releases have already been observed, but not in dangerous amounts so far [32].

Inspection of the area around the Komsomolets disclosed local irregularities in the distribution of natural and artificial (technogenic) radionuclides in bottom sediments. Sectors with somewhat elevated but not ecologically hazardous radionuclide concentrations have an area on the order of tens of km^2, located at distances of tens of kilometres from the NS. At present, the area's complex hydrology (currents up to 1.5 m/s) and geomorphology do not allow to establish a direct link between the presence of irregularities in technogenic radionuclides and their release from the Komsomolets.

Turning to the forecast, we should note that it is rather favourable for reactor radionuclides and no significant change in the marine environment is be expected in the near future.

The radioecological situation regarding the plutonium component of the NWHs is more alarming. The onset of ^{239}Pu escape can be expected in 1995-1996. The uncontrolled process of plutonium escape could occur in pulses and last for several years. This could create a zone of stable contamination by ^{239}Pu corrosion products, which will be both highly active and chemically toxic, on the bottom near the NS.

The Polar Institute of Marine Fishery and Oceanography (PINRO) has made assessments of the potential economic damage caused by ^{239}Pu contamination of sea products. Commercial fish is expected to be contaminated to levels two times above the allowable limit for ^{239}Pu. Moreover, in addition to heavy economic damage (up to 2.5 billion rubles in 1991 prices), a negative political reaction by the Scandinavian countries will inevitably follow.

The most radical preventive measure would be to raise the NS. The costs of such an operation would exceed 250 million U.S. dollars. The existing damage to the pressure hull and continuing corrosion could make NS salvage impossible.

Local sealing could impede the rapid release of radionuclides. To pump in a gel consisting of 1-2% chitosan (an active absorber of heavy metal salts) is one of the proposed methods of the NS sealing. The gel would undergo polymerization in the presence of calcium contained in seawater, forming a glassy substance (which would not erode quickly even in strong currents), and practically would completely prevent radionuclides from entering the external environment for decades.

Yet another alternative solution to the problem is to detach and raise only the NS's bow section containing the torpedo tubes (or the torpedo tubes only) and the NWHs they contain (with subsequent destruction or disposal of the warheads).

Any of the above alternatives must ensure systematic radioecological monitoring at the location of the Komsomolets. International co-operation in the monitoring operations should be enhanced.

3.6 Conclusion

Direct measurements of the radioactivity of surface seawater in the areas used for LRW disposal have shown no dangerous rise in levels of radioactive contamination against the backgrounds.

At the sites of direct disposal of the most hazardous SRW (reactors with SNF in place), no observations have been made since 1967. Now, a quarter of a century later, such observations must be resumed immediately. With this aim, a full-scale expedition must be held this very season (summer 1993) with a view to inspect the condition of sunken objects in inlets of the eastern coast of Novaya Zemlya and the Novaya Zemlya Depression. The tasks of the expedition should include monitoring of all SRW disposal areas, in both the northern and far eastern seas.

Radioecological monitoring at RW disposal sites must be carried out in co-operation with the Navy, the Russian Ministry of Nature and Roskomgidromet. For objects which prove to be a radioecological hazard, the Russsian Navy, Committee for Special-Purpose Underwater Work (KOPRON), Ministry of Atomic Energy and Ministry of Nature should draw up a plan of measures to raise the objects to the surface and subsequently dispose of them on shore.

Fleet hydrographic services must establish the precise co-ordinates of the large sunken objects and show their position on maps and in pilot's sailing directions.

To assess the radiological consequences of RW disposal at sea, scientific research should be initiated immediately concerning (a) the radionuclide composition of sunken objects and the condition of their protective barriers, and (b) the uptake of radionuclides by food chains and dose burdens in water life.

A thorough study of the radionuclide budget of ecosystems in the northern and far eastern seas should also be assigned.

SECTION 4. WAYS OF SOLVING THE PROBLEM OF HANDLING RADIOACTIVE WASTE PRODUCED BY THE NAVY AND MURMANSK SHIPPING COMPANY

The widespread RW disposal at sea, was practiced by the former USSR from 1959 to 1991, due to its unpreparedness for the deployment of an industry specializing in RW handling.

The design and construction of complexes for treating liquid RW and compacting solid RW, started in the 60s, was terminated for reasons of pseudo cost-effectiveness and due to the lack of immediate hazard of RW dumping at sea. As a result of it, Russia now has to solve a number of urgent problems relating to the operation of its nuclear fleet.

The USSR (and now Russia) has 235 nuclear-powered vessels and ships, including 228 in the Navy of the Russian Ministry of Defence and seven in the Russian Ministry of Transport (394 nuclear reactors in the Navy and 13 on icebreakers - 60% of the world total). Each year, the operation of NSs and nuclear-powered ships produces up to 20,000 m^3 of liquid RW and up to 6,000 tonnes of solid RW.

Identification of methods to solve the problem requires a full knowledge of the features of the RW produced.

Most of the LRW (up to 70%) is low-salinity discharges of circulating waters and water loop flushes with activities in the order of 1 µCi/l. Higher levels of activity are typical of wastes from loop decontamination, water from spent fuel assembly (SFA) holding ponds, and a number of other liquid wastes. This LRW has high salinity and comprises up to 15% of all LRW. Most of the total activity comes from this group of LRW. A third group includes waters from special sewage systems of shore sanitation stations, laundries, decontamination stations, and radiation safety laboratories. Their activity is low (up to 10 nCi/l), and they differ little in salinity from the second group, but contain surfactants. In volume, the third group also comprises about 15%.

The highest levels of contamination in SRW are found in equipment used in reactor compartments.

Significant levels of activity accumulated on filters during treatment of LRW. Most of the activity (by volume) can be attributed to contaminated film coatings, uniforms, and other objects. SRW with high levels of activity was produced in operations with SNF. Handling of SNF should be considered as a priority, along with the problem of NSs decommissioning and recycling.

4.1. Problems in recycling decommissioned nuclear submarines and handling spent nuclear fuel in the Northern Fleet and Murmansk Shipping Company

As a result of arms reductions and for technological reasons, the Navy of the Russian Ministry of Defence has been decommissioning NSs.

SNF in the decommissioned NS has to be removed from reactors, decontamination performed, reusable equipment removed, and the reactor compartment cut out and placed in a properly equipped, ecologically safe storage or disposal site. However, due to technical unpreparedness, this cycle cannot be at present fully implemented.

The most urgent problem is SNF removing from reactors. As of 1 January 1993, SNF had been removed from only 15% of NSs decommissioned by the Navy. Only six reactor compartments had been prepared for long-term storage. A special problem is the removal of SNF from NSs with damaged cores, which is impossible with current technology. Abroad, such damaged NSs are placed whole in underground repositories for long-term storage.

The removal of SNF from other NSs requires properly equipped transfer points and sufficient capacity for its storage.

As of 1 January 1993, the Northern Fleet was storing 3,000 bundles with SFA's. Since each bundle contains seven FAs, the total number of SFAs is 21,000.

The Murmansk Shipping Company is storing SFAs on the tenders Lepse, Imandra, and Lotta. They hold a total of about 4,500 SFAs, and their reserve storage capacity is practically exhausted. Conditions of removal of SFAs are just as unfavourable for the Murmansk Shipping Company as for the Navy. The repository aboard the Lepse is damaged, with a current activity of 750,000 Ci (and 17,000 Ci of that amount is due to long-lived and toxic transuranian elements)

However, the Navy and the Murmansk Shipping Company have not solved so far the problem of sending SFAs which are damaged, come from reactor cores with liquid metal coolant, or are being stored in containers at outdoor sites for reprocessing.

As a result of the unsatisfactory organization of work to provide timely removal of SNF from units of the Russian Navy to reprocessing plants of the Russian Ministry of Atomic Energy, existing SRW storage facilities are overfilled, both in the Navy and, to a lesser extent, in the Murmansk Shipping Company and at enterprises of the former USSR Ministry of the Shipbuilding Industry. Sufficient capacity for compacting solid (flammable) RW exists only in the Murmansk Shipping Company's Nuclear Fleet Radio Regiment. It has also set up a special system for LRW treatment. The Navy does not have such systems.

At present, on orders from the Russian Ministry of Defence's Navy, the industry has manufactured 50 TK-VG-18 containers. The containers' use will provide for the disposal of SNF. However their use is being held up as the fleets' lack SNF transhipment terminals (their construction is planned for 1998). According to schedules, the Navy is prepared to dispose of SNF from mid-1993 using the TK-VG-18 containers.

4.2 Problems in recycling decommissioned nuclear submarines and handling spent nuclear fuel and other radioactive waste in the Far Eastern Area

The shore bases and ships of the Pacific Fleet store 1,200 packing bundles (8,400 SFAs). SNF of 57% of the decommissioned NSs of the Navy has not been removed (see figures 12 and 13).

Only four reactor compartments have been prepared for long-term storage. As in the Northern Fleet, the problem of SNF storage facilities is critical: the facilities are over filled and do not comply with international requirements. The condition of low- and intermediate-level SRW storage facilities does not comply with the above requirements as well.

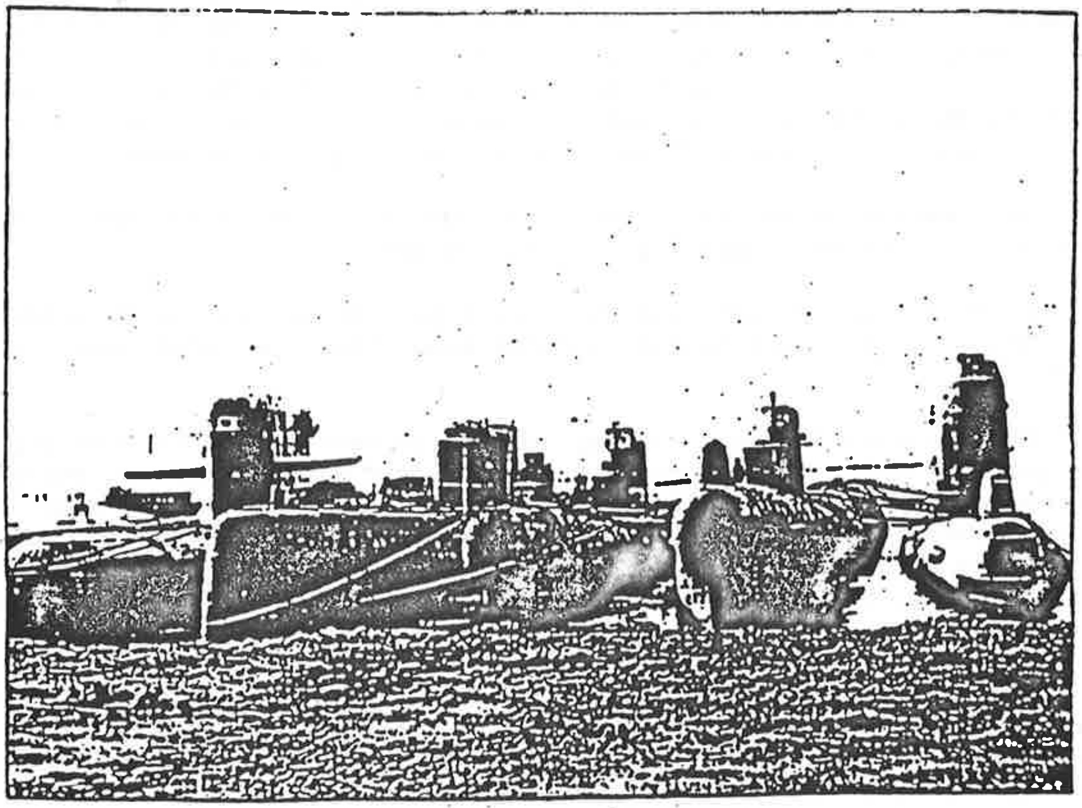


Figure 12. Decommissioned nuclear submarines awaiting reactor core removal and further recycling. Pacific Fleet, Pavlovskiy Bay.

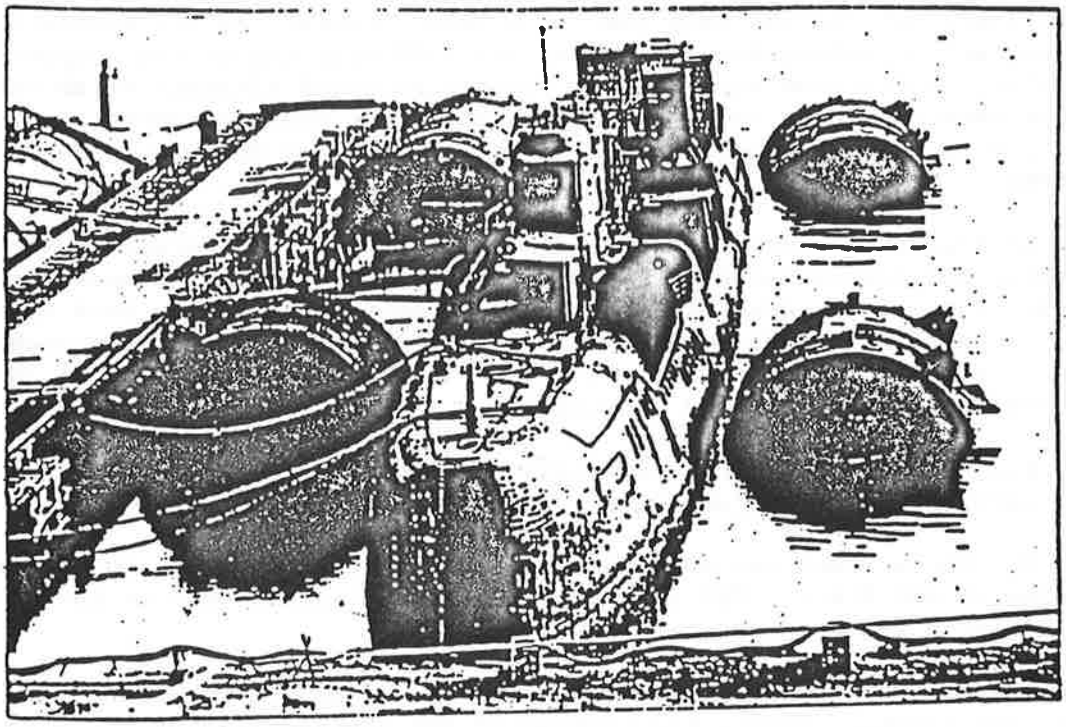


Figure 13. Pacific Fleet. Nuclear submarine on which unauthorized reactor startup was performed in August 1985, accompanied by thermal explosion and fire. Nuclear fuel from reactors was not removed.

Storage facilities for SFA's at floating maintenance centres for reactor refuelling are in a dangerous condition, and the SFAs cannot be removed. Moreover, the damaged reactors from three NSs are being stored with nuclear fuel, and the SFAs cannot be removed from them. This creates a problem of future disposal of the reactor units.

Thus, the Pacific Fleet, like the Northern Fleet, does not have regional strategies for handling RW and SNF that specify and develop all technological operations involving RW from production to disposal. In fact there is no consistent technical policy in this vital area of the fleet activity. There is no adequate co-ordination of work of designers, manufacturers of nuclear-powered ships and vessels and local authorities. At present disregard of the interest of local authorities cannot be tolerated any more.

4.3 Analysis of the Draft National Programme of the Russian Federation for Handling, Recycling and Disposal of Radioactive Wastes and Spent Nuclear Materials for the 1993-1995 Period and Through 2005, and of the Russian Federation Government Resolution of 31 August 1992 on the Recycling of Nuclear Submarines

The termination of discharges of LRW produced on ships of the Navy and at shipyards will require development and implementation of a special programme. Expert assessments show that the realization of such a programme will require at least five years and will cost about a billion rubles. A programme of compaction, reprocessing, storage and disposal of SRW will require significantly greater funds. The implementation of both programmes can be realized in the framework of the special-purpose National Programme of the Russian Federation for Handling, Recycling and Disposal of Radioactive Wastes and Spent Nuclear Materials for the 1993-1995 Period and Through 2005. The programme is presently under review by the Government of the Russian Federation.

Section 9 of the Programme, called Handling Wastes Produced in the Operation and Decommissioning of Nuclear Propulsion Units, stipulates the allocation of over six billion rubles (in 1992 prices) for the creation of shore and ship systems and units for reprocessing liquid and solid RW produced during the operation and repair of nuclear power plants.

According to the Programme for Handling Radioactive Waste it is scheduled in 1993 to make a general analysis of the formation and accumulation of RW in the northern and far eastern areas of Russia and carry out of a feasibility study for the development of specialized industrial capacity that will meet the needs for temporary storage, processing and disposal of RW. Under the 1993-1995 Programme, pilot repositories are to be developed for disposal of solid and solidified low- and intermediate-level RW.

If work on the Programme starts immediately, the capacity for disposal of high-level SRW could be put into operation in 1996. The plan calls for developing designs and by 2000 completing work on the decommissioning or modernization of radioactively contaminated engineering structures of shore maintenance centres and other facilities of the Navy.

Measures to normalize the radiation conditions in Chazhma Bay and the town of Shkotovo-22, Primorski Kraj, are to be developed in 1993 and implemented by 1995.

One item in Section 9 of the Programme provides for assessment of the radioecological consequences of RW disposal at sea and the sinking of NSs.

The study of the sites of sinking of the reactors with SNF in place is a priority and must be performed by a Russian expedition with international involvement not later than summer 1993.

Other urgent measures of the Programme for Handling Radioactive Waste should include arrangements for immediate removal of SNF from storage facilities (primarily floating ones) of the Navy and Murmansk Shipping Company. Construction of new SNF storage facilities at the Navy bases must also be started immediately and included in the programme, and commissioning of the proposed SNF storage facilities of the Murmansk Shipping Company has to be carried over from 1995 to 1994.

Thus, the current draft Programme does not take sufficient account of the RW handling problems that have arisen in the operation of nuclear-powered ships and vessels.

Slow progress of the Programme is a matter of concern. Funds allocated for the Programme seem to be inadequate and do not answer its purpose.

A resolution adopted by the Government of the Russian Federation in August 1992 specified practically the entire range of priority steps to recycle NSs and nuclear-powered ships decommissioned through 2000. These steps include the construction of temporary storage sites for floating NSs; the retrofitting of shelters for temporary storage of NS reactor compartments; and the construction of shore bases for vessels, compartments and equipment for removing reactor cores and receiving and reprocessing RW, decontamination shops, sections for preparing SRW for disposal with incinerators, special water treatment and laundries with tanks for temporary storage of liquid RW and space for temporary storage of solid RW.

On the other hand, the resolution does not resolve problems of the disposal of NS reactor compartments from which removal of SNF is technically impossible, and does not resolve problems of the selection of optimal methods and techniques for disposing of reactor compartments and their equipment and technologies for dismantling and recycling nuclear-powered ships and NSs and their weapons and armaments in order to prevent radioactive contamination of the environment.

4.4 Conclusion

Thus, the Northern and Pacific Fleets have accumulated an aggregate total of about 30,000 SFAs which corresponds to the contents of about 140 NS reactor cores. Storage facilities have free space to accept only three more cores.

Given that the normal operation of NSs requires the transfer of about ten reactor cores in each fleet annually, it is obvious that a critical situation now exists that rules out the further safe operation of the NS fleet.

At present, the Navy is not prepared to completely halt the discharge of LRW at sea before commissioning of shore processing centres, planned for 1997.

The current draft of the National Programme for Handling Radioactive Wastes does not adequately account for problems connected with the comprehensive solution of the RW handling problems created by operation of the nuclear-powered ships and vessels.

The Government resolution adopted in August 1992 provides for solution of most of the urgent problems relating to the recycling of NSs and nuclear-powered ships. However, even if the measures called for in the resolution are fully realized, the necessary capacity to recycle RW produced thereunder will not be commissioned until 1996-1997. The resolution also does not address the problem of recycling liquid and solid RW produced during operation of nuclear powered naval vessels, and does not resolve problems of the disposal of damaged reactor compartments.

CONCLUSION

In accordance with the objectives stated by the President of the Russian Federation, we have examined two basic aspects of the problem, international and domestic Russian.

The problems of RW disposal at sea have acquired special importance from the standpoints both of Russia's compliance with international obligations and of ensuring Russia's ecological safety.

The unacceptability of RW disposal at sea for Russia follows from the Russian Federation Law, Protection of the Natural Environment, article 50, paragraph 3 of which prohibits the sinking of RW, and from the reiterated official position of the Russian Federation, which signed a corresponding declaration in Rio de Janeiro and two conventions on the protection of the marine environment (the Baltic and Black Seas) that prohibit the disposal of RW at sea.

The performance of Russia's international obligations under the London Convention require:

(1) presentation of data collected by the Commission on RW dumpings performed at sea and official statistical manuals to the Secretariat of the International Maritime Organization and the IAEA;

(2) inspection of RW disposal sites at sea with the support and participation of representatives of the interested nations and competent international organizations;

(3) organization of effective monitoring of the sites where dumpings of high-level RW were carried out in the past;

(4) development of plans for removing from the seas of high-level RW that presents an environmental hazard;

(5) immediate resolving of problems relating to processing and safe storage of RW produced by nuclear-powered vessels and ships (primarily regarding the construction of storage facilities and commissioning of capacity to process RW).

FINDINGS

1 We have established and documented that from 1959, the former USSR disposed of RW having various levels of activity. This refers to RW produced during the operation and repair of nuclear-powered vessels of the Navy and ships of the Murmansk Shipping Company. There were cases of unauthorized and accidental sinking of vessels containing RW. Some RW (including NS reactor compartments and damaged reactors with nuclear fuel residues) was transferred for sinking from ship repair enterprises of the USSR Ministry of the Shipbuilding Industry.

In 1991-1992, the Navy continued liquid RW dumping in the Barents Sea, as well as liquid and solid RW dumping in the Far Eastern seas.

2 The Soviet Union did not furnish any information to the International Maritime Organization or the International Atomic Energy Agency on RW dumping at sea performed by the USSR. The normative legal acts and departmental instructions regarding the disposal or RW at sea inherited from the former USSR and applicable in the Russian territory either do not comply with or directly conflict with the London Convention accepted by the Russian Federation, other international agreements in this area, and the 1991 Russian Federation Law Protection of the Natural Environment.

3 Due to the fleets' unpreparedness for a transition to new means of SNF transportation, existing temporary storage facilities for SFA's are overfilled. SRW from vessels, ships and yards has been accumulating in containers in outdoor areas.

The above-mentioned only makes it practically impossible to stop RW dumping at sea without simultaneous solving of RW handling problems on shore. It would lead to further accumulation of RW at its points of production and temporary storage, deteriorate radiation and overall ecological conditions, and cause a rise in social tensions and a real threat to personnel and the population.

4 Since the leaders of the former USSR adopted the concept of disposing of intermediate and low-level RW at sea, construction of the capacity for processing solid RW and purifying liquid RW, started by the Navy in the 60s, was terminated in 1972.

The 1985 USSR Government decision to build special storage facilities in the northern and Pacific Fleets for disposal of reactor compartments from NSs, with commissioning of their first stages scheduled for 1993, has not been implemented.

5 It seems to be impossible to establish with the desired accuracy the amount of radionuclides that entered the marine environment in RW discharges from the territory of the USSR. According to documentary data at the Commission's disposal, the activity of the dumped RW was 325 kCi. According to expert estimates, the maximum activity of RW that entered seas adjacent to the Russian territory could have been as much as 2,500 kCi (at the time of disposal).

6 The greatest potential radioecological hazard is presented by reactors from NSs and the core plate of the nuclear icebreaker Lenin, with nuclear fuel in place, which were dumped in shallow inlets of Novaya Zemlya archipelago in the Kara Sea.

7 Monitoring of radiation conditions in marine disposal areas for SRW has not been performed for over 25 years.