INTERNATIONAL MARITIME ORGANIZATION

IMO

LC 16/INF.2
14 September 1993
ENGLISH ONLY

SIXTEENTH CONSULTATIVE MEETING OF CONTRACTING PARTIES TO THE CONVENTION ON THE PREVENTION OF MARINE POLLUTION BY DUMPING OF WASTES AND OTHER MATTER
8-12 November 1993
Agenda item 5

MATTERS RELATED TO THE DISPOSAL OF RADIOACTIVE WASTES AT SEA

Submitted by the Russian Federation

The Fifteenth Consultative Meeting of Contracting Parties to the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter (London, 9-13 November 1992) requested the Russian Federation to provide comprehensive information on disposal at sea of radioactive materials carried out by the former USSR.

The report prepared by the Russian Federation Governmental Commission on Matters Related to Radioactive Waste Disposal at Sea covering the issues requested by the Consultative Meeting is presented herewith.

The Consultative Meeting is invited to take note of this information.

W/9830e

Facts and Problems Related to Radioactive Waste Disposal in the Seas Adjacent to the Territory of the Russian Federation

(Materials for a Report by the Governmental Commission on Matters Related to Radioactive Waste Disposal at Sea, established by Decree No.613 of the Russian Federation President, 24 October 1992)

Office of the President of the Russian Federation
Moscow, 1993

Authors:

A.V. Yablokov
V.K. Karasev
V.M. Rumyantsev
M.Ye. Kokeyev
O.I. Petrov
V.N. Lystsov
A.F. Yemelyanenkov
P.M. Rubtsov

Full composition of the Governmental Commission and Working Group can be found on pp.58-59.

From the Authors

The world public has been vigorously discussing the problem related to the disposal of radioactive wastes (RW) by the former USSR in the seas adjacent to the territory of the Russian Federation. This debate has drawn upon reports based on rumours and unverified information, which substantially distorts the actual picture and creates a pretext for various forms of speculation.

In October 1992 the President of the Russian Federation formed a Governmental Commission on Matters Related to Radioactive Waste Disposal at Sea (hereafter the Commission) in order to obtain the objective information and subsequently to ensure Russia's compliance with the obligations under the international treaties to which it became party as successor to the Soviet Union. The Commission included representatives of the Ministry of Nature, the Ministry of Defence, the Ministry of Foreign Affairs, the Ministry of Public Health, the Ministry of Atomic Energy, the State Committee for the Supervision of Nuclear and Radiation Safety, the State Committee for Sanitary and Epidemiological Supervision, other ministries and agencies of the Russian Federation and representatives of administrations of the northern and far eastern areas of Russia (cf. p.58). The Commission formed a working group and an expert group (cf. p.59). The working group was divided into subgroups: data collection, radiology, international law, and archives. Members of the working group visited deployment locations of ships and vessels of the Russian Navy and Russian Ministry of Transport. The central federal executive agencies and the administrations of Primorski Kraj, Arkhangelsk, Kamchatka and Murmansk Provinces have furnished volumes of factual material as requested by the Commission.

The Commission's report on the accomplished work was based on the obtained information and in February 1993 submitted to the President of the Russian Federation.

When the text of the Commission's report was being processed into a White Paper, in addition to certain changes in the wording some significant ommissions were made, the Commission's suggestions to the President and the Government of the Russian Federation concerning plans for specific measures to establish monitoring and processing of liquid and solid RW were deleted, and some comments were added and italicized in the text.

In the future, some data presented below on calculations of the amount of radioactive contamination of the seas should be adjusted since the level of radioactivity of the submerged reactors was not determined precisely at the time and the Commission had to rely on expert estimates.

In our opinion, the data provided reflect fully and objectively the situation with regard to RW disposal in the seas adjacent to the territory of the Russian Federation.

TABLE OF CONTENTS[1/]

1/ Page numbers in this section have been adjusted to correspond to those in the translation, with parenthesized figures corresponding to those in the original. - Trans.

PREFACE

RW disposal[2/] at sea was primarily intended to isolate the hazardous wastes from the human habitat for a sufficient period required for physical decay of radionuclides.

The disposal of liquid and solid RW has been practiced by many countries having nuclear-powered vessels fleet and nuclear industries.

The accumulation of RW dumped at sea and accidents on nuclear-powered ships and nuclear submarines (NSs) is causing growing concern in the world community, and serious grievances are brought against the former USSR, and at present against Russia.

It should be noted that the first press reports on the former Soviet Union's practice of RW dumping in the northern seas appeared in publications by activists of the ecological movement Toward a New Earth. A.A. Zolotkov, an engineer in the radiation safety service of the Murmansk Shipping Company played a leading role in that debate. As no official confirmations or denials were made, the international organization Greenpeace held a briefing on the subject in Moscow in September 1991 and prepared material, for submission to the Fifteenth Consultative Meeting of Contracting Parties to the London Convention (November 1992), on the need to correct the IAEA list on RW dumped at sea taking into account the available unofficial reports. The material included maps of disposal sites and fragmentary, sometimes erroneous data on RW disposal in the northern seas by the former USSR.

This White Paper consists of four sections that examine international aspects of the problem of RW disposal at sea, present and analyse the factual data, examine radioecological conditions and formulate conclusions.

The appendix presents all data obtained by the Commission on RW disposal in the northern and far eastern seas.

The White Paper does not contain data on the characteristics, time or sites of underwater, surface, or above-water nuclear explosions in the waters of the Kara and Barents Seas. It is known, for example, that explosions were produced in Chernaya Bay in connection with a study of the possible destruction of enemy warships in closed harbours. A small

---

2/ In accordance with established practice radioactive waste in the White Paper means both liquid radioactive waste (circulating water from ship nuclear reactors, flushing and deactivation water, and domestic sewage from special lines), and solid waste (reactors with reactor fuel in place and reactor components with induced radioactivity, wastes produced when ships and vessels were repaired or damaged, nuclear warheads that were lost or accidentally fell into the sea, and other radioactive objects).

According to the accepted classification, radioactive wastes are divided into:

low-level	less than 100 kBq/l (26 μCi/l);
intermediate-level	more than 100 kBq/l (26 μCi/l);
high-level	more than 15 GBq/l (0.4 Ci/l).

- P. Rubtsov

number of nuclear explosions was evidently produced not very high above the surface of the Barents Sea northwest of Matochkin Shar Strait. There is eyewitness evidence of the production of underground nuclear explosions. In all these cases, some fraction of radioactive materials must have entered the sea. Knowing the characteristics of the nuclear explosions, we can calculate the amount of activity and the spectrum of radionuclides that entered the sea.

Radionuclides produced by the nuclear explosions in Novaya Zemlya archipelago is another possible source of radioactive contamination not considered by the Commission. Recent data (J. Scorve, J.K. Slogan, 1992) show that at a test site near the town of Severny, 5 of 28 detonations produced craters in the Earth's surface. The formation of such craters indicates the destruction of the entire perma-frost layer under the explosion site and the formation of a so-called chimney over the explosion cavity. Leakage of a significant amount of radionuclides through such structures is inevitable, and some portion (possibly a substantial one) of the released radioactivity could have entered the sea. In principle, the entry of radioactivity from underground explosions into the sea through subsoil and underground water cannot be ruled out. As yet, even an approximate estimate of the amount of radioactive contamination that could have entered the ecosystems of the Barents and Kara Seas has not been made. - A. Yablokov.

SECTION 1. INTERNATIONAL ASPECTS OF RADIOACTIVE WASTE DISPOSAL AT SEA

An objective assessment of the status of the problem of RW disposal in the seas adjacent to the coast of the Russian Federation requires an examination of its international legal aspects, an analysis of the factual data on practices followed by other nations in disposing of RW at sea, and consideration of the position of various nations with respect to the problem.

1.1 International law governing radioactive waste handling procedures

In international law, matters of RW disposal at sea are governed primarily by the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter, which was signed in London in 1972 and took effect on 30 August 1975 (January 1976 for the former USSR). The scope of the Convention extends to all marine spaces except internal salt waters [2].

According to the London Convention, the Contracting Parties pledge themselves to take all possible steps to prevent pollution of the sea by dumping of waste and other matter that is liable to create hazards to human health or harm living resources or marine life (Art. I). The dumping of high-level RW is prohibited (Art. IV). The disposal of low- and intermediate-level RW is allowed by special permission with notification of the Secretariat of the International Maritime Organization, provided an observer from a competent international organization is present aboard the ship performing the disposal operations and three main IAEA requirements [3] are met:

- the location of the disposal sites is beyond the limits of the continental shelf, internal and marginal seas;
- depths in the disposal area are at least 4,000 metres;
- the latitude is between 50°N and 50°S.

As figure 1 shows, the Russian Federation has water areas that meet these requirements only in its far eastern seas.

The provisions of the London Convention (Art. 7) do not apply to vessels and aircraft entitled to sovereign immunity (that is, belonging to a State), but reports required by the IAEA on dumpings must cover all RW discharges regardless of the departmental subordination of the originating source.

Since the London Convention took effect, 15 Consultative Meetings of Contracting Parties have been held.

In 1983, the Seventh Consultative Meeting of Contracting Parties adopted resolution LDC.14(7) [4], urging Parties to refrain from disposal of all types of RW at sea. Two years later, resolution LDC.21(9) was adopted in a roll-call vote [4], favouring a voluntary moratorium on the disposal of all types of RW at sea until completion of assessment of all aspects of their impact on human health, the marine environment and life in the sea. The USSR abstained in the voting on this resolution[3/].

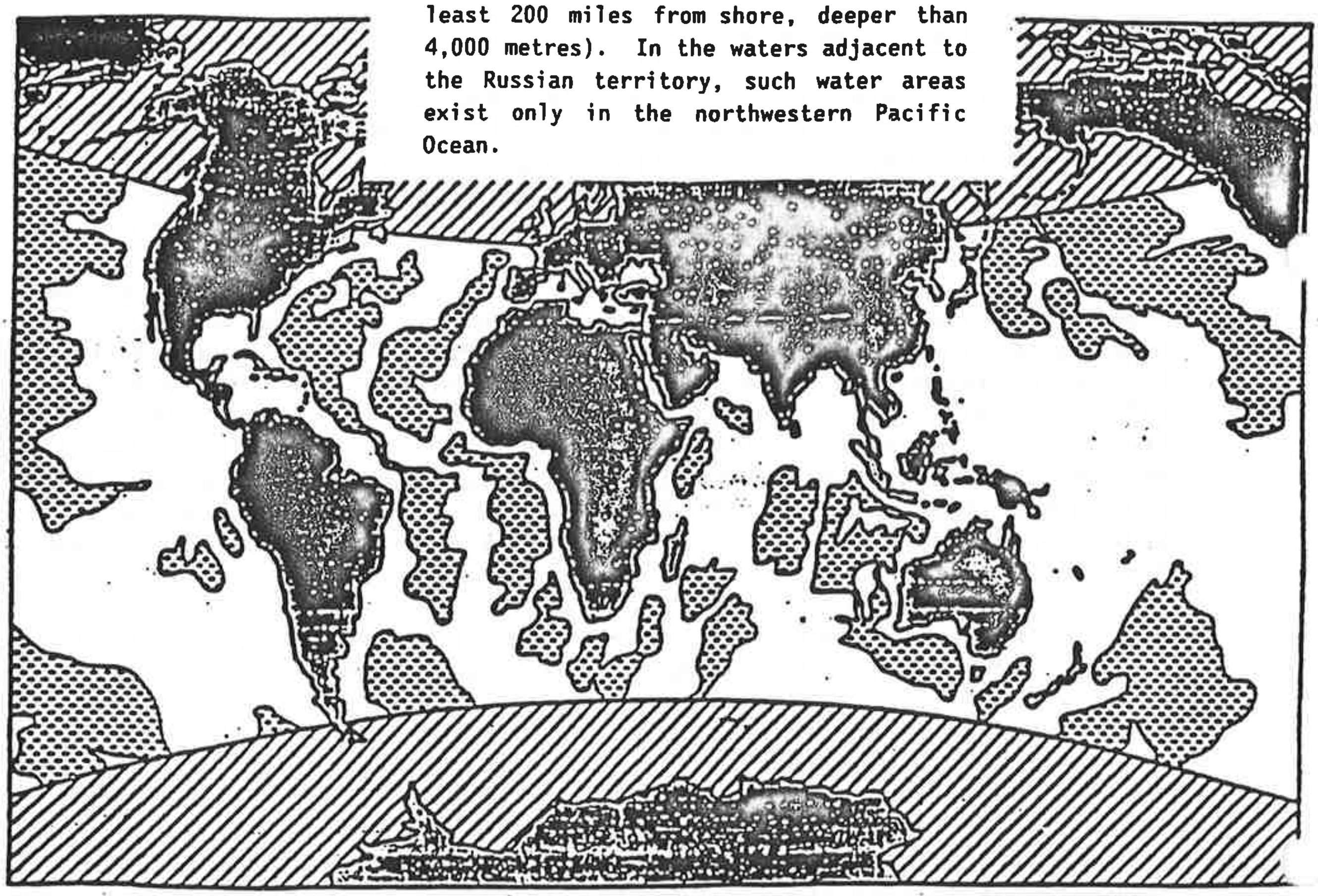

Figure 1. Map of the location of water areas of the world's oceans complying with IAEA requirements for disposal of low- and intermediate-level radioactive wastes (between 50°N and 50°S, beyond the limits of the continental shelf, at least 200 miles from shore, deeper than 4,000 metres). In the waters adjacent to the Russian territory, such water areas exist only in the northwestern Pacific Ocean.

The Fourteenth Consultative Meeting (1991) demanded that the USSR furnish information on past dumpings.

In the course of the Fifteenth Consultative Meeting (1992), this demand was made in a stronger form, and accompanied by a recommendation urging Russia to furnish information on RW disposal to the IAEA and the IMO Secretariat for inclusion in official international documents and use to complete the work of IGPRAD.

3/ The USSR's official position, as stated by the Soviet delegation to the Ninth Consultative Meeting of Contracting Parties to the London Convention in 1985 [5] in a discussion of the moratorium question, claimed that the USSR had not dumped, was not dumping, and did not plan to dump radioactive waste in the sea for the purposes of disposal, and therefore a 'zero report' was sent to the IMO Secretariat. This position was confirmed in 1989 when the IAEA circular questionnaire was completed [6].

The UN Conference on Environment and Development in Rio de Janeiro (June 1992), with Russia participating, unanimously adopted the main programme document, Agenda 21, which proposed a transition from the "voluntary moratorium on the disposal of low-level radioactive waste at sea currently in effect" to a ban on the practice, taking account of the "preliminary approach for purposes of adopting a valid and timely solution to this problem" (paragraph 22.5c). It also proposed not to encourage or permit storage or disposal of RW "near the marine environment" without a preliminary assessment of the acceptability of the risk arising from the practice (paragraph 22.5c).

Among regional multilateral agreements related to the problems of RW disposal at sea, reference should be made to the Convention on the Protection of the Marine Environment of the Baltic Sea Area (Helsinki, 1992) [7], which requires the Parties to the Convention to prevent and reduce pollution of this sea area by hazardous substances, including RW.

The Convention on the Protection of the Marine Environment of the Northeastern Atlantic (Paris, 1992) [8], signed by Belgium, Great Britain, Germany, Denmark, Iceland, Ireland, Spain, the Netherlands, Norway, Portugal and some other States, imposes a ban on the dumping of RW in the sea (Art. 3, paragraph 3a, appendix II). However, paragraph 3b of the same appendix contains a stipulation granting Great Britain and France the opportunity to reduce RW dumping in the sea through 2018[4/].

The Convention on the Protection of the Black Sea from Pollution (Bucharest, 1992) [9], signed by all Black Sea nations, including the Russian Federation, unconditionally bans the disposal of RW in the basin (Art. X and the special Protocol on the Protection of the Black Sea from Pollution Caused by the Disposal of Radioactive Waste in the Sea).

1.2 Radioactive waste disposal at sea as practiced by some States using nuclear power technologies

The major areas of disposal of solid radioactive waste (SRW) in the world's oceans are shown in figure 2. The first disposal of RW at sea was carried out in 1946 by the United States in the northeastern Pacific Ocean at a distance of about 80 km from the California coast.

The dumping of low-level SRW at sea went practically alongside of the widespread development of nuclear power and industry. Dumpings were initiated by Great Britain in 1949, Japan in 1955, the Netherlands in 1965, and so on. By 1983, 11 countries (table 1) were practising the dumping of SRW in the open sea. The last officially recorded disposal of RW at sea (not counting dumpings by the USSR and Russia - see section 3) was carried out in 1982, in an area of the Atlantic 550 km from the boundary of the European continental shelf.

4/ If the Russian Federation accedes to this Convention, our obligations would concern a part of the Barents Sea and the whole of the White Sea.

Table 1. Characteristics of radioactive wastes dumped in the world's oceans by various countries (omitting data for the USSR and Russia) [10]*

Country	Amt. dumped (TBq)	Percentage [of total]	Years
Atlantic Ocean			
Belgium	2,120	4.63	1960-1982
Great Britain	35,077	76.55	1949-1982
Germany	0.20	0.0004	1967?
Italy	0.19	0.0004	?
Netherlands	336.1	0.73	1967-1982
United States	2,942	6.42	1949-1967
France	353.4	0.77	1967-1969
Switzerland	4,419	9.64	1969-1982
Sweden	3.23	0.01	1963
Total	45,252.5	98.76	
Pacific Ocean			
Korea	not determined		?
New Zealand	1.04	0.02	?
United States	554.2	1.21	1946-1970
Japan	15.44	0.03	1955-1969
Total	570.7	1.24	

* Neglecting waste water from nuclear fuel processing plants, lost nuclear warheads, and other sources of ionizing radiation, sunken nuclear submarines, and radionuclides that have entered the ocean as a result of underwater nuclear explosions.

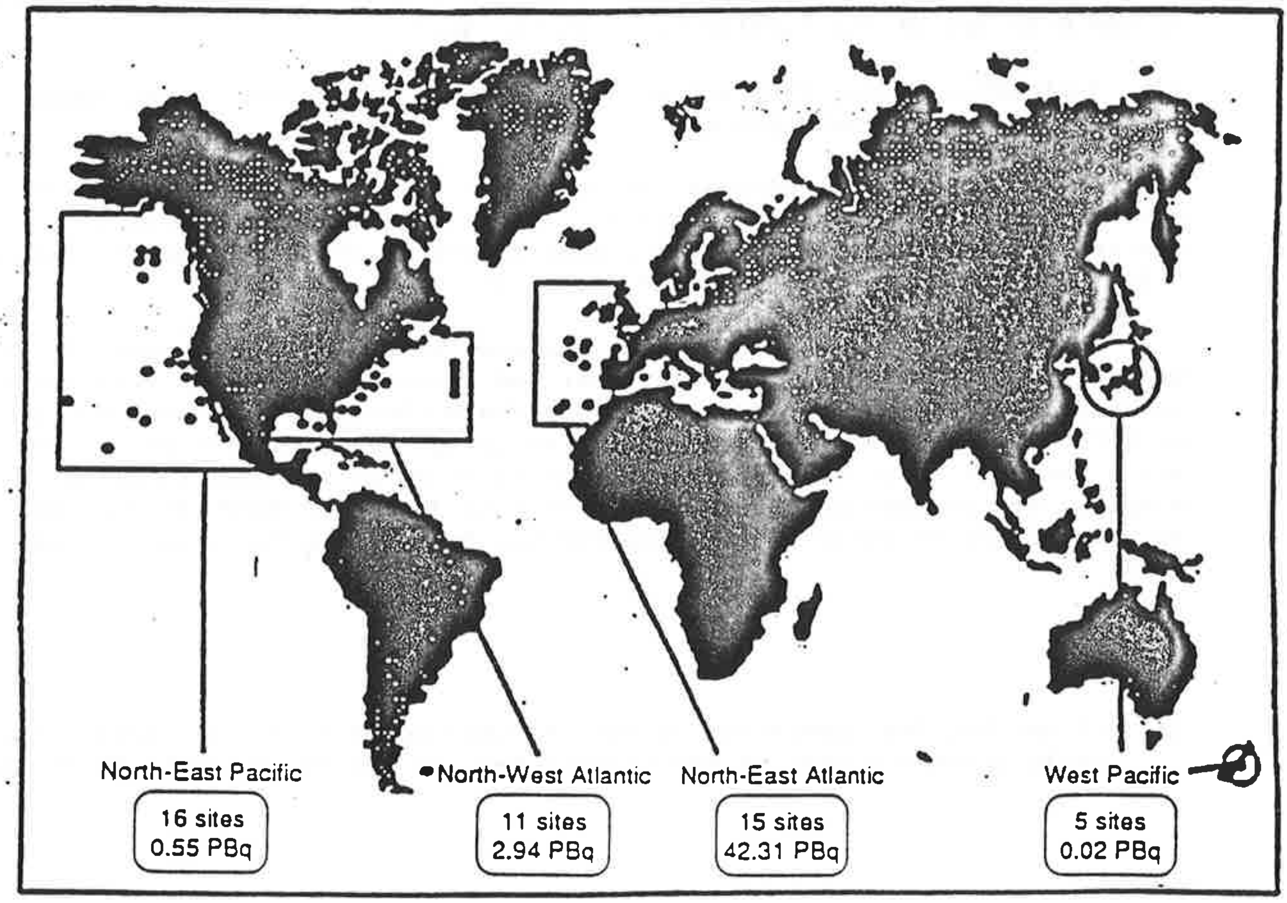

Figure 2. Location of areas used by foreign countries for radioactive waste disposal at sea [11]

According to IAEA data [10], dumpings of SRW in the world's oceans (neglecting the USSR and Russia) are characterized by the following data[5]:

Pacific Ocean

Northeastern part	0.55 PBq	(14.9 kCi)
Western part	0.02 PBq	(0.5 kCi)

Atlantic Ocean

Northwestern part	2.94 PBq	(79.4 kCi)
Northeastern part	42.3 PBq	(1143.0 kCi)

Thus, for the period from 1946 to 1982, according to IAEA data, RW with a total activity of about 46 PBq (1.24 MCi) has been dumped in the world's oceans (not counting dumpings by the USSR and Russia, which have not been reported either to the IAEA or to other international organizations to this day, and neglecting the sea dumping of liquid radioactive waste (LRW) from nuclear fuel processing plants; cf. figure 2).

1.2.1 Data on radioactive waste disposal at sea by some States

Belgium. Between 1960 and 1982, Belgium (as well as Great Britain) dumped low-level RW in the North Atlantic, Bay of Biscay and English Channel. There were a total of 15 dumpings at six sites. 55,324 containers (weighing 23,100 tonnes in totality) contained a total of 2.12 PBq (57.24 kCi).

Great Britain, which has dumped three-quarters of all RW at sea, carried out 34 dumpings of SRW between 1949 and 1982 at 15 sites in the North Atlantic, English Channel, and Bay of Biscay and off the Canary Islands. The weight of the containers (their number has not been officially reported) was 75,052 tonnes, and they contained a total activity of 35.1 PBq (949 kCi).

It should be pointed out that Great Britain has widely practiced the disposal of LRW from enterprises in the nuclear industry by discharge through pipelines into the Irish Sea. Figure 3 shows total annual discharges for ^{137}Cs and tritium between 1970 and 1988 from one nuclear fuel processing plant.

The scale of the dumpings was so great (on the order of 1 MCi) that their effect could be traced to the Barents and Kara Seas.

Germany carried out one RW disposal operation in 1967 in the North Atlantic. It dumped 480 containers weighing 185 tonnes with a total activity of 203 GBq (0.0055 kCi) at a minimum depth of 2,500 metres.

Korea performed dumpings between 1968 and 1972 at one site in the Sea of Japan. In all, 115 containers with a combined weight of 45 tonnes were dumped. No official data on activity are available.

Italy performed one RW dumping operation at one site in the North Atlantic at a depth of about 4,000 metres in 1969. It dumped 100 containers weighing 44.7 tonnes with a total activity of 185 GBq (0.005 kCi).

5/ Neglecting lost nuclear warheads and other sources of ionizing radiation, sunken nuclear submarines and radionuclides that have entered the ocean as a result of underwater nuclear explosions.

The Netherlands carried out 14 dumpings between 1967 and 1982 at four sites in the North Atlantic at a depth of 3,200-5,200 metres. The dumpings were made in 28,428 containers (weighing 19,162 tonnes) with a total activity of 336,000 GBq (9.08 kCi).

New Zealand performed 11 dumpings between 1954 and 1976 at four sites in southern Cook Strait. Thirty-nine RW containers with a total activity of 1,040 GBq (0.028 kCi) were dumped.

France performed two RW dumpings at sea (in 1967 and 1969) at two disposal sites in the Atlantic Ocean at depths of 4,000-5,300 metres. It sank 46,396 containers of RW (total weight 14,299 tonnes) with a total activity of 353,000 GBq (9.54 kCi). In 1979, discharges from French nuclear enterprises into the English Channel amounted to 920 GBq of plutonium [11].

Switzerland performed 12 RW dumpings between 1969 and 1982 at three sites in the North Atlantic at depths of 3,600 to 4,700 metres. It dumped 7.420 containers weighing 5,321 tonnes with a total activity of 4.42 PBq (119 kCi).

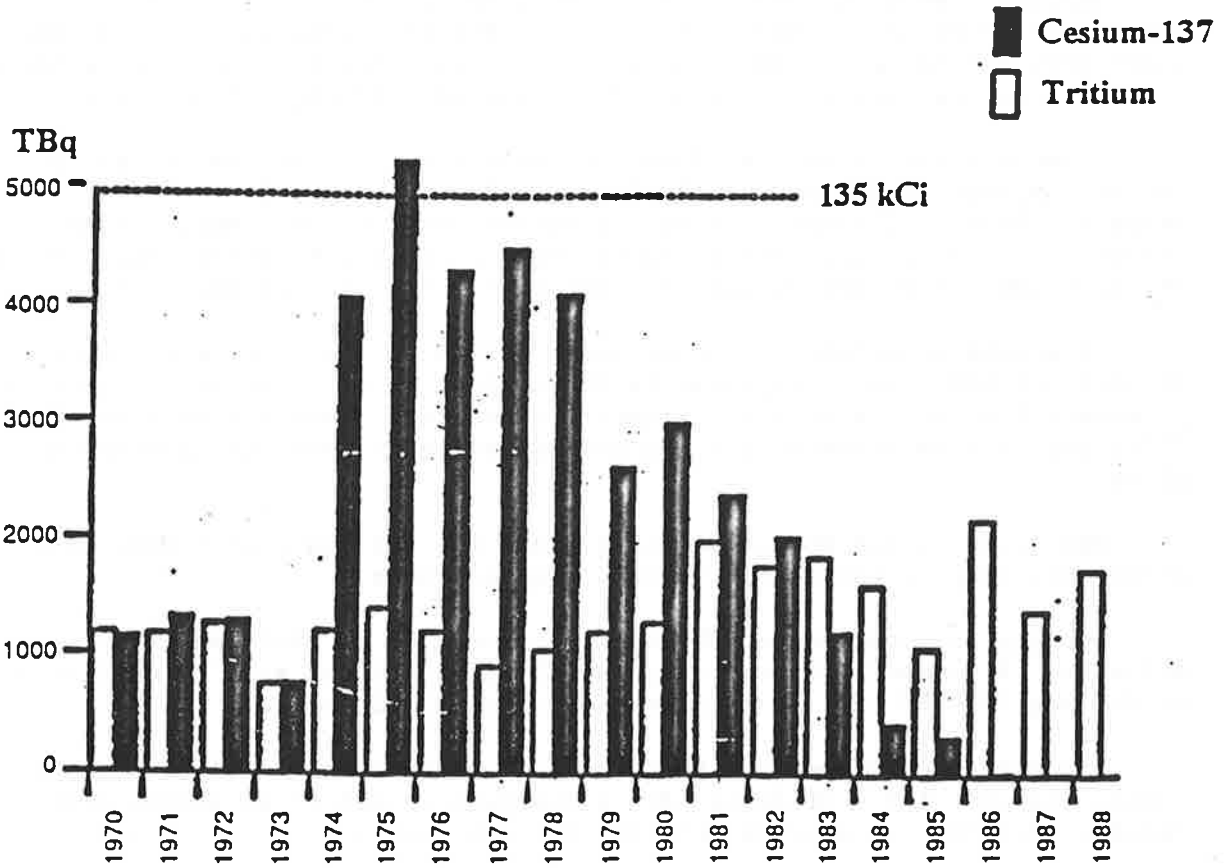

Figure 3. Total Activity of Liquid Radioactive Waste (^{137}Cs and tritium) Dumped in the Irish Sea from the Sellafield plant (Great Britain), by Year [11].

Sweden performed one RW dumping in 1969 at a single site in the North Atlantic at a depth of 4,000 metres. It dumped 2,895 containers weighing 1,080 tonnes with a total activity of 3,240 GBq (0.09 kCi).

The United States dumped 34,282 containers (weight not specified) with a total activity of 2.94 PBq (79.4 kCi) (some of them at a minimum depth as low as 11 metres!) between 1949 and 1967 at 11 sites in the Atlantic (the number of operations has not been reported).

Between 1946 and 1970, the United States performed dumpings (the number of operations not specified) of 560,261 containers (weight not specified) with a total activity of 554,000 GBq (15.0 kCi) at 18 sites in the Pacific Ocean at a minimum depth of 896 metres.

According to some data [12], RW dumpings by the United States in the northeastern Atlantic exceed the amounts specified in official reports. In at least one case in 1957, the United States Navy sank radioactive materials in the open sea.

In 1960 alone, the total activity of wastes dumped by the United States along the California coast was about 1 PBq (27 kCi). Almost as much was dumped in the waters of the Atlantic Ocean [15].

During the whole period of operation of the nuclear submarine fleet (i.e., since the mid-50s), the United States Navy lost two NSs: the Thresher in April 1969, and the Scorpion in May 1968. Both submarines sank after accidents in the areas of intense traffic shipping lanes and active fishing. Besides its reactor, the Scorpion carried two Astor nuclear torpedoes, according to expert opinions [14]. About 270 kCi (10 PBq) of fission products was deposited at the site of the Thresher's sinking on the bottom of the Atlantic Ocean [12].

Earlier, in 1959, the United States Navy sank the compartment of the nuclear submarine Sea Wolf's reactor, which had performed unsatisfactorily, 120 miles from the United States Atlantic coast.

The foreign press reported that there was a loss at sea of the nuclear warheads (NWHs) carried by an A-4 Skyhawk attack plane that fell off an aircraft carrier into the Pacific Ocean in December 1965, as well as a loss of NWHs installed on two Thor missiles during unsuccessful launches from Johnston Atoll in 1962. In March 1956, in the Mediterranean Sea the United States Air Force lost a bomber carrying radioactive components for nuclear weapons, and in January 1966, a United States plane lost 4 hydrogen bombs, which fell into the Mediterranean near Palomares, Spain [14].

An incident with a United States NS in February 1980 off the coast of Scotland resulted in a discharge of radioactive materials from a reactor cooling system [14].

Since 1977, the United States Environmental Protection Agency has performed radiological studies at RW disposal sites in the northwestern Atlantic and in the Pacific [15].

In a number of cases, high levels of cesium and plutonium have been found in close vicinity to the dumped containers [13].

Japan dumped RW in the Pacific near its coast between 1956 and 1969. It performed 12 dumping operations at six sites. It dumped 3,031 containers (weight not specified), with a volume of 606,200 m^3, containing a total of 15,400 GBq (0.416 kCi) of activity.

Analysis of all available information shows that the official data furnished by 12 countries to the IAEA [10] do not give a complete picture of RW dumpings at sea, in particular after 1989. There is little information on radionuclides that entered the marine environment due to accidents and disasters.

1.3 Position adopted by some States on matters of radioactive waste disposal at sea

The problem of RW disposal in the world's oceans is being actively debated in the United States. In 1992, the United States Senate Intelligence Committee conducted public hearings on the matter, during which the possibility of enhancing international co-operation with a view to minimize possible dangerous consequences of such dumpings was discussed [16].

Most nations favour a ban on the disposal of all types of RW at sea, considering the growing international and national concern over contamination of the marine environment by RW. This was the purpose of a Danish initiative calling for a total ban on RW disposal at sea, and of a proposal advanced initially in 1983 within the framework of the London Convention, of a moratorium on RW dumping at sea [4]. A resolution adopted at the time urged refraining from disposal of all kind and type of RW at sea until IGPRAD completed its work. As a result, the moratorium was extended until the Sixteenth Consultative Meeting of Contracting Parties to the London Convention, which is to be held in November 1993, with the understanding that by that time IGRAD would complete its assessment and offer recommendations for disposal of intermediate- and low-level RW at sea (the USSR abstained from the vote on the moratorium resolution in 1985, and Russia has not expressed a position on the matter).

The United States, France, Great Britain, and Japan hold a special position on matters of RW disposal at sea: they do not reject the idea of a moratorium *per se*, but insist on a transition period, during which all questions of the handling, recycling, storage and land disposal of RW could be resolved.

In answering the IAEA 1989 questionnaire, Belgium, Great Britain and Nauru did not give a clear response on whether they plan to dispose of RW at sea in the future. Germany, Greece, Italy, Canada, China, Mexico, Nauru, the Netherlands, the United States and Finland stated at the time that they considered RW disposal at sea still an open question. Canada reserved the right to sea disposal of RW produced by decontamination of contaminated soils, as did France for tritium [10].

China has adopted recently an increasingly active position on these matters.

The UN Conference on Environment and Development endorsed an initiative by Denmark, Iceland and Norway in favour of adopting a recommendation prohibiting RW disposal at sea. The recommendation [17], adopted by a consensus of some 150 nations (including Russia), will have evergrowing reflection in the position of many nations.

1.4 Conclusion

RW dumping at sea is stricly regulated by international law, primarily by the 1972 Convention on Prevention of Marine Pollution by Dumping of Wastes and Other Matter (the London Convention), as well as special IAEA regulations and standards.

According to the official IAEA data, the current practice of RW disposal and its restricting to the countries that use nuclear technologies in most cases meets international legal requirements (although according to unofficial data, some countries do not comply with them).

In 1992, the UN Conference on Environment and Development in Rio de Janeiro favoured ending the practice of RW disposal at sea. The same year, the Conventions on the Protection of the Marine Environment of the Baltic Sea Area and on the Protection of the Black Sea from Pollution were signed (with Russia signing), as was the Convention on the Protection of the Marine Environment of the Northeastern Atlantic (which the Russian Federation has not yet signed). The latter (Paris) Convention provided for a phase-out of RW sea discharges by Great Britain and France through 2018, i.e., it offers a solution that meets Russia's interests and capabilities.

SECTION 2. RADIOACTIVE WASTE DISPOSAL IN THE SEAS ADJACENT TO THE TERRITORY OF THE RUSSIAN FEDERATION

The nuclear arms race and development of nuclear power have raised the problem of handling large quantities of RW, which has never been adequately addressed. This neglect caused significant contamination of the territories of nuclear power enterprises and the environment.

The launch of a nuclear-powered icebreaker fleet in the USSR and deployment of a fleet of NSs required allocation of disposal sites for the RW produced.

In the atmosphere of the cold war, this problem was not given priority, and the simplest solution was to dispose of RW directly in the sea, which was practiced widely by most countries with developed nuclear industries.

After the London Convention took effect, the USSR took a number of steps with a view to complying with the international standards and obligations it had assumed. In 1979, the Council of Ministers adopted resolution 222, Measures to Ensure Performance by the Soviet Party of the Obligations arising from the 1972 Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter.

RW discharges from the facilities of the Murmansk Shipping Company were gradually reduced and consequently completely halted. However, RW discharges by the Navy were not discontinued. The reasons were the inefficient system of RW handling in the country as a whole, the lack of RW processing equipment in the Navy, the insufficient capacity of shore storage facilities, and the USSR Ministry of Foreign Affairs' misinterpretation of the "immunity of warships" concept, which made it possible not to consider RW discharges from the Navy vessels as violations of the requirements of the London Convention.

2.1 Normative documents that regulated radioactive waste disposal at sea in the USSR

The first normative document in this field was the 1960 Provisional Sanitary Requirements for Discharge of Liquid Wastes Containing Long-Lived Radioactive Substances into the Sea from Naval Facilities. It was drafted by the Navy and the USSR Ministry of Medium Machine-Building and the Third Main Administration of the USSR Ministry of Public Health. The purpose of the above regulations was to ensure that discharges of RW into the sea complied with sanitary and hygienic standards existing at the time.

In 1962, a new version of the Requirements was drafted. It determined the amount of LRW that could be discharged in terms of volume (not over 1,000 m^3), volumetric activity (not over 50 μCi/l (1850 kBq/l), for short-lived isotopes and not over 10 μCi/l (370 kBq/l), for long-lived isotopes), and total activity (not over 10 Ci). It stipulated that ships be outfitted with equipment to dilute RW by at least 250% during a dumping operation. Direct discharges of RW from NSs were permitted only in case of emergency.

In 1965, the Navy implemented new regulatory measures permitting the dumping of LRW from NSs outside the 10-mile limit, discharge of secondary-loop water and waste water with an activity of less than 10 nCi/l (370 Bq/l). These measures also provided for the possibility of disposing of SRW in metal containers without special shielding, and large pieces of waste without containers. The Northern and Pacific Fleet Commands were charged to select areas for disposal of SRW. Thus, the Navy attempted to solve problems falling beyond the scope of its departmental authority, since it made decisions with long-term consequences, without co-ordination with State executive authorities, that threatened the ecological state of large areas of the country and areas under international jurisdiction.

A more detailed RW sea disposal regulation was adopted in 1966 by means of the implementation of the Provisional Sanitary Requirements for Disposal of Radioactive Wastes at Sea (VSTZ-66), approved by the Navy and the USSR Ministry of Public Health.

VSTZ-66 applied to all facilities where NSs were based, refuelled or repaired, as well as ship repair and shipbuilding yards. VSTZ-66 contained requirements for RW discharge and disposal areas, standards for the discharge of LRW and disposal of SRW, procedures for preparation and transportation of RW, and instructions on the conduct of radiation hygiene monitoring at disposal sites. VSTZ-66 by and large complied with generally accepted standards, but since the regulation applied to the open sea, it should have been approved by the Government but not by an individual department.

The sea areas for LRW discharge and disposal of SRW were selected by the headquarters of the Northern and Pacific Fleets and approved by the Navy General Staff in 1966-1967. Until 1986 the Murmansk Shipping Company of the USSR Merchant Marine Ministry also dumped RW in the areas allocated to the Northern Fleet. The areas selected are shown in figure 4.

The procedures defined by VSTZ-66 for RW disposal at sea remained in effect until 1983. When the USSR acceded to the 1972 London Convention and when it came into force for the USSR on 29 January 1976 it had to review the standards and fulfil the assumed obligations.

On 6 March 1979, the USSR Council of Ministers adopted a resolution [18] prohibiting the intentional discharge for purposes of disposal at sea of RW and other radioactive substances with high levels of radiation insofar as such a discharge at sea proved to be unacceptable for biological and other reasons from Soviet ships and other surface vessels, aircraft, platforms, and other structures artificially constructed at sea. As for RW and other radioactive materials that do not fall into the above classifications, their discharge was permitted by special permission of the USSR State Committee for Hydrometeorology (Goskomgidromet), in consultation with the USSR Ministry of Fisheries.

Under the resolution, Goskomgidromet was charged with the following tasks:

- recording the characteristics and amount of RW and other materials approved for dumping;

- recording the site, time, and method of dumping;

- observing the condition of the sea in conformity with the purposes of the London Convention;

- furnishing the information on dumpings performed to the International Maritime Organization responsible for Secretariat duties in relation to the Convention and to other Contracting Parties to the Convention.

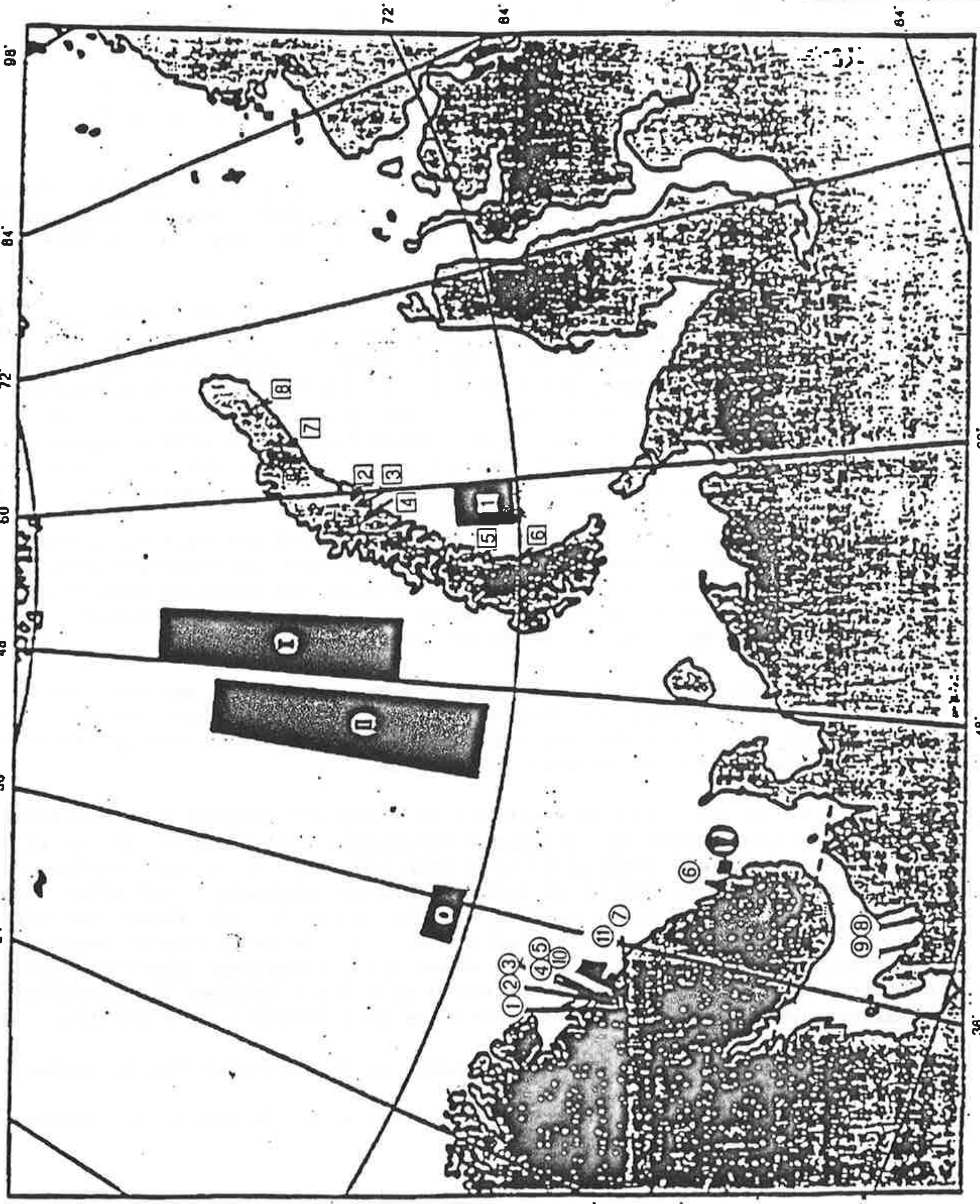

Figure 4. Location of Major Radioactive Waste Sources and Disposal Areas in the Northern Seas [14]. Northern Fleet Bases: 1-Nerpichya Bay; 2-Andreyev, Bolshaya Lopatka and Malaya Lopatka Bays; 3-Olenya and Sayda Bays; 4-Ara Bay; 5-Pala Bay; 6-Yokanga. Holding and Recycling Sites for Decommissioned Nuclear-Powered Naval Vessels and Ships: 4-Polyarny; 6-Yokanga; 7-Murmansk (Nuclear Fleet Radio Regiment); 8-Severodvinsk (water area of Zvëzdochka Shipyard, North Production Association). Temporary Storage Sites for Spent Nuclear Fuel: 1-Andreyev Bay; 6-Yokanga; 7-Mother ships Imandra, Lepse, and Lotta; 2-Navy tender for refuelling reactors of NSs. Shipyards: 8-Severodvinsk (Northern Machinery Enterprise Production Association, North Production Association); 4-Polyarny (Naval shipyard); 4-Vyuzhny (Nerpa Shipyard). Not shown on map: Saint Petersburg (Baltic Yard Production Association, Admiralty Production Association), Nizhniy Novgorod (Krasnoye Sormovo Production Association). I, V: LRW dumping sites. I, VIII (boxed): SRW disposal areas.

In 1983, in co-operation with Goskomgidromet, the Navy developed, approved and implemented Regulations for Discharge of Radioactive Waste at Sea (PS-82).

The USSR performed most of its RW dumpings at sea between 1959 and 1976, i.e., before the London Convention came in force for the USSR and after the Convention became effective its provisions were deliberately and recurrently violated, including by application of PS-82.

These Regulations did not require selection of disposal sites beyond the continental shelf, internal and marginal seas, contained no prohibition on disposal in areas at high latitudes (above 50°N), and did not stipulate regular notification of the disposal of RW at sea using the form prescribed by the IMO and IAEA, as required by the London Convention.

When endorsing PS-82, Goskomgidromet assumed that the Navy was planning to commission RW handling facilities by 1986, and to review the Regulations in 1986-1987 in accordance with the recommendations of the IAEA and London Convention [2, 3, 4]. However, no RW handling facilities had been built, and the Navy had to continue RW dumping at sea. In 1985, the USSR Goskomgidromet refused to agree to the Navy's proposed disposal areas in the northern seas, some of which were on the eastern coast of the Novaya Zemlya archipelago. In view of the continued RW dumping at sea, the USSR Goskomgidromet withdrew its endorsement of PS-82 effective 1 December 1987. From then on, permits to dump RW at sea were issued by Navy Headquarters.

In February 1992, the Commander-in-Chief of the Navy requested the Government of the Russian Federation to maintain for the time being the existing procedures for RW dumping at sea. In accordance with Instruction No.A-2-611 of the Government of the Russian Federation, the Russian State Nuclear Power Supervisory Administration (Gosatomnadzor) reviewed the request and recommended that the Navy had to obtain advice of scientific institutions and interested ministries. According to the opinions of the Russian Ministry of Nature, Ministry of Foreign Affairs, and the Scientific Commission for Radiation Protection, decision-making on matters of RW disposal at sea should be governed by international standards and this actually implies a ban on RW disposal at sea.

In violation of the requirements of the London Convention and the USSR Council of Ministers resolution [18], Goskomgidromet did not furnish information on RW disposal at sea to IMO and IAEA. Moreover, in its answers to the London Convention's questionnaire in 1989, it was stated that "the USSR has not dumped, is not dumping, and does not plan to dump radioactive waste at sea" [6].

It is especially important to refer to the normative documents relating to the disposal of high-level RW. Such dumpings are completely prohibited by the London Convention and existing national regulations, but the USSR performed them since 1965 under ad hoc decisions of the USSR State Committee for Shipbuilding, the USSR State Committee for the Use of Atomic Energy, and the Navy on individual projects developed earlier by scientific research institutes (in particular, the Russian Ministry of Atomic Energy's Scientific Research and Engineering Institute of Power Technology).

From 1987, the dumping of RW at sea by the USSR was unlawful in two aspects:

- first, the normative documents approved by the USSR contained requirements for disposal of RW at sea that did not comply with the requirements of international standards recognized by the USSR;

- second, even requirements of the normative documents approved by the USSR were violated (RW was dumped without consultation with the environmental bodies and without any non-departmental government monitoring and supervision of nuclear safety in RW handling).

Thus the information presented in this section of the report on the normative acts regulating RW disposal procedures in the northern and far eastern seas shows that the international agreements in this area were disregarded by the USSR either completely or partially. The discrepancy between the USSR's actions and obligations under the London Convention, was recurrently revealed at the closed interdepartmental conferences held between 1983 and 1990 by Goskomgidromet and the USSR State Committee for Nature but no corrective actions were taken by the USSR Government.

The legal aspects of all the departmental standards, regulations, and methodological instructions permitting RW disposal at sea (in violation of the provisions of the London Convention binding upon the USSR) requires special assessment from the standpoint of law.

2.2 The Russian Federation Law on Radioactive Waste Disposal at Sea

When the Russian Federation assumed the obligations of the USSR arising from the international accords and agreements, the London Convention came to apply to Russia in full, and therefore, the disposal of RW at sea must be governed by generally accepted international standards.

The RW sea disposal regulations followed by the Navy, and the areas where such dumping was performed in the north and (partly) the far east are in sharp contradiction with the London Convention, and therefore all departmental instructions and regulations have become invalid for Russia.

This conclusion is fully incorporated into the Russian Federation Law, Protection of the Natural Environment (December 1991), Article 50 of which, Ecological Requirements in the Use of Radioactive Materials, provides:

> "50.3 The import of radioactive waste and materials from other countries for storage or disposal purposes, and the sinking or sending into space of radioactive waste and materials for disposal purposes, is prohibited" [20].

Thus, this Law prohibits both the disposal of RW in the territorial waters of the Russian Federation and any disposal of RW produced in the Russian territory in any sea.

2.3 Total volume and characteristics of radioactive waste dumped at sea by the USSR between 1959 and 1991

The first dumpings of RW in the USSR were performed during the run testing of NSs and the nuclear icebreaker Lenin. In 1959, 600 m^3 of low-level waste (20 mCi) were discharged in the White Sea, and in 1960, the Lenin discharged 100 m^3 of LRW (total activity 200 mCi) near Gogland Island in the Gulf of Finland.

Regularly LRW dumping began in 1960, and the disposal of SRW in the northern and far eastern seas began in 1964.

2.3.1 Disposal sites, volumes, and total activity of radioactive waste dumped by the USSR in the northern seas

This section reviews the situation with LRW discharges and the disposal of low-, intermediate-, and high-level SRW at sea.

The data presented on the activity of sea-dumped SRW (excluding reactor components and reactors proper with spent nuclear fuel (SNF)) require the following clarification:

> Information in original sources used by the Commission on the activity of SRW is presented as "activity (^{90}Sr equivalent), curies." This artificial characteristic was recommended for practical use in the departmental methodology Regulations for Discharge of Radioactive Wastes at Sea (PS-82) and is designed for generalized description of various amounts of SRW (for example, a container) as a source of radiation at the time of disposal. Numerical values of "activity (^{90}Sr equivalent)" were determined on the basis of measurements of the dose power near the SRW mass using a simple empirical dependence, taking into consideration *a priori* knowledge of the radionuclide content of the SRW mass.
>
> Information on the activity of LRW is presented in the customary form "activity, curies," which simplifies quantitative comparison with discharges performed by other countries, which is not the case with SRW when the form "activity (^{90}Sr equivalent), curies" is used.
>
> An assessment of the radioecological consequences of solid and liquid RW dumping on the basis of the data presented in the Appendix is rather a difficult task due to the lack in both cases of the detailed information on the radionuclide composition of wastes and the shielding properties of the containers or tanks. In this respect work on a more detailed description of SRW dumpings and LRW discharges should be continued.
>
> It must be noted that the summary results (for years, areas, etc.) presented in the tables in the Appendix have no physical meaning, and therefore cannot be used in scientific research, although they do have a certain illustrative meaning. Moreover, the lack of information on radionuclide content does not allow recalculation of the activity at a given moment in time after disposal.

Nevertheless, on the basis of the information presented in the Appendix, a relative comparison can be made both for solid and for liquid RW of the amount of RW dumped in various areas of the northern and far eastern seas, and a comparison can also be made with similar data for other countries.

- P.M. Rubtsov

The geographic location of the five officially designated areas for dumping of LRW in the northern seas was shown in figure 4. Characteristics of these areas are presented in table A1 of the Appendix. As noted in the previous section, these areas were selected in 1960-1966 by the Northern Fleet Headquarters and approved by the Navy General Command.

Detailed information on LRW dumping in the northern seas is given in table A2 of the Appendix. A small portion of the dumping was conducted outside the designated areas. Information on the rate of dumpings of LRW in the northern seas is shown in figure 5.

The data show that according to available data,1/ the total activity of LRW is 24 kCi (903 TBq), and is distributed as follows across various seas:

Baltic Sea	0.2	Ci	(0.007 TBq)
White Sea	100	Ci	(3.7 TBq)
Barents Sea	12,153	Ci	(450 TBq)
Kara Sea	8,500	Ci	(315 TBq)

Liquid RW discharges at sea were extremely irregular (figure 5), with the maximum activities of dumped RW occurring:

- in 1965: northeastern Barents Sea, Area 2, about 1,000 Ci (37 TBq);
- in 1975: central Barents Sea, Area 3, over 800 Ci (29.6 TBq), and Kara Sea, 8,500 Ci (315 TBq) (dumped from the Lenin);
- in 1988: northeastern Barents Sea, Area 1, about 5,300 Ci (196 TBq);
- in 1989: Ara Bay, 2,000 Ci (74 TBq) (result of an NS accident)

1/ The activity of liquid radioactive waste that entered [the sea] through leaks from shore storage facilities and due to accidents on nuclear submarines was not included.

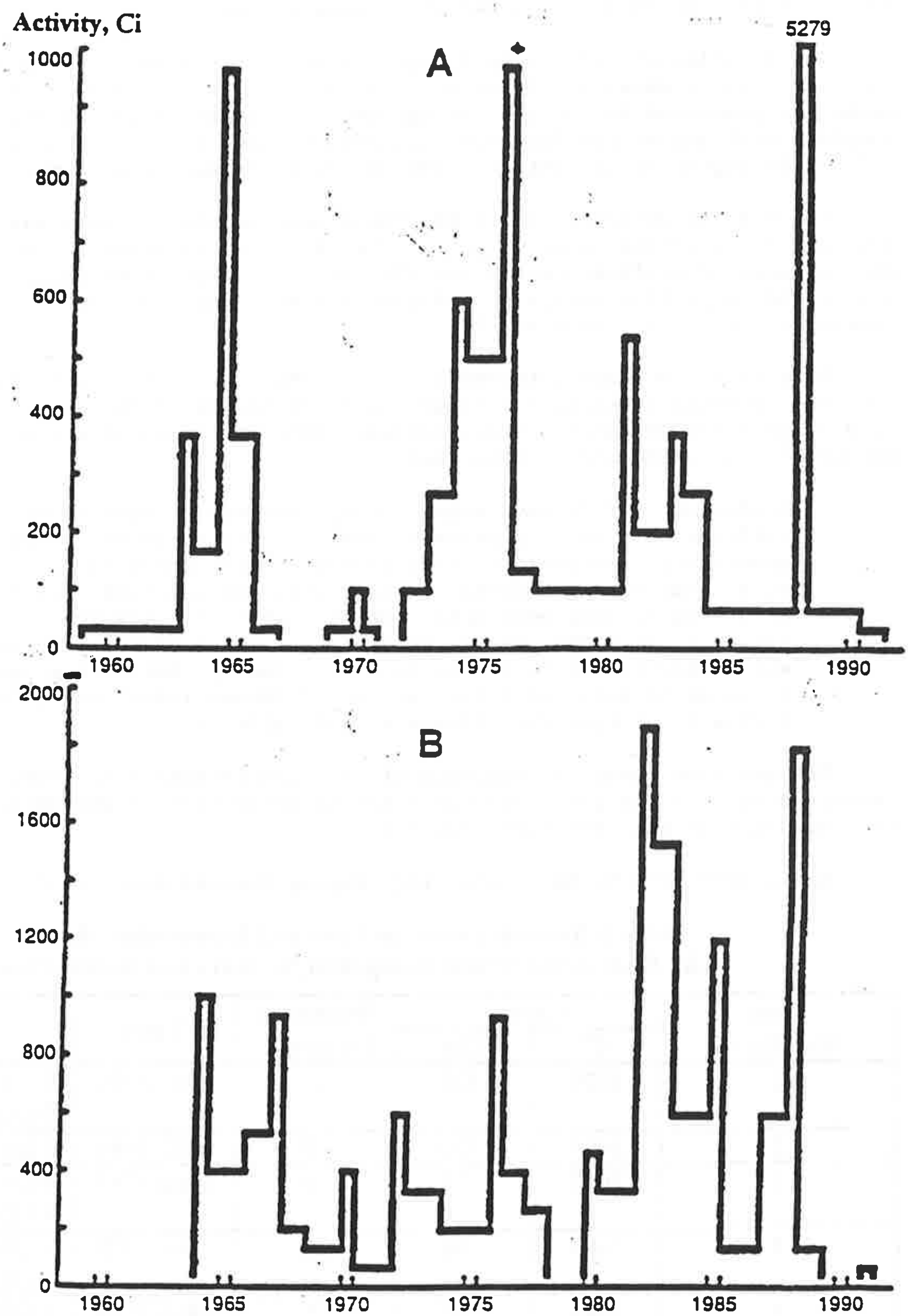

Figure 5. Rate of Radioactive Waste Disposal in the Northern Seas by Year. A: dumping of liquid RW; B: disposal of low- and intermediate-level solid RW. Bar height is proportional to annual dumping activity.

The Murmansk Shipping Company stopped LRW dumping at sea in 1984, but the Navy continues to this day, although in lesser amounts.

The location of officially designated areas for disposal of SRW in the northern seas is shown in figure 4. Characteristics of the main disposal areas are presented in table A3 of Appendix. None of these SRW disposal areas complies with any of the international requirements for this kind of activity (either in depth, or in distance from shore, or in location on the globe).

In terms of volume, most of the SRW dumped in the northern seas is low- and intermediate-level RW produced during the operation of the Navy nuclear-powered surface vessels and NSs and the nuclear icebreaker fleet, and at the respective shipyards. Figure 4 showed the location of the main sources of SRW in northern Russia.

As a rule, low- and intermediate-level SRW sunk in the northern seas was enclosed in metal containers. Large pieces of RW were sunk separately or within specially designated ships-barges, lighters, or tankers (table A4 in Appendix). This SRW mainly comprised:

- contaminated film coverings, tools, personal protective devices, uniforms, fittings, pipelines, activity filter boxes, pumps, steam generators, and various contaminated objects produced during ship repair work. The total activity of the sunken intermediate- and low-level SRW, according to available data, was over 15.5 kCi (574 TBq) in the Kara Sea and 40 Ci (1.5 TBq) in the Barents Sea. Most of SRW in terms of volume was dumped in the Kara Sea, in Area 1 (Novaya Zemlya Depression), and in terms of total activity, in Area 2 (Sedov Inlet, Novaya Zemlya) (table A4 of Appendix, figure 6, and table 2).

The greatest number of dumpings of low- and intermediate-level SRW was performed in 1967 and 1982, and the greatest activities of SRW dumped was recorded in 1983 and 1988 (see figure 5).

Since 1986, the Murmansk Shipping Company stopped disposal of SRW at Sea.

Table 2. Summary Data on Low- and Intermediate-Level Solid Radioactive Waste Dumped in the Kara and Barents Seas

Area (See Fig. 4)	Activity		Number of Dumpings	Years	Remarks
	Ci	TBq			
1	3320	123	22	1967-1991	3174+? C, 9 LO, 8 V
2	3410	126	8	1982-1984	1108 C, 104 LO
3	2027	75	8	1968-1983	472+? C, 4 LO, 1 V
4	2684	99	8	1964-1978	1600+? C, 6 LO, 1 V
5	1280	47	5	1968-1975	5 LO
6	661	25	7	1966-1981	8+? C, 7 LO, 4 V
7	235	8	1	1972	1 LO
8	1845	68	3	1982-1988	146+? C, 18 LO, 1 V
Off Kolguyev Island	40	1.5	1	1978	1 V

Key to Remarks: *C*—containers; *LO*—large objects; *V*—vessels.

Table 2 (continued)

Area (See Fig. 4)	Activity		Number of Dumpings	Years	Remarks
	Ci	TBq			
Chernaya Bay (Novaya Zemlya)	300	11	1	1991	1 LO
Barents Sea	>100	>4	1	?	Barge with solid RW in welded hold
Total	~6000	~590	65		6508+? C, 155 LO, 17 V

Key to Remarks: *C*—containers; *LO*—large objects; *V*—vessels.

Among all RW dumpings in the northern seas, the greatest ecological hazard is created by the sunken objects with SNF, which are a mixture of fission products and actinides. Summary information on these objects is presented in Table 3.

Table 3. Objects with Spent Nuclear Fuel Dumped in the Northern Seas

Object	Coordinates, Year	Depth, meters	Total Activity (max.), kCi*	Radionuclide Content	Description of Protective Barriers
Compartment of NS No. 285 with two reactors, one containing SNF in place (see also Table 4)	71°56'2" N, 55°18'5" E, Abrosimov Inlet, 1965	20	800	Fission products	Stock reactor compartment and interior structures filled with furfurol mixture
Compartment with two reactors containing SNF from NS No. 901	71°56'2" N, 55°18'9" E, Abrosimov Inlet, 1965	20	400	Fission products	Same
Shielding assembly of reactor from OK-150 unit of nuclear icebreaker *Lenin* with residual SNF (60% of fuel complement based on UO_2)	74°22'1" N, 58°42'2" E, Tsivolka Inlet, 1967	49	100	^{137}Cs (~50 kCi), ^{90}Sr (~50 kCi), ^{238}Pu, ^{241}Am, ^{244}Cm (~2 kCi)	SNF residue bound by furfurol-based mixture, shielding placed in reinforced concrete container and metal shell
Reactor from NS No. 421 with SNF	72°40' N, 58°10' E, Novaya Zemlya Depression, 1972	300	800	Fission products	Metal container with lead shell dumped along with barge
NS No. 601 with two reactors containing SNF	72°31'15" N, 55°30'15" E, Stepovoy Inlet, 1981	50	200	Fission products	Stock reactor compartment and interior structures filled with furfurol mixture
Total: 5 objects with 7 reactors containing SNF	1965-1981		2300		

*—Expert estimates were made at the time of sinking, based on power generated by NS reactors (12.5 GW/day).

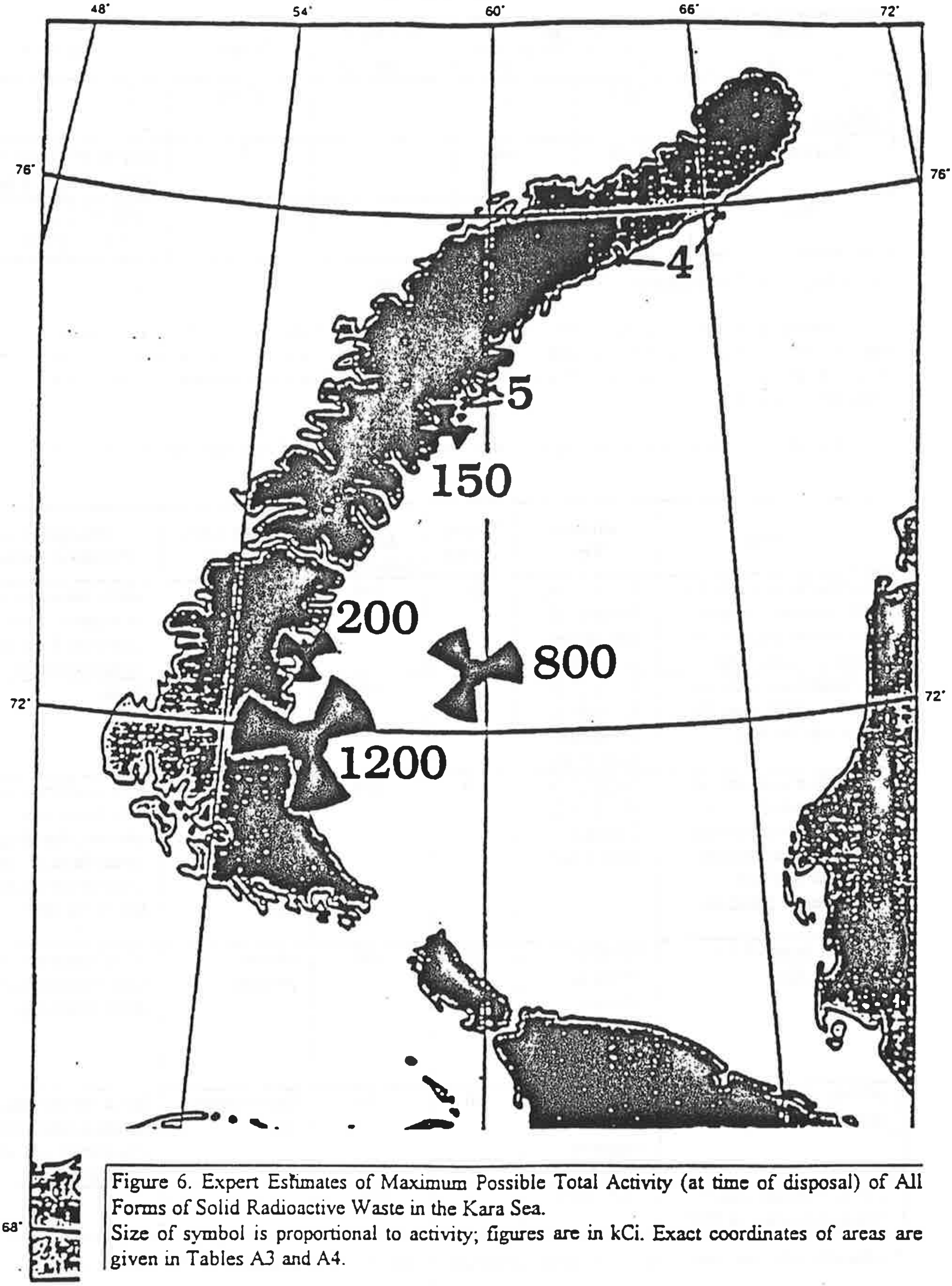

Figure 6. Expert Estimates of Maximum Possible Total Activity (at time of disposal) of All Forms of Solid Radioactive Waste in the Kara Sea.
Size of symbol is proportional to activity; figures are in kCi. Exact coordinates of areas are given in Tables A3 and A4.

As the table indicates, the inlets along the coast of Novaya Zemlya hold one NS with two reactors containing fuel in place, a reactor compartment with two reactors containing SNF, a reactor compartment with one reactor containing SNF in place and one reactor with SNF removed, and an NS reactor with SNF in place. Removing the SNF from all six sunken NS reactors was impossible due to the damaged condition of their cores. For the same reason, 125 irradiated fuel assemblies (FAs) could not be removed from the core plate of the OK-150 reactor unit on the nuclear icebreaker Lenin. Thus, according to available official data, six reactors with SNF in place and one shielding assembly from the Lenin with partially removed SNF were dumped in the inlets of Novaya Zemlya and the Novaya Zemlya Depression of the Kara Sea.

An exact estimate of the radionuclide content of these cores (without knowledge of which the environmental consequences of each dumping cannot be assessed) and determination of their total activity requires hard scientific research. Such estimates can be made only after analysis of the data on the operating conditions of each nuclear reactor throughout its life. Such an analysis has been performed only for the Lenin. This permitted the activity of the SNF at the time the reactor was dumped in 1967 to be estimated at 100 kCi. This work has not been done for NS reactors sunk off Novaya Zemlya, and the minimum estimate of their total activity furnished by the Navy, 120 kCi, is not substantiated enough and requires further calculations with due account of the reactors' operating conditions. The maximum estimate of the overall total activity at the time of dumping, in the opinion of an expert of the Commission, could be at least 2.3 MCi (see table 3 and figure 6).

We should note the activity of the reactor sunk as a result of an accident aboard the NS Komsomolets, which is lying at the boundary between the Norwegian and Barents Seas at a depth of 1,700 m, 300 km from shore. According to expert estimates, the total activity of this NS's reactor core is at least 150 kCi.

Before sinking, the reactor compartments with SNF in place were filled with a hardening furfurol-based mixture (except one NS reactor). According to estimates by the power plant's designer, this filling will prevent the SNF from contacting seawater for a period of several hundred (up to 500) years. As noted in table 3, the shield assembly with SNF from the Lenin was additionally placed in a reinforced concrete container and a metal shell. Table 4 presents available data on the disposal of reactor compartments and reactors with SNF in place in the northern seas. These data show that a grand total of 10 reactors with SNF in place were dumped in the inlets of Novaya Zemlya and the Kara Sea.

It is difficult to determine their total radioactivity accurately enough. In these reactors, most of the radionuclides were produced through the action of neutron fluxes in the working reactor, so their activity is also crucially determined by the reactor's operating history. Moreover, the activity of these objects depends on their elemental make-up. Thus, in the structural parts of the Lenin, cobalt was used, which resulted in a very high level of induced ^{60}Co activity (about 50 kCi). An expert estimate of the total induced activity is at least 1,000 kCi at the time of sinking.

Thus, the available data show that RW was discharged and dumped in the Barents and Kara Seas from 1960. The RW dumped was mainly liquid and solid RW (the latter low-, intermediate-, and high-level, including reactor compartments from NSs with fuel in place) produced during operation of nuclear icebreakers and ships of the Navy.

Analysis of the situation with radioactive contamination of the northern seas will not be complete without reference to the possible entry into the marine environment of man-made radioactive substances from the atmosphere, from river runoff, possible drift from the Gulf Stream, one branch of which passes through the Barents Sea, and products of underground and surface nuclear tests on Novaya Zemlya.

Table 4. Objects without Spent Nuclear Fuel Dumped in Northern Seas, 1965-1968

Object	Coordinates, Year	Depth, meters	Total Activity	Radio-nuclide Content	Description of Protective Barriers
Reactor of NS No. 285 (see Table 3)	71°56'2" N, 55°18'5" E, Abrosimov Inlet, 1965	20	Requires special analysis	Unclear	Stock reactor compartment structures
Reactor compartment (two reactors) from NS No. 254	71°55'13" N, 55°32'32" E, Abrosimov Inlet, 1965	20	Requires special analysis	Unclear	Stock reactor compartment structures
Reactor compartment (two reactors) from NS No. 260	71°56'2" N, 55°18'5" E, Abrosimov Inlet, 1966	20	Requires special analysis	Unclear	Stock reactor compartment structures
OK-150 nuclear power plant from icebreaker *Lenin*, comprising three reactors with primary loop pipelines and watertight stock equipment	74°26'4" N, 58°37'3" E, Tsivolka Inlet, 1967	50	~50 kCi	Mainly ^{60}Co	Biological shielding unit (B-300 steel, concrete)
Two reactors from NS No. 538	73°59' N, 66°18' E, Techeniye Inlet, 1988	35–40	Requires special analysis	Unclear	Metal container with lead shell
Total: 5 objects with 10 reactors without SNF	1965-1988	20–40	Requires special analysis (possibly up to 100 kCi at time of dumping)		

As a result of radioactive fallout, the soils of the Far North contain ^{137}Cs at a level of about 40 mCi/km^2, and ^{90}Sr at about 30 mCi/km^2. According to the data from the Russian Committee for Hydrometeorology (Roskomgidromet), entries of ^{90}Sr and ^{137}Cs to the Barents Sea with river runoff between 1961 and 1989 were about 6 kCi(200 TBq). The total entry of ^{137}Cs and ^{90}Sr to the Barents Sea from the atmosphere with global fallout of the products of nuclear explosions over the same period is estimated at approximately 100 kCi (3,700 TBq).

Similar calculations for the Kara Sea provide corresponding values of 33 kCi (1,200 TBq) and 70 kCi (2,600 TBq).

Some calculations indicate that the transport of LRW dumped by nuclear fuel processing plants at Sellafield, Great Britain and La Hague, France could have contributed about 200 kCi (7,400 TBq) to the Arctic Sea and the ecosystem of the Barents Sea. Without denying the very principle of transport of some portion of LRW from the Arctic Sea, we should note that this matter requires further considerable research (see figure 7).