



Inventory of radioactive waste disposals at sea



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FOREWORD

The IAEA was requested by the Contracting Parties to the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter (London Convention 1972) to develop and maintain an inventory of radioactive material entering the marine environment from all sources. The rationale for having such an inventory is related to its use as an information base with which the impact of radionuclides from different sources entering the marine environment can be assessed and compared.

To respond to the request of the London Convention, the IAEA has undertaken the development of the inventory to include:

- disposal at sea of radioactive wastes, and
- accidents and losses at sea involving radioactive materials.

This report addresses disposal at sea of radioactive waste, a practice which continued from 1946 to 1993. It is a revision of IAEA-TECDOC-588, *Inventory of Radioactive Material Entering the Marine Environment: Sea Disposal of Radioactive Waste*, published in 1991. In addition to the data already published in IAEA-TECDOC-588, the present publication includes detailed official information on sea disposal operations carried out by the former Soviet Union and the Russian Federation provided in 1993 as well as additional information provided by Sweden in 1992 and the United Kingdom in 1997 and 1998.

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EDITORIAL NOTE

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1. INTRODUCTION

The Report of the United Nations Conference on Human Environment held in Stockholm in 1972 [1] defined principles for environmental protection. One of the principles specifically addressed the protection of the marine environment by development of General Principles for Assessment and Control of Marine Pollution. Pursuant to Recommendation 86 of the Stockholm Conference, these principles for Assessment and Control of Marine Pollution were forwarded to an Inter-Governmental Conference held in London in 1972 which adopted the Convention on the Prevention of Marine Pollution by Dumping¹ of Wastes and Other Matter [2]. This Convention is referred to as the London Convention 1972 but was formerly known as the London Dumping Convention (LDC). The London Convention 1972 entered into force on 30 August 1975.

The Contracting Parties to the London Convention 1972 agreed to "promote the effective control of all sources of pollution of the marine environment, and pledged themselves especially to take all practicable steps to prevent the pollution of the sea by the dumping of waste and other matter that is liable to create hazards to human health, to harm living resources and marine life, to damage amenities or to interfere with other legitimate uses of the sea" [2]. Contracting Parties to the London Convention 1972 designated the IAEA as the competent international body in matters related to sea disposal of radioactive waste and entrusted the IAEA with specific responsibilities, as follows:

- to define high level radioactive wastes or other high level radioactive matter unsuitable for dumping at sea as referred in Annex I to the Convention, and
- to recommend a basis for issuing special permits for dumping those materials not listed in Annex I of the Convention.

The IAEA was mandated to keep the definition of high level waste and recommendations for special permits to limit the impact of the disposal operation under continuing review. As requested, a provisional definition of high level waste unsuitable for disposal at sea and recommendations were provided in 1974 [3] and successively revised in 1978 [4] and 1986 [5]. The revisions reflect the increasing knowledge of relevant oceanographic behaviour of radionuclides and improved assessment capabilities.

The 1986 definition of high level radioactive waste or other high level radioactive matter unsuitable for dumping at sea is as follows [5]:

- (1) Irradiated reactor fuel; liquid wastes from the first solvent extraction cycle of chemical reprocessing of irradiated reactor fuel, or equivalent processes; and solidified forms of such waste; and
- (2) Any other waste or matter of activity concentration exceeding:
 - (a) 5×10^{-5} TBq²/kg for alpha emitters;

¹ As defined by the London Convention 1972 [2], "dumping" means:

- (i) Any deliberate disposal at sea of wastes and other matter from vessels, aircraft, platforms or other man-made structures at sea;
- (ii) Any deliberate disposal at sea of vessels, aircraft, platforms or other man-made structures at sea.

² 1 TBq = 10¹² Bq.

- (b) 2×10^{-2} TBq/kg for beta/gamma emitters with half-lives of greater than one year (excluding tritium); and
- (c) 3 TBq/kg for tritium and beta/gamma emitters with half-lives of one year or less.

To further discharge its responsibilities, the IAEA, from time to time, has issued recommendations and guidance to ensure that disposal of any radioactive waste into the sea does not result in unacceptable hazards to man and marine organisms. Major events associated with sea disposal of radioactive waste are presented in Table I [3–24].

In 1985, Resolution LDC.21(9) of the Contracting Parties to the London Convention introduced a voluntary moratorium on the disposal of low level radioactive wastes at sea [15]. After the adoption of this Resolution, the IAEA continued to support the London Convention by providing scientific advice on issues relevant to the review of the moratorium.

In 1993, at the 16th Consultative Meeting, the Contracting Parties to the Convention adopted a Resolution which prohibited the sea disposal of radioactive wastes and other radioactive matter [24].

The proposal to develop a global inventory of radioactive materials entering the marine environment from all sources was first raised at the Third Consultative Meeting of Contracting Parties to the London Convention 1972 (1978) [25] and again in 1985 as part of the studies called for in resolution LDC.21(9) of the Ninth Consultative Meeting [15]. At the Eleventh Consultative Meeting (1988) [26], Contracting Parties requested the IAEA to work actively towards this objective.

At the Twelfth Consultative Meeting (1989) [27] of the London Convention 1972, the Working Group on the Implications of Accidents to Nuclear-powered Vessels (in accordance with Article V of the Convention on dumping of vessels in case of force majeure) recommended that "Contracting Parties should be requested to provide all relevant information to the IAEA regarding accidents at sea involving releases of radioactive material". The Chairman of the Consultative Meeting encouraged Contracting Parties to submit information for the compilation of the above mentioned inventory insofar as this was possible.

The inventory serves the function of providing a unique record of worldwide disposal of radioactive materials at sea and of accidents and losses at sea involving radioactive materials; it is also expected to find use for assessing and comparing the radiological impact of radionuclides from different sources entering the marine environment.

As a separate activity, the Marine Environment Laboratory (MEL) of the IAEA is maintaining the Global Marine Radioactivity Database (GLOMARD) which contains information on radionuclide concentrations in sea water, sediments and biota throughout the world oceans [28]. The objective of the GLOMARD database is to provide both historical and up-to-date information on radionuclide levels in the marine environment and to investigate temporal changes in both concentrations and isotopic ratios, as well as correlate the activity data with salinity, temperature, bathymetry and sediment geochemistry data.

TABLE I. CHRONOLOGICAL SEQUENCE OF MAJOR EVENTS AND DOCUMENTS PUBLISHED BY THE IAEA AND IMO IN CONNECTION WITH SEA DISPOSAL OF RADIOACTIVE WASTES [3–24]

Year	Event
1946	First dumping operations (USA)
1957	First IAEA Advisory Group Meeting on Radioactive Waste Disposal into the Sea
1958	First United Nations Conference on the Law of the Sea (UNCLOS I)
1961	Radioactive Waste Disposal into the Sea. IAEA Safety Series No. 5 [6]
1965	Methods of Surveying and Monitoring Marine Radioactivity. IAEA Safety Series No. 11 [7]
1970	Reference Methods in Marine Radioactivity Studies. IAEA Technical Reports Series No. 18 [8]
1972	Adoption of the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter [2]
1974	Provisional Definition of High Level Radioactive Waste Unsuitable for Dumping at Sea and Recommendations. IAEA INFCIRC/205/Add.1 [3]
1975	Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter enters into force
1978	Revised Version of the Definition and Recommendation for the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter. IAEA INFCIRC/205/Add.1/Rev.1 [4]
1980	Packaging of Radioactive Wastes for Sea Disposal. IAEA-TECDOC-240 [10]
1981	Considerations Concerning "de minimis" Quantities of Radioactive Waste Suitable for Dumping at Sea under a Suitable Permit. IAEA-TECDOC-244 [11]
1983	Control of Radioactive Waste Disposal into the Marine Environment. IAEA Safety Series No. 61 (Revision of the IAEA Safety Series No. 5) [12]
1983	Decision on moratorium on low level waste dumping [9]
1984	Environmental Assessment Methodologies for Sea Dumping of Radioactive Wastes. IAEA Safety Series No. 65 [13]
1984	The Oceanographic and Radiological Basis for the Definition of High Level Wastes Unsuitable for Dumping at Sea. IAEA Safety Series No. 66 [14]
1985	Resolution calling for a Voluntary Moratorium on Radioactive Waste Dumping. LDC.21(9) [15]
1985	Sediment K_d s and Concentration Factors for Radionuclides in the Marine Environment. IAEA Technical Reports Series No. 247 [16]
1986	An Oceanographic Model for the Dispersion of Wastes Disposed of in the Deep Sea. IAEA Technical Reports Series No. 263 [10]

Year	Event
1986	Definition and Recommendations for the Convention for the Prevention of Marine Pollution by Dumping of Wastes and Other Matter. IAEA Safety Series No. 78 [5]
1988	Assessing the Impact of Deep Sea Disposal of Low-level Radioactive Waste on Living Marine Resources. IAEA Technical Reports Series No. 288 [18]
1989	Principles for the Establishment of Upper Bounds to Doses to Individuals from Global and Regional Sources. IAEA Safety Series No. 92 [19]
1990	Estimation of Radiation Risks at Low Dose. IAEA-TECDOC-557 [20]
1990	Low Level Radioactive Waste Disposal: An Evaluation of Reports Comparing Ocean and Land Based Disposal Options. IAEA-TECDOC-562 [21]
1991	Inventory of Radioactive Material Entering the Marine Environment: Sea Disposal of Radioactive Waste. IAEA-TECDOC-588 [22]
1993	Risk Comparisons Relevant to Sea Disposal of Low Level Radioactive Waste. IAEA-TECDOC-725 [23]
1993	Resolution on Disposal at Sea of Radioactive Wastes and Other Radioactive Matter LC.51(16) [24]
20 Feb. 1994	Total prohibition on radioactive waste disposal at sea came into force

2. THE SOURCES OF RADIONUCLIDES IN THE MARINE ENVIRONMENT

2.1. SOURCES CONSIDERED

Five sources of anthropogenic radionuclides that could enter in the marine environment have been identified. These are: (i) disposal at sea of radioactive waste; (ii) accidents and losses at sea involving radioactive materials; (iii) controlled coastal discharges of low level radioactive liquid effluents; (iv) fallout from atmospheric nuclear weapon testing and releases from underwater testing; and (v) accidental releases from land based nuclear installations.

For comparative purposes and to respond to the primary concern of the London Convention 1972, the IAEA has focused on the following two sources of radioactive materials entering the marine environment:

- (i) Dumping at sea of radioactive waste, arising from sources such as nuclear power plants, reprocessing plants, nuclear powered vessels, industries, hospitals, scientific research centres and nuclear weapons facilities; and
- (ii) Accidents and losses involving radioactive materials: for example the sinking of a nuclear powered submarine, or a loss of vessel carrying nuclear fuel or nuclear weapons, or the re-entry of a satellite containing nuclear materials, or the loss of sealed radioactive sources.

The first output of the inventory database was IAEA-TECDOC-588, Inventory of Radioactive Material Entering the Marine Environment: Sea Disposal of Radioactive Waste, which was published in 1991 [22]. This report is a revision of TECDOC-588. It contains, in addition to the information already published in TECDOC-588, information on the dumping operations carried out by the former Soviet Union and the Russian Federation up to and including 1993 [22, 29–33]. Additional data provided by Sweden and the United Kingdom have also been included in this report [34, 35]. A separate report on the inventory of accidents and losses at sea involving radioactive material is in preparation.

The third source, that is, the controlled discharges of low level radioactive liquid effluents from civil installations, is documented in national and regional reports but in addition, the reports of the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) periodically summarize information on both airborne and liquid discharges from nuclear installations in many countries and assessments of radiation doses to populations associated with these practices [36, 37]. Recently, as a contribution to the Global Programme of Action for the Protection of Marine Environment from Land-based Sources under the United Nations Environmental Programme [38], the IAEA has initiated the development of a database on discharges of radionuclides to the atmosphere and aquatic environment.

The fourth source of radionuclides entering the marine environment is fallout from nuclear weapons testing in the atmosphere carried out mostly in the northern hemisphere between 1945 and 1980. The radioactive debris from nuclear tests, the estimated fallout and radiation exposures of humans to fallout have been extensively reviewed by UNSCEAR [39]. Contribution of anthropogenic radionuclides to the world oceans due to fallout from nuclear weapons testing in the atmosphere has been estimated to be over 10^5 PBq³, more than 99 per cent of it being tritium [40].

The fifth source of radionuclides that could enter the marine environment is related to accidental releases from land-based installations. The largest single contribution has come from the accident at the Chernobyl nuclear power station in 1986 which released a significant quantity (1000–2000 PBq) of mainly short lived anthropogenic radionuclides to the environment [36]. A measurable inventory reached the marine environment [41]. The most radiologically significant radionuclides in the fallout which reached the northern European waters were ¹³⁷Cs and ¹³⁴Cs. The amounts of these radionuclides were estimated to be 10 PBq and 5 PBq respectively [42].

For perspective it is noted that the naturally occurring radionuclides in the ocean remain as the most significant contributors to radiation dose to man from marine sources. The total inventory of such naturally occurring radionuclides as ⁴⁰K, ²²⁶Ra, ²³²Th and ²¹⁰Po in world oceans has been estimated to exceed 10^4 PBq [43].

2.2. RADIOACTIVE WASTE DISPOSAL AT SEA

2.2.1. Background

In 1946, the first sea disposal operation took place at a site in the Northeast Pacific Ocean, some 80 km off the coast of California. Such operations continued until 1993 and included

³ 1 PBq = 10^{15} Bq.

disposal of liquid and solid wastes and nuclear reactor vessels, with and without fuel, into the oceans. Liquid waste was mainly disposed into the Arctic and Pacific Oceans. Solid waste, mostly packaged, was dumped into the Atlantic, Arctic and Pacific Oceans. Nuclear reactor vessels without fuel were disposed into the Atlantic, Arctic and Pacific Oceans, while nuclear reactor vessels with fuel were disposed only in the Arctic Ocean (Kara Sea). After 1946, over the next thirty-five years, most sea disposal operations were performed under national authority approval and, in many cases, under an international consultative mechanism: Organisation for Economic Co-operation and Development/Nuclear Energy Agency (OECD/NEA) Consultation Mechanism for North East Atlantic Dump Sites.

In 1975, the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter was ratified and entered into force. The Annexes to the Convention [2] called upon the IAEA to develop a definition of high level radioactive waste unsuitable for disposal at sea and Recommendations governing the disposal at sea of all other radioactive wastes. The IAEA contribution to the regulation of and studies on the sea disposal of radioactive wastes during the years 1961–1993 is contained in Table I.

In 1977, the Council of the OECD/NEA established a Multilateral Consultation and Surveillance Mechanism to co-ordinate the sea disposal of its Member States. In 1980, the Council established a Coordinated Research and Environmental Surveillance Programme (CRESP) to keep the suitability of the disposal site under review [44]. The OECD/NEA has kept records of the disposal operations of packaged low level radioactive waste carried out by its Member States [45]. In addition, the OECD/NEA has developed specific guidelines for waste package design [46] and site operational procedure [47]. With respect to waste package performance requirements, the OECD/NEA has specifically stated that "... the packages should be designed to ensure that their content is retained within them during descent to the sea-bed. This should normally ensure that the packages will remain intact for a period of time after they have reached the sea bed" [46].

2.2.2. Types of waste and packaging

Three types of radioactive waste were disposed of at sea:

- (1) Liquid waste;
- (2) Solid waste; and
- (3) Nuclear reactor pressure vessels, with and without fuel.

Liquid waste in two forms was disposed of at sea as follows:

- (a) Unpackaged and diluted in surface waters at designated sites; and
- (b) Contained, but unsolidified on to the sea bottom at designated sites.

Solid radioactive waste of two subcategories was disposed of at sea as follows:

- (a) Low level waste such as paper and textiles from decontamination processes, resins and filters, etc., solidified with cement or bitumen and packaged in metal containers; and

- (b) Unpackaged solid radioactive waste, mainly large parts of nuclear installations such as steam generators, main circuit pumps, lids of reactor pressure vessels, etc.

Reactor vessels were disposed of at sea as follows:

- (a) Without nuclear fuel by the former Soviet Union and the USA;
- (b) Containing damaged spent nuclear fuel by the former Soviet Union. These reactor pressure vessels were usually filled with a polymer-based solidification agent (furfural) to provide an additional protective barrier. In most cases reactor pressure vessels with damaged fuel were further contained in a reactor compartment; and
- (c) A special container with damaged spent nuclear fuel from the icebreaker *Lenin* by the former Soviet Union.

2.2.3. Environmental impact of dumping

The North-East Atlantic dumping site, used until 1982 by the OECD/NEA Member States, has been periodically surveyed since 1977. The final report by CRESO was issued in 1996 [48]. The IAEA Marine Environment Laboratory in 1992 also participated in site specific measurements at this site along with the Bundesforschungsanstalt für Fischerei (BFA), Germany, and the Fisheries Laboratory of the Ministry of Agriculture, Fisheries and Food, United Kingdom, by analysing samples collected above the sea-bed of the main sites for anthropogenic radionuclides such as ^{14}C , ^{137}Cs , ^{238}Pu , $^{239+240}\text{Pu}$ and ^{241}Am . The analysis showed enhancements of activities at the dumping sites suggesting measurable leakages but negligible radiological impact [49].

Radiological surveys of the North-East Pacific and North-West Atlantic Ocean sites are carried out from time to time by the US Environmental Protection Agency and the US National Oceanic and Atmospheric Administration. So far, samples of sea water, sediments and deep sea organisms collected near the various sites have not shown any excess in the level of radionuclides above those due to nuclear weapons fallout, except in certain instances where isotopes of caesium and plutonium were detected at elevated levels in sediments samples taken close to disposed packages [50, 51].

The joint Russian–Norwegian expeditions, in 1992–1994, visited four principal radioactive waste dumping sites in the Kara Sea in the Arctic. Sea water, sediment and biota samples were collected for activity analysis. The results of these expeditions showed that the influence of the dumped radioactive waste on the general levels of radioactive contamination in the Kara Sea was insignificant [52], but, the sediment samples taken in the immediate vicinity of waste containers showed elevated levels of ^{60}Co , ^{90}Sr , ^{137}Cs and $^{239+240}\text{Pu}$.

The former Soviet Union also disposed of radioactive waste in the Far Eastern Seas, although, unlike in the Arctic, no reactors containing fuel were dumped there. The Joint Japanese–Korean–Russian expeditions carried out during 1994 and 1995 took samples of sea water, sea-bed sediments and biota from dump sites and from reference sites. The results show that the concentrations of ^{90}Sr , ^{137}Cs , ^{238}Pu and $^{239+240}\text{Pu}$ in the Far Eastern Seas were low and were predominantly due to global fallout [49, 53, 54].

3. DATABASE ON RADIOACTIVE WASTE DISPOSAL AT SEA

3.1. THE DATABASE

The database with the acronym RAMEM (**R**adioactive **M**aterial **E**ntering the **M**arine **E**nvironment) has two modules:

- a module on radioactive waste disposal at sea; and
- a module on accidents and losses at sea involving radioactive material.

Each of the database modules has been established separately for the storage and rapid retrieval of specific information on each source. The module on radioactive waste disposal at sea is the subject of this report and is described below.

3.2. THE DATABASE MODULE ON RADIOACTIVE WASTE DISPOSAL AT SEA

3.2.1. Type of information

Various types of data and information such as quantity and nuclear composition of the waste, the methods of preparation and packaging of the waste and the characteristics of the disposal sites are needed for assessing the environmental impact of sea disposal [13].

The data in this report is in the same format as in the previous IAEA report [22]. Information is provided on:

- (1) the disposal operation: State responsible for the operation and date;
- (2) the site: geographical co-ordinates (latitude and longitude) and depth;
- (3) the containers: number, volume and type of containers, total weight of container/package;
- (4) the matrix: type (concrete, bitumen, polymer, etc.);
- (5) the type of waste: solid objects, solidified or liquid, reactor vessels (with and without fuel); and
- (6) the radionuclides: total volume and activity of the waste. A value for total alpha and beta-gamma emitters and tritium is given, where the information was available. Further, a detailed inventory of specific radionuclides is also included where available. The activities are expressed in Becquerels at the date of the disposal operation. The remaining activity of specific radionuclides at a later time is available in the database. The total activity disposed by each country is given in both becquerels and curies.

3.2.2. Collection of information

Pursuant to resolution LDC.28(10) of the Tenth Consultative Meeting of the London Dumping Convention [55], a Questionnaire on Radioactive Waste was sent to the Contracting Parties in 1986. In 1988 the Inter-Governmental Panel of Experts on Radioactive Waste Disposal at Sea reported on the responses to the questionnaire [56]. The responses are shown in Table II.

Using the information thus obtained and subsequently supplemented, the IAEA established a provisional database on sea dumping operations. Confirmation that the data were accurate was obtained separately from official sources in each of the countries responsible for the dumping. In 1991, IAEA-TECDOC-588, Inventory of Radioactive Material Entering the Marine Environment: Sea Disposal of Radioactive Waste [22], was published.

TABLE II: SUMMARY OF RESPONSES OF CONTRACTING PARTIES TO THE LONDON DUMPING CONVENTION [56] TO A QUESTIONNAIRE ON DISPOSAL OF RADIOACTIVE WASTE (Resolution LDC.28(10)) [55]. THE QUESTION NO. 11 WAS "HAVE YOU DUMPED? ARE YOU DUMPING OR ARE YOU PLANNING TO DUMP RADIOACTIVE MATERIAL AT SEA?" (position in 1988)

Country	Having Dumped	Planning dumping?
Australia	no	no
Belgium	yes	not mentioned
Canada	no	no
Chile	no	no
China	no	no
Denmark	no	no
Finland	no	no
France	yes	no
Germany	yes	no
Greece	no	no
Ireland	no	no
Italy	yes	no
Japan	no	no
Mexico	no	no
Nauru	not mentioned	not mentioned
Netherlands	yes	no
New Zealand	yes	no
Norway	no	no
Portugal	no	no
South Africa	no	no
Spain	no	no
Sweden	yes	no
Switzerland	yes	no
former USSR	no	no
United Kingdom	yes	not mentioned
United States of America	yes	no

3.2.3. New data

In May 1993, the Russian Federation provided the IAEA with the information on sea disposal operations of the former Soviet Union and the Russian Federation [29]. The Russian Federation published a report concerning its radioactive waste disposal practices in the marine environment, referred to as the "White Book" [30]. The report was provided to the Secretariat of the London Convention 1972, the International Maritime Organization (IMO) and to the IAEA. This report contains information of the waste disposal activities carried out by the former Soviet Union and the Russian Federation in seas adjacent to the territory of the Russian Federation in Northern Seas and Far Eastern Seas. It includes disposal sites, volumes, total activities and characteristics of liquid radioactive waste discharges and solid radioactive waste dumping. This report also contains tables describing "Objects with and without spent nuclear fuel dumped in Northern Seas" (specifically the Kara Sea). These tables refer to the need for "special analyses" to calculate the total activity in these objects.

In October 1993, the Russian Federation informed the IAEA and IMO about a liquid waste disposal operation which took place at the Sea of Japan [31, 33]. Additional information on disposal operations carried out by Sweden in the years 1959 and 1961 in the Baltic Sea was provided by the Swedish Radiation Protection Institute [34]. The United Kingdom provided additional data on dumping operations carried out by them in their coastal waters from 1948–1976 based on their recent findings from the Public Records Office [35]. These events led to the decision to update TECDOC-588. The update includes disposal operations carried out by the former Soviet Union and the Russian Federation and additional information provided by Sweden and the United Kingdom.

The information on sea disposal of radioactive waste as provided by the countries is presented in the annexes of this report.

The IAEA organized in 1993-1996 a study project, namely the International Arctic Seas Assessment Project (IASAP), with the overall objective of evaluating the potential impact to human health and to the environment posed by the radioactive waste dumped in the Arctic Seas. Under this project, special analyses were carried out in order to calculate the activities of the different radionuclides and the total activity in the reactors with and without spent nuclear fuel. The Source Term Working Group of the scientific team participating in the IASAP study analysed all available information and provided revised estimates of the total activity in the ten reactors without spent nuclear fuel and the 6.6 reactors⁴ with spent nuclear fuel [57]. Summary results of these further analyses are presented in Table III and Annexes 17-b and 18-b. It was estimated that the total activity at the time of dumping (37 000 TBq) was approximately 2.4 times smaller than reported in the "White Book". In the case of the *Lenin* icebreaker (installation OK-150), the estimated total activity at the time of dumping was underestimated in the White Book by almost a factor of four, whereas, in all cases for nuclear submarines, the estimated total activity at the time of dumping was overestimated by factors ranging between 3 and 83.

⁴ Close to 60% of an active core of one of the *Lenin* icebreaker reactors was placed in a special container and was dumped (0.6 reactor).

TABLE III. THE INVENTORY OF ACTIVITY IN REACTORS DUMPED IN THE KARA SEA

Site	Year of dumping	Factory number	Number of reactors		Total activity TBq (kCi)					
			Without spent nuclear fuel	Containing spent nuclear fuel	White Book ^b		IASAP study			
					At the time of dumping		At the time of dumping		1993/94	
					TBq	(kCi)	TBq	(kCi)	TBq	(kCi)
Abrosimov Fjord	1965	(No. 285)	1	1	30 000	(807)	11 610	(313.8)	655	(17.7)
		(No. 901)	-	2	14 800	(400)	2946	(79.6)	727	(19.7)
		(No. 254)	2	-	500	(14)	93	(2.5)	9.5	(0.3)
	1966	(No. 260)	2	-	500	(14)	44	(1.2)	5.1	(0.1)
Tsivolka Fjord	1967	(OK-150)	3	0.6 ^a	5 500	(150)	19 552	(528.4)	2200	(59.5)
Novaya Zemlya Depression	1972	(No. 421)	-	1	29 600	(800)	1048	(28.3)	293	(7.9)
Stepovoy Fjord	1981	(No. 601)	-	2	7400	(200)	1720	(46.5)	838	(22.7)
Techeniye Fjord	1988	(No. 538)	2	-	500	(14)	6	(0.2)	5.1	(0.1)
Total			10	6.6	88 800	(2400)	37 019	(1000.5)	4732.7	(128.0)

^a The spent nuclear fuel was not contained in the naval reactor, but in a reinforced concrete and metal container.

^b Fission products as in the White Book, activation products estimated on the basis of the White Book as follows: total content of activation products in reactors without spent nuclear fuel not more than 100 kCi (3700 TBq), 50 kCi of which was in three reactors of OK-150. Thus, the remaining seven reactors contained not more than 7 kCi each.

3.2.4. Data quality

The information received by the IAEA is heterogeneous due to the different ways in which records on disposal operations have been kept in different countries. Usually an indication of the date of the disposal operation as well as of the location of the disposal site, in geographical coordinates, is given. The type, number and weight or volume of the disposed containers is reported. The weight or volume is representative of the disposed containers but not of the radioactive waste itself. Total alpha and total beta-gamma activities of disposed wastes are reported. In addition, some countries have provided more detailed information on radionuclide composition of the wastes. Some of the data from a few other countries are more extensive in terms of radionuclide composition. This information is contained in the database, although not fully presented in this report.

With respect to the information on the Arctic Seas dumping provided by the Russian Federation, the total activity of solid low level wastes is given in "curies of ^{90}Sr equivalents". These values are reported to have been obtained as follows: the gamma radiation dose rate of each waste package was converted to ^{90}Sr equivalents using an empirical relationship which is based on the radionuclide content of a standard package and the ratios of the maximum permissible concentration of different radionuclides in drinking water to the maximum permissible concentration of ^{90}Sr .

4. SUMMARY OF SEA DISPOSAL OPERATIONS OF RADIOACTIVE WASTE

This section summarizes the country specific data presented in the annexes. Data contained in the annexes include all data presented in the earlier publication, IAEA-TECDOC-588 [22] and, in addition, data on dumping operations carried out by the former Soviet Union and the Russian Federation provided in 1993 and some supplementary data provided by Sweden in 1992 and the United Kingdom in 1997 and 1998.

4.1. DISTRIBUTION OF DISPOSAL OPERATIONS — GEOGRAPHICAL AND TEMPORAL

The first reported sea disposal operation of radioactive waste took place in 1946 and the latest in 1993. During the 48 year history of sea disposal, 14 countries have used more than 80 sites to dispose of approximately 85 PBq (2.3 MCi^5) of radioactive waste (Fig. 1, Table IV). An examination of the quantities of waste disposed of by each country involved (annexes and Table IV) shows that some countries used this waste management option only for small quantities of waste. Two countries conducted only one disposal operation each and one country conducted only two disposal operations. On the other hand, five countries used the sea disposal option regularly for the disposal of large quantities of waste. Figure 2 summarizes, as a percentage, the total activity of radioactive waste disposed of by countries in the Atlantic, Pacific and Arctic Oceans.

The past dumping operations of radioactive waste can be summarized broadly as follows (Table V): close to 53.4% of the activity in the disposed radioactive waste is associated with the disposal of low level packaged solid waste, of which some 93.5% was disposed of at the North-East Atlantic dumping sites by eight countries, mainly the UK. Some 43.3% of the activity in the disposed radioactive waste is associated with the dumping of reactors with spent nuclear fuel by the former Soviet Union in the Kara Sea. The dumping of low level liquid and solid waste in the Arctic Ocean makes up less than 1.6% of the total activity dumped. The inventory of waste dumped into the Pacific Ocean amounts to close to 1.7% of the total activity dumped.

⁵ 1 mCi = 10^6 Ci.

TABLE IV. ACTIVITIES OF ALPHA AND BETA-GAMMA EMITTERS AND TRITIUM DISPOSED OF IN THE ATLANTIC, PACIFIC AND ARCTIC OCEANS BETWEEN 1946 AND 1993

	Alpha	Beta-gamma ^a	Tritium	Totals	Per cent of total activity
	TBq	TBq	TBq	TBq	
Atlantic sites					
Belgium	29	2091	787	2120	2.49
France	8.5	345		353.5	0.42
Germany	0.02	0.18		0.2	-
Italy	0.07	0.11		0.2	-
Netherlands	1.1	335	99	336.1	0.40
Sweden	0.94	2.3		3.2	-
Switzerland	4.3	4415	3902	4419.3	5.19
UK	631.2	34 456.3	10781	35 087.5	41.24
USA		2942		2942	3.46
Subtotals	675.13	44 586.90	15569	45 262.05	53.20
Arctic sites					
Former Soviet Union		38 369.1		38 369.1 ^b	45.10
Russian Federation		0.7		0.7	
Subtotals		38 369.8		38 369.8	45.10
Pacific sites					
Japan	0.01	15.07		15.08	0.02
Korea, Rep. of				NI ^c	
New Zealand	0.01	1.03		1.04	-
Russian Federation		2.05		2.05	-
Former Soviet Union		873.6		873.6 ^b	1.01
USA		554.25		554.25	0.66
Subtotals	0.02	1446.00		1446.02	1.70
Totals (All Sites)				85 077.87	100.00
				~ 85 078	

^a Tritium activities are included in the beta-gamma values.

^b For solid packaged low level waste, activity is expressed as ⁹⁰Sr equivalents.

^c No information available in terms of activity disposed of by the Republic of Korea.

TABLE V. DISTRIBUTION OF ACTIVITY (TBq) FOR DIFFERENT TYPES OF WASTE DUMPED IN THE WORLD'S OCEANS

Waste type	Atlantic	Pacific	Arctic	Totals	Per cent of total activity
Reactors with spent nuclear fuel	Nil	Nil	36 876	36 876	43.34
Reactors without spent nuclear fuel	1221	166	143	1530	1.80
Low level solid waste	44 042.5	820.9	585.4	45 448.8	53.42
Low level liquid waste	<0.001	458.5	764.7	1223.2	1.44
Total	45 263.5	1445.4	38 369.1	85 078.0	
Per cent of total activity	53.20	1.70	45.10		100.00

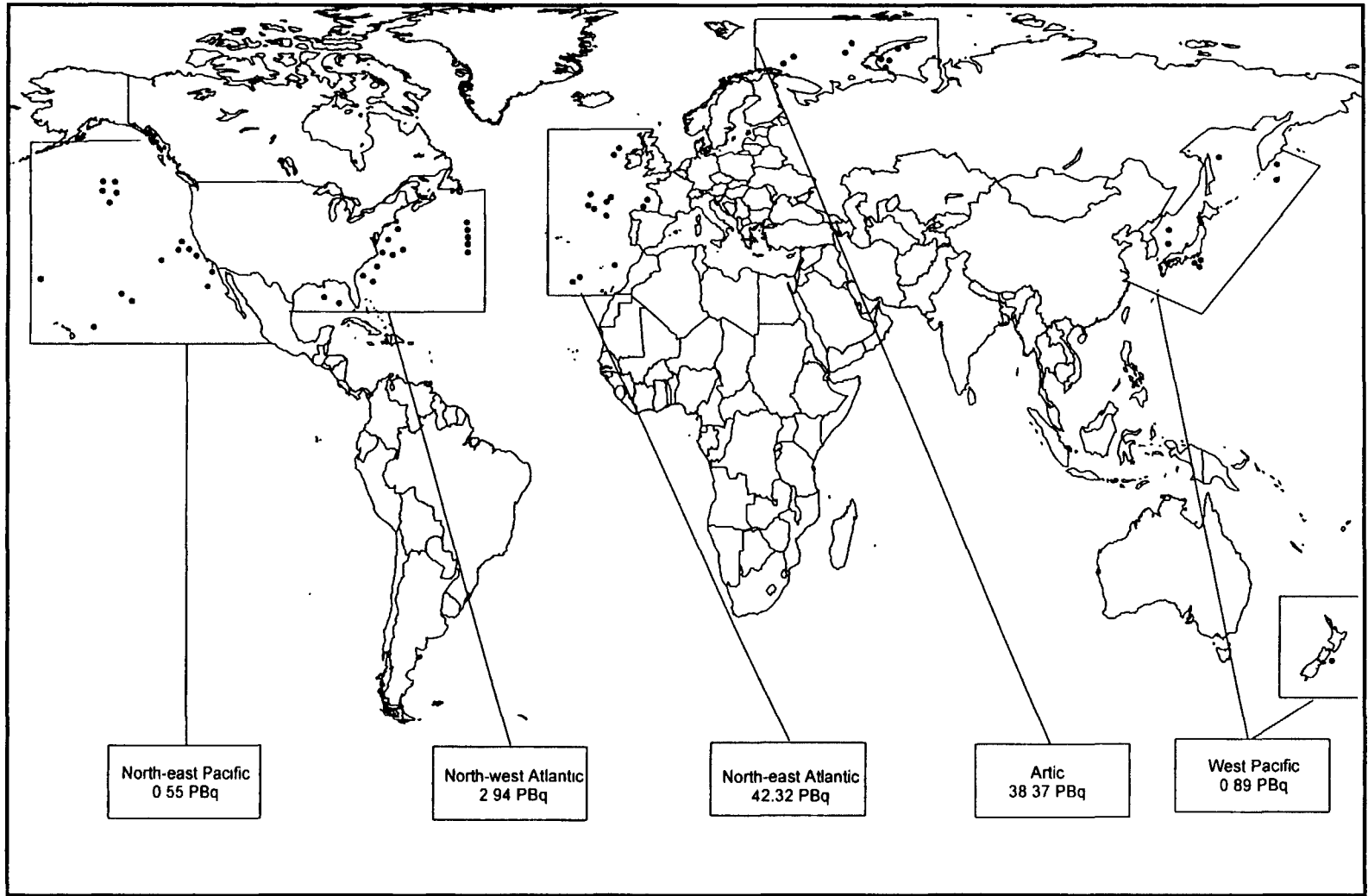
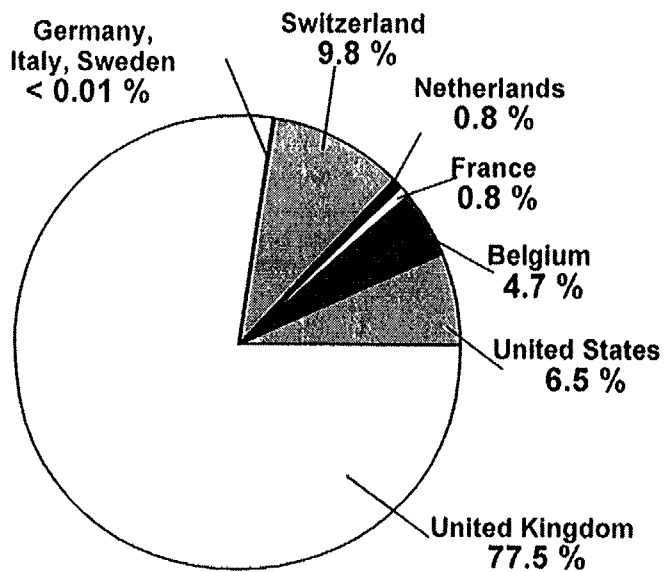
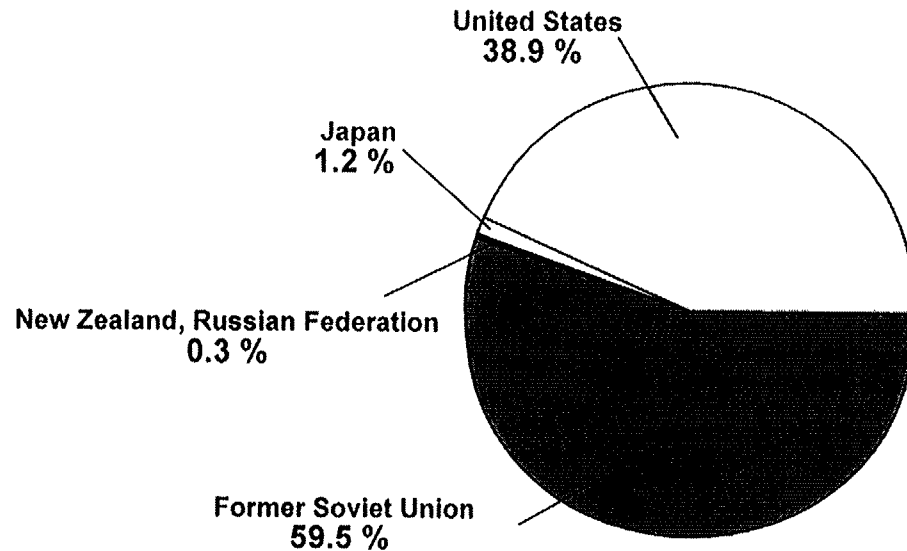


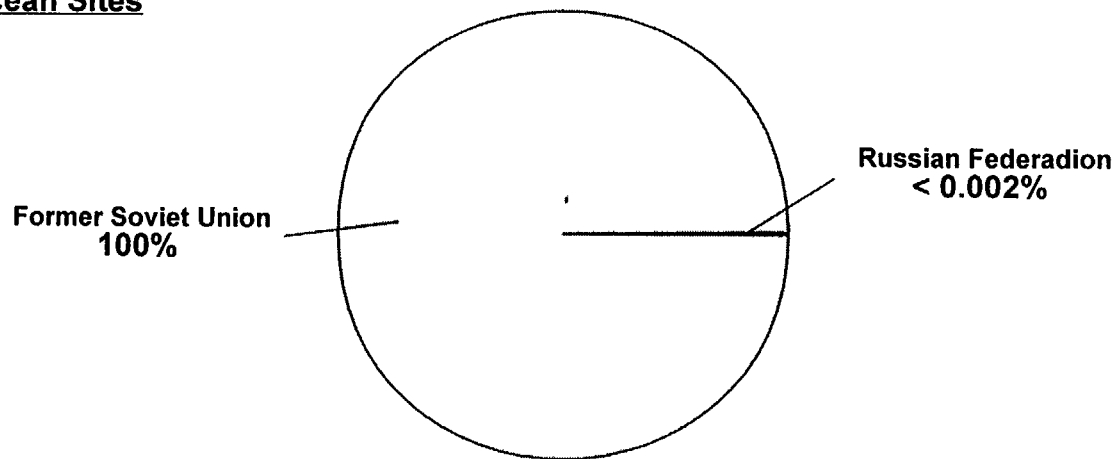
FIG. 1. Disposal at sea of radioactive waste – worldwide



North Atlantic Ocean Sites



Pacific Ocean Sites



Arctic Ocean Sites

POOR QUALITY ORIGINAL

FIG. 2 Percentage of the total activity of radioactive material disposed of by countries at the Atlantic, Pacific and Arctic Oceans. 1965-1994

The temporal distribution of the dumping operations is shown in Figs 3–5. The dumping at the North-East Atlantic site (Fig. 3) started at a very low level in 1954 (0.02 PBq), increased gradually and was at its highest level of almost 7 PBq in 1980, shortly before the moratorium on low level radioactive waste disposal was introduced.

The temporal distribution of disposal of solid packaged and unpackaged low and intermediate level waste (without nuclear reactors and without spent fuel) into the Arctic Seas is presented in Fig. 4. The disposal started in 1964 and the annual activities remained less than 40 TBq until 1982 when a peak of more than 75 TBq was reached. The last high peak of near 70 TBq occurred in 1988. The temporal distribution of disposal of liquid low level waste into the Arctic Ocean is presented in Fig. 5. It started in 1959 and continued until 1992. Two prominent peaks, 350 TBq in 1976 and 195 TBq in 1988, dominate the picture. The last case of disposal in the Arctic Ocean occurred in 1992 when low level liquid radioactive waste was released by the Russian Federation into the Barents Sea [30]. The last case of sea disposal occurred in 1993 when the Russian Federation released low level liquid radioactive waste into the Sea of Japan [31]. Solid radioactive wastes were dumped in the Russian Far-Eastern Seas during 1959–1991. Two submarine nuclear reactors without spent fuel were dumped in area no. 6 (Fig. A.20) in 1971. Two other submarine reactors without spent fuel were dumped in area no. 10 (Fig. A.20) in 1979 [32]. The activity in the dumped reactors was mainly due to the activation products and according to the latest studies was close to 78.7 TBq at the time of dumping [30].

4.2. RADIONUCLIDE COMPOSITION OF WASTES

In the North Atlantic dumping sites, tritium alone represents one third of the total activities (see Table IV). Tritium, together with other beta-gamma emitters such as ^{90}Sr , ^{134}Cs , ^{137}Cs , ^{55}Fe , ^{58}Co , ^{60}Co , ^{125}I and ^{14}C , constitutes more than 98% of the total activity of the waste. The waste also contains low quantities (less than 2%) of alpha-emitting radionuclides, with plutonium and americium isotopes representing 96% of the alpha-emitters present [58].

The initial information on the radionuclide composition of waste disposed of by the former Soviet Union is presented in the 1993 "White Book" and concerns only the reactor compartment of the nuclear icebreaker *Lenin* at the time of disposal. It includes estimations for the reactor compartment with three nuclear reactors without fuel and for a special container with damaged spent nuclear fuel from one of the icebreaker reactors (nearly 60% of the total fuel loading). Table A.17-a indicates that radionuclides present in the special container include ^{137}Cs , ^{90}Sr , ^{238}Pu , ^{241}Am and ^{244}Cm . The activity of the fission products was 3.7 PBq, primarily ^{137}Cs and ^{90}Sr , and of the actinides, approximately 0.07 PBq. Table A.18-a indicates that the primary radionuclide in the reactor compartment of the icebreaker is ^{60}Co [30]. The results of the special analysis of radionuclide composition performed by the Source Term Working Group is summarized in Tables A.17-b and A.18-b. The activities of radionuclides in the reactor compartment and special container with damaged spent nuclear fuel (SNF) from the *Lenin* were calculated to be approximately 17.41 PBq of fission products, 1.87 PBq of activation products, and 0.27 PBq of actinides at the time of dumping. The current activity in dumped reactors and fuel containers as of 1994 was estimated to be 2.2 PBq. Similar calculations were performed by the IASAP group for all dumped reactors in the Kara Sea [57]. A special analysis related to the dumping operations and inventory of four reactors without spent nuclear fuel dumped in the Sea of Japan in 1971 and 1979 was carried out by Y. Sivintsev and O. Kiknadze of the Russian "Kurchatov Institute Research Centre", the results of which were published in 1997 [32]. The study suggests that the total activity of activation products in dumped reactors exceeds the corresponding estimate given in the White Book [30] by nearly 100 times.

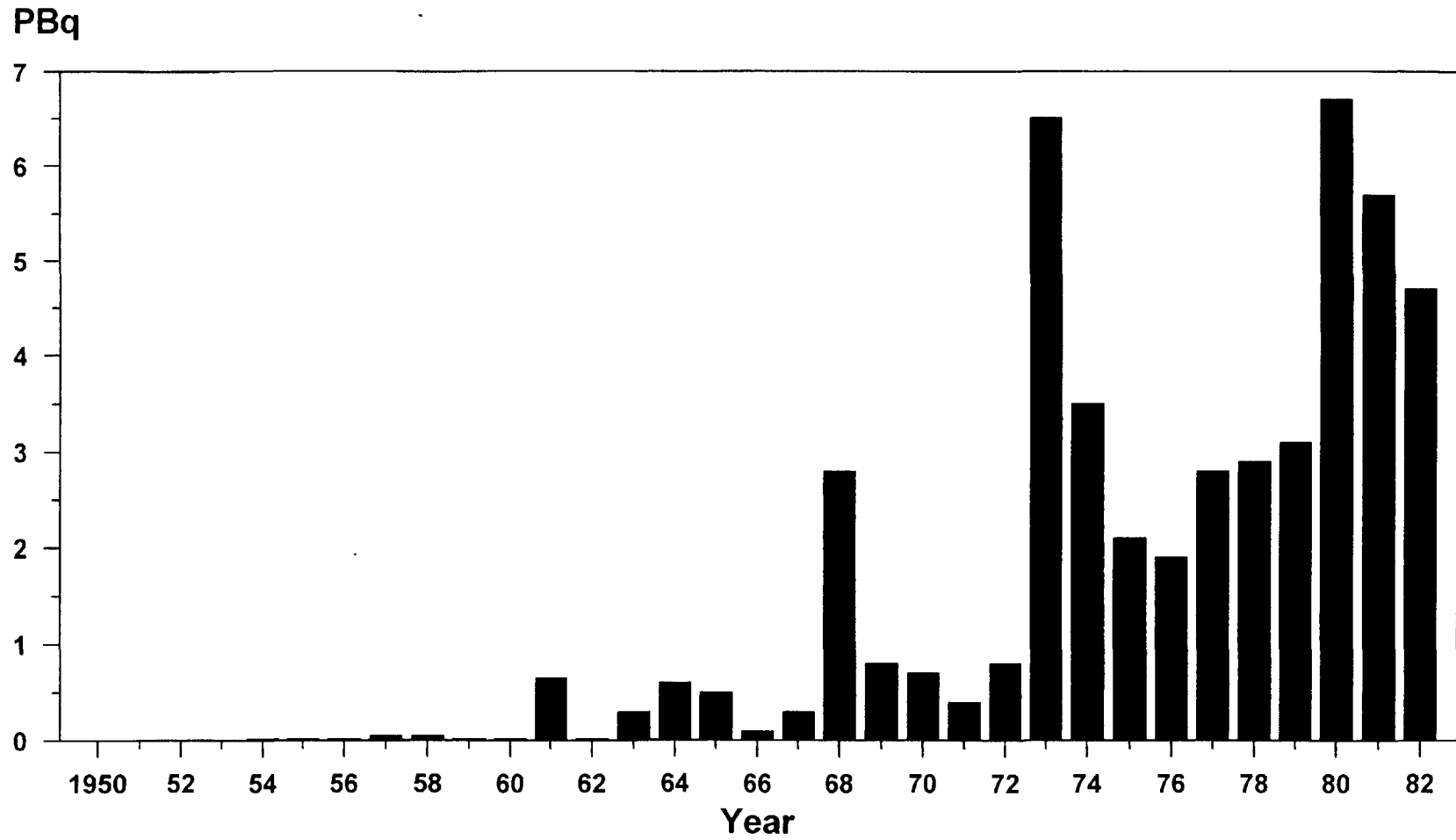


FIG. 3. Temporal distribution of radioactive waste disposals at the North-East Atlantic Ocean dump sites.

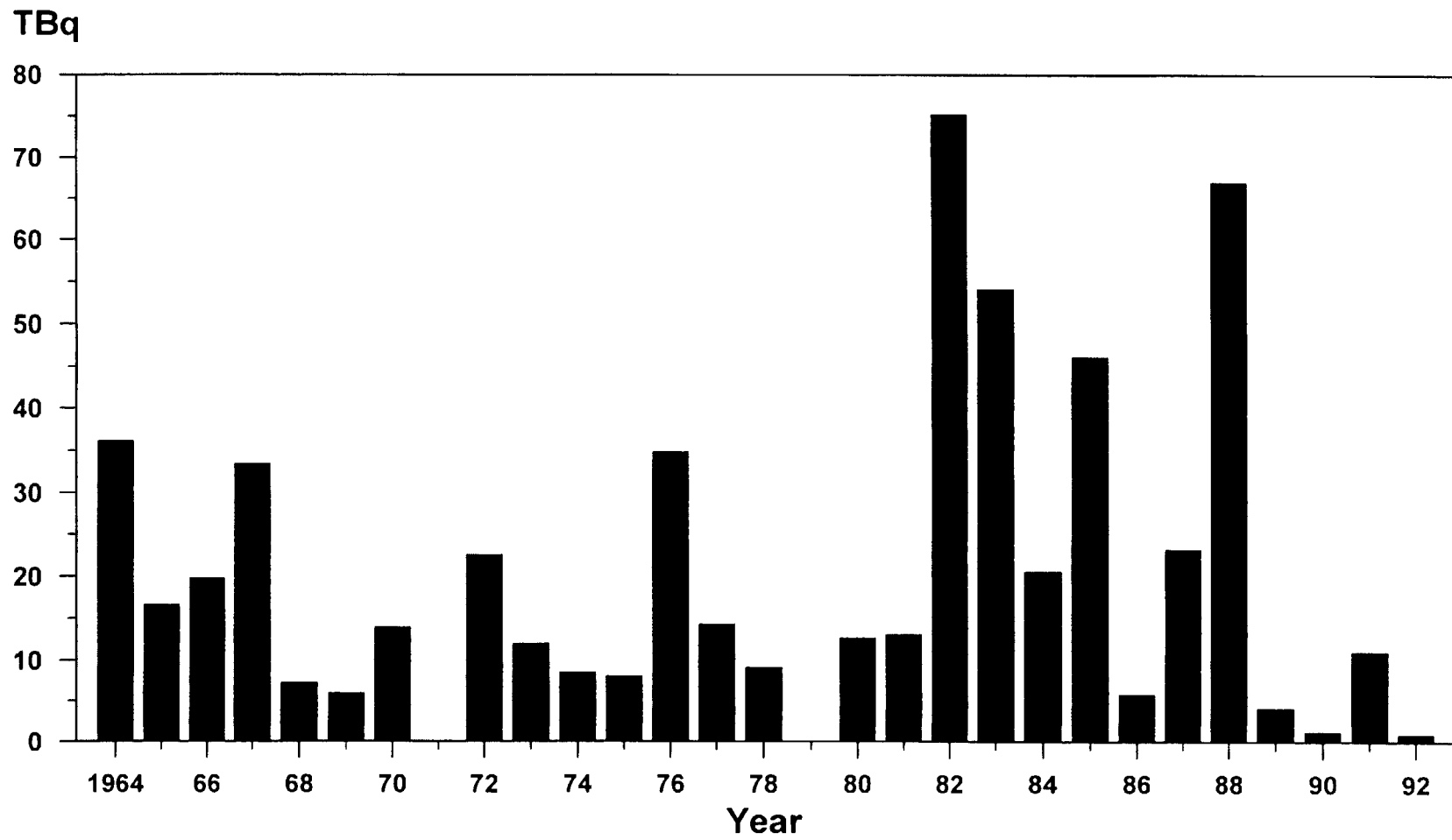


FIG. 4. Temporal distribution of low and intermediate level solid waste disposals in the Arctic Ocean (spent nuclear fuel not included).

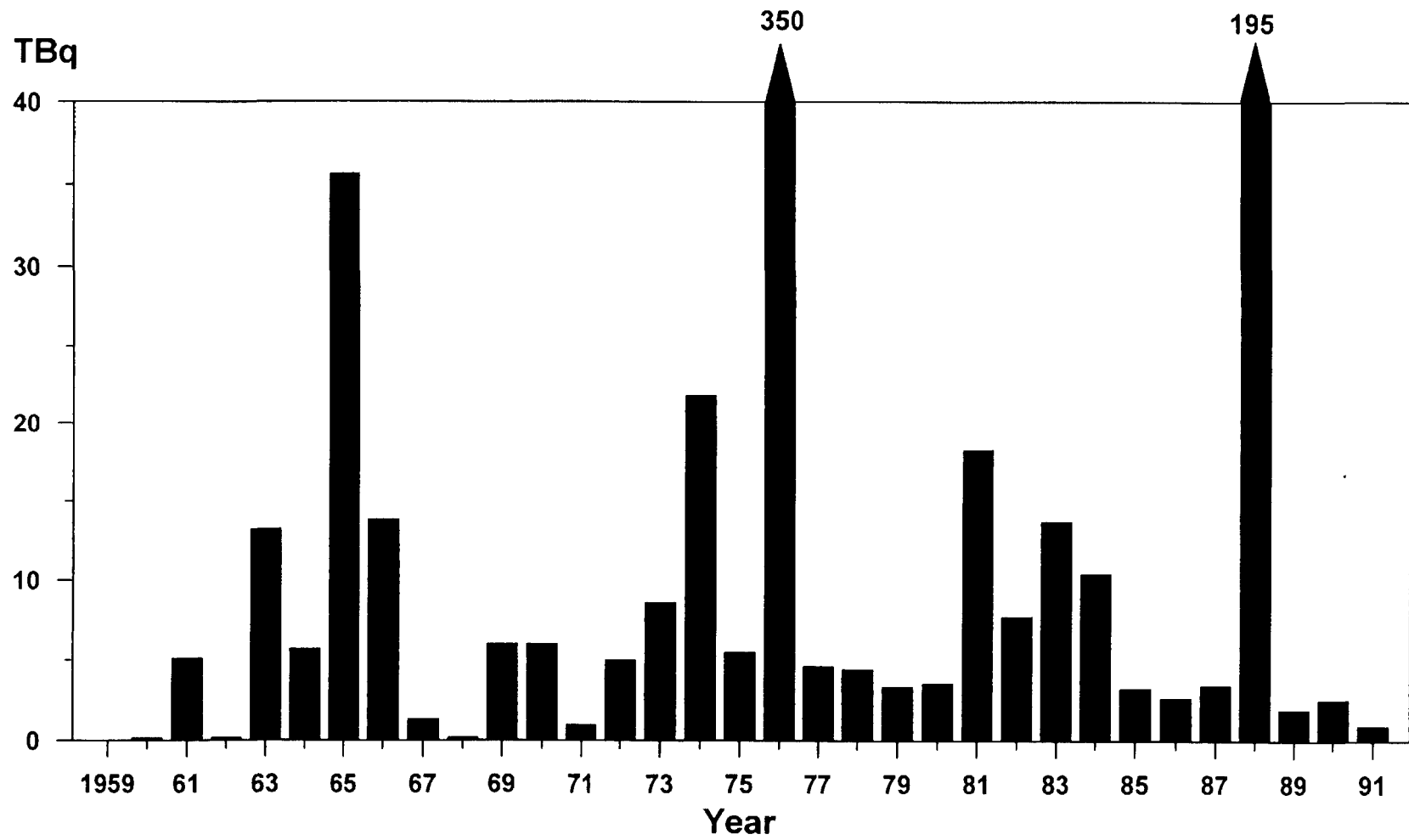


FIG 5 Temporal distribution of low level liquid waste disposals in the Arctic Ocean

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Annexes A.1–A.22

**INVENTORY OF RADIOACTIVE WASTE DISPOSALS
AT SEA BY COUNTRY**

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Annex A.1 BELGIUM

Disposal period: 1960–1982

Total number of years of disposal operations: 15

Total number of sites: 6

Total number of containers dumped: 55324

Total weight of containers dumped: 2.31×10^4 tons

Total activity: 2.12×10^6 GBq (5.73×10^4 Ci)

Information provided to IAEA on: 14 November 1989

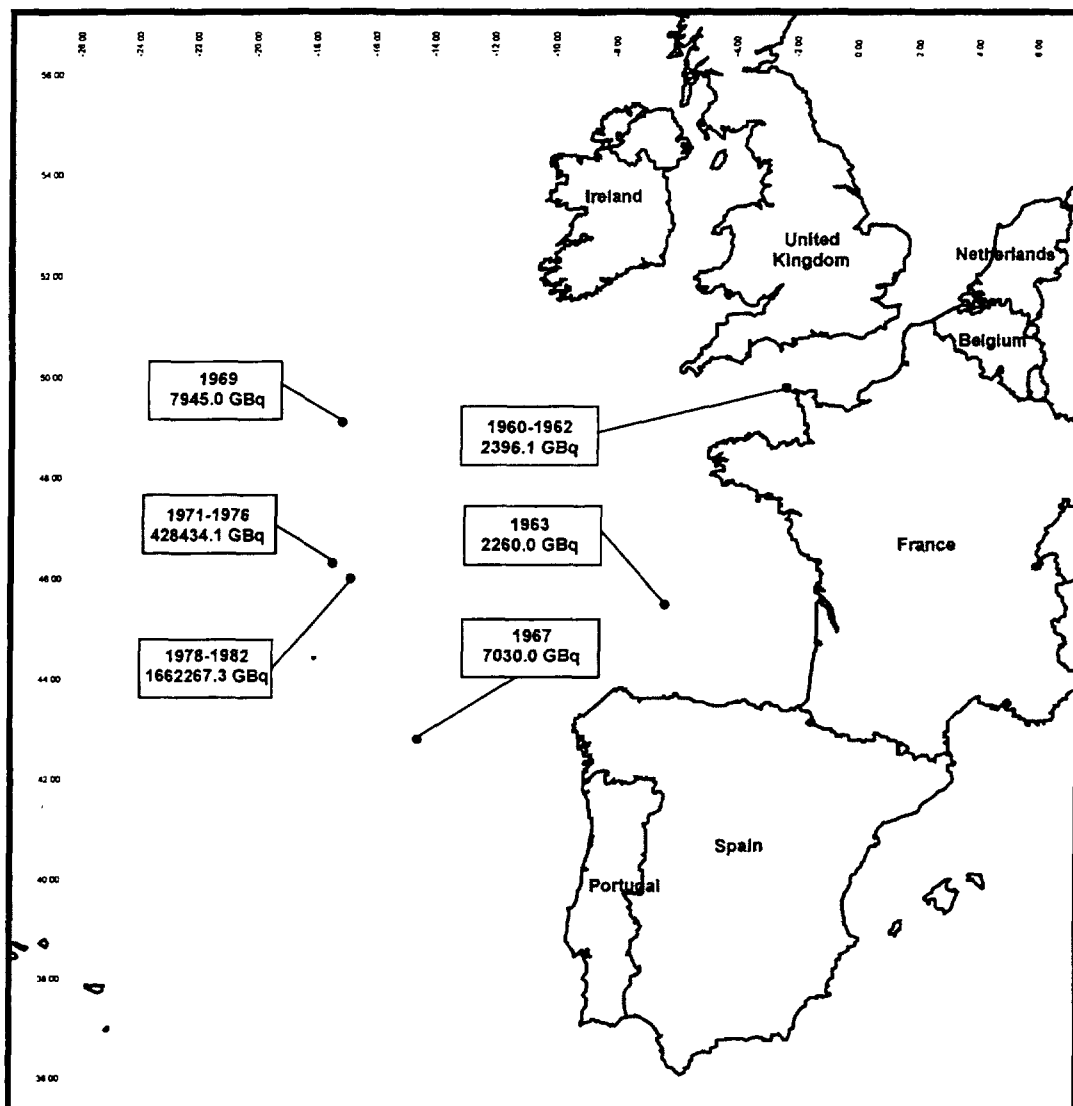


FIG. A.1. Geographical positions of the dump sites, disposal periods and total activity disposed.

DATE	CO-ORDINATES		DEPTH m	Package	CONTAINER*			Total weight t	ACTIVITY			H-3 GBq
	Latitude	Longitude			Number	Type	Matrix		Total GBq	Alpha GBq	Beta-gamma GBq**	
1960	49° 50'N	2° 18'W	65-160	Yes			B/C	284.0	543.9	25.9	518.0	-
1962	49° 50'N	2° 18'W	65-160	Yes			B/C	431.0	1852.2	2.2	1850.0	-
1963	45° 27'N	6° 16'W	4100-4800	Yes			B/C	789.0	2260.0	40.0	2220.0	-
1967	42° 50'N	14° 30'W	5200-5200	Yes	1945	M 220 l	B	599.9	7030.0	37.0	6993.0	-
1969	49° 05'N	17° 05'W	4000-4600	Yes	2222	M 220 l	B	600.4	17945.0	370.0	17575.0	-
1971	46° 15'N	17° 25'W	3600-4750	Yes	2861	M 220 l	B			703.0	54501.0	33226.0
					1968	M 220 l	C			31709.0	30229.0	
					42	M 400 l	B			1073.0	1036.0	
					146	M 400 l	C			1924.0	1850.0	
					16	C 1000 l	C			1184.0	-	
			Subtotals	5033				1768.4	91094.0	703.0	90391.0	66341.0
1972	46° 15'N	17° 25'W	3600-4750	Yes	2964	M 220 l	B			37.0		-
					98	m 400 l	C					
			Subtotal	3062				1112	71447.0	37.0	71410.0	70300.0
1973	46° 15'N	17° 25'W	3600-4750	Yes	2083	M 220 l	B			814.0	62189.6	59296.2
					3791	M 220 l	C			55.5	-	
					156	M 400 l	C			0.4	-	
					145	M 600 l	C			3129.8	3122.8	
					2	M 1000 l	C			3.7	-	
			Subtotal	6177				2296	66193.0	814.0	65379.0	62419.0
1975	46° 15'N	17° 25'W	3600-4750	Yes	5920	M 220 l	B			296.0	120039.1	111925.0
					127	M 400 l	C			321.9	-	
					9	M 400 l	B			1110.0	0.0	
			Subtotal	6056				2001.6	121767.0	1406.0	120361.0	111925.0

DATE	CO-ORDINATES		DEPTH	Package	CONTAINER*			Total weight t	ACTIVITY			H-3 GBq							
	Latitude	Longitude	m		Number	Type	Matrix		Total GBq	Alpha GBq	Beta-gamma GBq**								
1976	46 ° 15'N	17 ° 25'W	3600-4750	Yes	2887	M 220 I	B	2242.7	77933.1	2590.0	47989.0	37555.0							
					2196	M 220 I	C						16942.3						
					138	M 400 I	C							40.7					
					300	M 600 I	C								111.0	10260.1			
					Subtotal	5521												2701.0	75232.1
1978	46 ° 00'N	16 ° 45'W	3900-4750	Yes	3761	M 220 I	B	3671.5	169360.1	9435.0	120657.0	112887.0							
					1691	M 220 I	C						2960.0						
					195	M 400 I	C							2405.0					
					45	M 400 I	Cm								555.0				
					48	M 600 I	C									740.0			
					28	C 1000 I	Cm										2220.0		
					302	C 1500 I	Cm											10237.9	
					128	C 1500 I	P												20150.2
					Subtotal	6198													
1979	46 ° 00'N	16 ° 45'W	3900-4750	Yes	1465	M 220 I	B	872.0	41935.8	1084.1	36940.8	34817.0							
					343	M 220 I	C						595.7						
					144	M 220 I	Cm							717.8					
					70	M 400 I	C								7.4				
					135	M 400 I	Cm									1628.0			
					Subtotal	2157													

DATE	CO-ORDINATES		DEPTH m	Package	CONTAINER*			Total weight t	ACTIVITY			H-3 GBq
	Latitude	Longitude			Number	Type	Matrix		Total GBq	Alpha GBq	Beta-gamma GBq**	
1980	46 ° 00'N 16 ° 45'W		3900-4750	Yes	3438	M 220 I	B			1868.5	240093.0	235098.0
					322	M 220 I	C		55.5	490.0	-	
					57	M 220 I	Cm			185.0	-	
					513	M 400 I	C		347.8	10804.0	10027.0	
					264	M 400 I	Cm			2664.0	-	
					105	M 600 I	C			3404.0	-	
					152	C 1000 I	Cm		7.4	583564.0	19240.0	
					71	C 1500 I	Cm			4329.0	-	
					177	C 1500 I						
					Subtotal	5099			P	3512.0	858616.2	2279.2
1981	46 ° 00'N 16 ° 45'W		3900-4750	Yes	3102	M 220 I	B			2586.3	14204.3	8284.3
					51	M 220 I	C		22.2	0.0	-	
					1716	M 400 I	C		1968.4	710.4	340.4	
					207	M 400 I	Cm			1147.0	-	
					40	M 600 I	C			677.1	196.1	
					56	M 1200 I	C			333.0	-	
					25	C 1000 I	Cm			275761.0	-	
					234	C 1500 I	Cm			16169.0	-	
					116	C 1500 I	P			32375.0	-	
					Subtotal	5547				4450.0	345953.7	4576.9
1982	46 ° 00'N 16 ° 45'W		3900-4750	Yes	2984	M 220 I	B			3296.7	7585	2923
					106	M 220 I	C			3.7	-	
					1960	M 400 I	C			2301.4	1036	370

DATE	CO-ORDINATES		DEPTH m	Package	CONTAINER*			Total weight t	ACTIVITY			H-3 GBq
	Latitude	Longitude			Number	Type	Matrix		Total GBq	Alpha GBq	Beta-gamma GBq**	
					591	M 400 l	Cm				3404.0	-
					209	M 600 l	C			40.7	925.0	-
					2	M 600 l	Cm				111.0	-
					34	M 1200 l	C				925.0	-
					255	C 1500 l	Cm				95349.0	-
					166	C 1500 l	P				131424.0	-
				Subtotal	6307			5100.0	246401.5	5638.8	240762.7	3293.0
				Total	55324			29730.5	2120332.5	29242.6	2091089.9	786967.8
									(5.73 × 10 ⁴ Ci)			

* Key for the type of containers and matrix:

- B: bitumen
- C: concrete
- Cm: cement
- M: metallic
- P: polymers.

** Tritium activities are included in the beta-gamma figures.

Annex A.2.
FRANCE

Disposal period: 1967–1969
Total number of years of disposal operations: 2
Total number of sites: 2
Total number of containers dumped: 46 396
Total weight of containers dumped: 14 299 tons
Total activity: 3.53×10^5 GBq (9.54×10^3 Ci)
Information provided to IAEA on: 1 June 1989

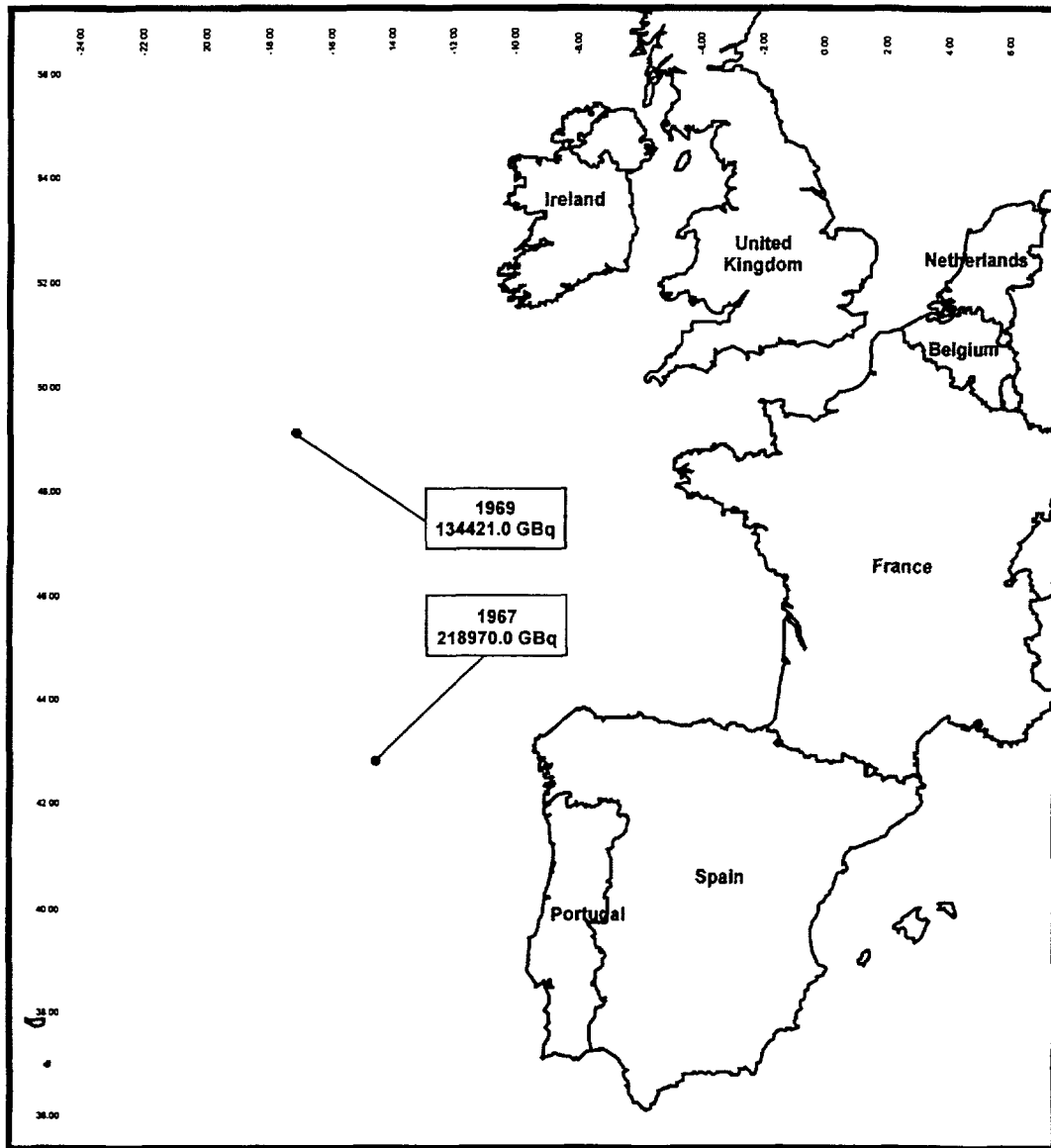


FIG. A.2. Geographical positions of the dump sites, disposal periods and total activity disposed.

DATE	CO-ORDINATES		DEPTH		Package	CONTAINER			Total weight t	ACTIVITY		
	Latitude	Longitude	Min. m	Max. m		Number	Type	Matrix		Total GBq	Alpha GBq	Beta-gamma GBq
1967	42 ° 50'N	14 ° 30'W	4590	5310	Yes	30700	Metal		8837.0	218560.0	5920.0	212640.0
						896	Metal		347.0	410.0	40.0	370.0
					Subtotal	31596		9184.0	218970.0	5960.0	213010.0	
1969	49 ° 05'N	17 ° 05'W	4000	4600	Yes	14800			5015.0	134421.0	2516.0	131905.0
					Total	46396		14199.0	353391.0	8476.0	344915.0	
									(9.54 × 10 ¹ Ci)			

Annex A.3
GERMANY

Disposal period: 1967
Total number of years of disposal operations: 1
Total number of sites: 1
Total number of containers dumped: 480
Total weight of containers dumped: 185 tons
Total activity: 2.03×10^2 GBq (5.5 Ci)
Information provided to IAEA on: 26 September 1990

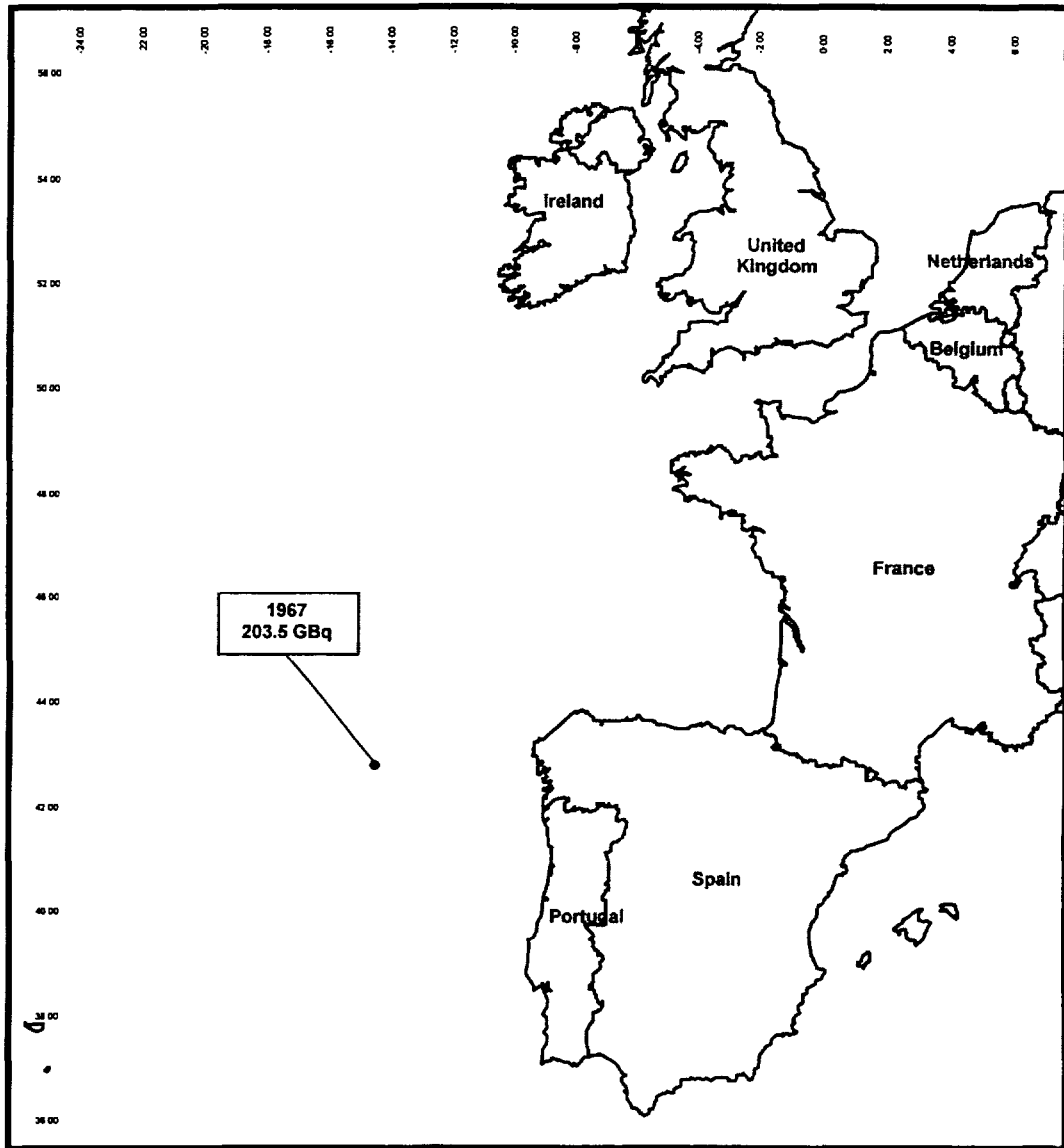


FIG. A.3. Geographical position of the dump site, disposal period and total activity disposed.

DATE	CO-ORDINATES		DEPTH	Package	CONTAINER			Total weight t	ACTIVITY		
	Latitude	Longitude	m		Number	Type	Matrix		Total GBq	Alpha GBq	Beta-gamma GBq
1967	42 ° 50'N	14 ° 30'W	2500 - 5200	Yes	480	Barrel*	Concrete	180.5	203.5 (5.5 Ci)	18.5	185.0

* Rolling hoop barrel, DIN-Standards 6635 and 6636.

Annex A.4
ITALY

Disposal period: 1969
Total number of years of disposal operations: 1
Total number of sites: 1
Total number of containers dumped: 100
Total weight of containers dumped: 44.74 tons
Total activity: 1.85×10^2 GBq (5 Ci)
Information provided to IAEA on: 18 May 1990

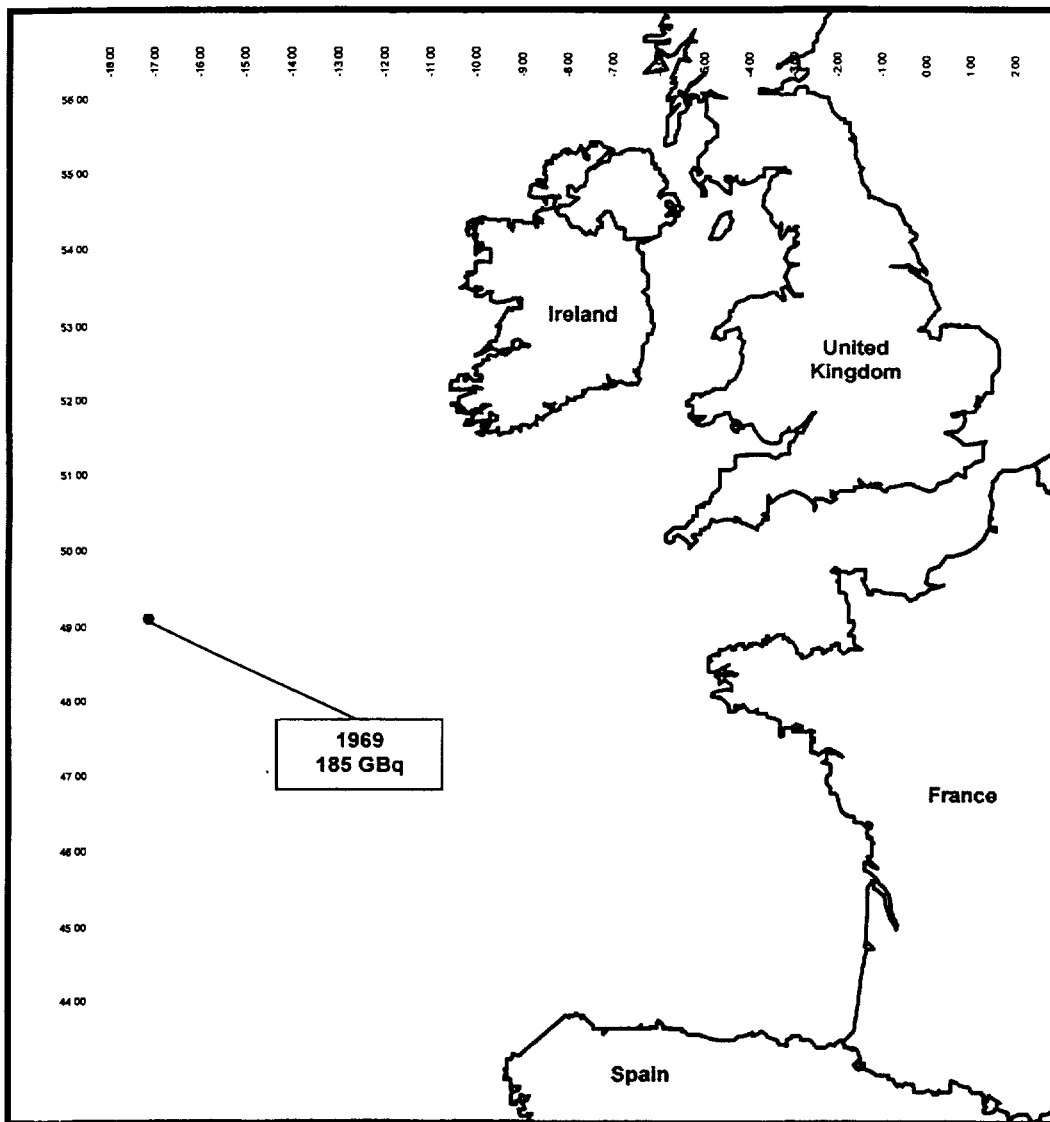


FIG. A.4. Geographical position of the dump site, disposal period and total activity disposed.

DATE	CO-ORDINATES		DEPTH	Package	CONTAINER			Total weight t	ACTIVITY		
	Latitude	Longitude	m		Number	Type	Matrix		Total GBq	Alpha GBq	Beta-gamma GBq
1969	49 ° 05'N	17 ° 05'W	4000-4600	Yes	100	Metal d.*	Concrete	44.74	185.0 (5 Ci)	74.0	111.0

* Type of container: metal drum lined with concrete.

Annex A.5 JAPAN

Disposal period: 1955–1969

Total number of years of disposal operations: 12

Total number of sites: 6

Total number of containers dumped: 3031

Total weight of containers dumped: $606.2 \times 10^3 \text{ m}^3$

Total activity: $1.51 \times 10^4 \text{ GBq}$ (407.5 Ci)

Information provided to IAEA on: 30 May 1989

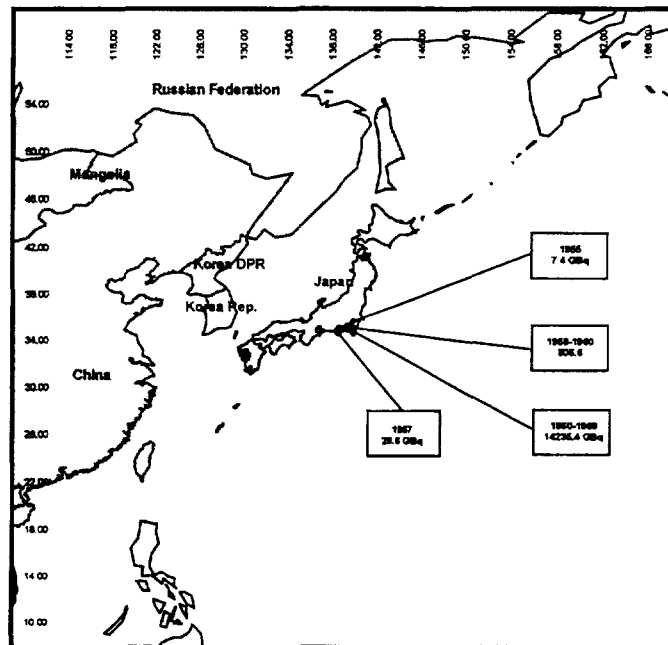


FIG. A.5. Geographical positions of the dump sites, disposal periods and total activity disposed.

DATE	CO-ORDINATES		DEPTH	Package	CONTAINER			ACTIVITY			
			m		Number	Type*	Matrix	Total GBq	Alpha GBq	Beta-gamma GBq	
1955	34 °	55'N 139 °	25'E	1400–1500	Yes	27	M 200 l	Mortar	7.4	–	7.4
1957	34 °	34'N 138 °	32'E	2000–2500	Yes	10	M 200 l	Mortar	29.6	–	29.6
1958	34 °	42'N 139 °	56'E	2400–2800	Yes	11	M 200 l	Mortar	29.6	–	29.6
1959	34 °	42'N 139 °	56'E	2400–2800	Yes	54	M 200 l	Mortar	185.0	–	185.0
						52	M 200 l	Mortar	222.0	–	222.0
1960	34 °	42'N 139 °	56'E	2400–2800	Yes	43	M 200 l	Mortar	185.0	–	185.0
						40	M 200 l	Mortar	185.0	–	185.0
1962	34 °	41'N 139 °	53'E	2400–2800	Yes	70	M 200 l	Mortar	370.0	–	370.0
						1523	M 200 l	Mortar	1023.9	6.3	1017.6
1963	34 °	42'N 139 °	56'E	2400–2800	Yes	165	M 200 l	Mortar	2410.0	5.0	2405.0
1964	34 °	42'N 139 °	56'E	2400–2800	Yes	135	M 200 l	Mortar	2553.8	0.1	2553.7
1965	34 °	42'N 139 °	56'E	2600–2600	Yes	201	M 200 l	Mortar	1007.2	0.8	1006.4
1967	34 °	41'N 139 °	55'E	2600–2600	Yes	225	M 200 l	Mortar	2813.7	0.4	2813.3
1968	34 °	42'N 139 °	56'E	2600–2600	Yes	230	M 200 l	Mortar	1303.3	0.02	1303.3
1969	34 °	42'N 139 °	56'E	2600–2600	Yes	245	M 200 l	Mortar	2753.5	0.3	2753.2
					Total:	3031	606200		15078.9	12.9	15066.0
									(407.5 Ci)		

* Key for the type of container: M: metal.

**Annex A.6
REPUBLIC OF KOREA**

Disposal period: 1968–1972
Total number of years of disposal operations: 5
Total number of sites: 1
Total number of containers dumped: 115
Total weight of containers dumped: 45 tons
Total activity: ? GBq
Information provided to IAEA on: 11 August 1989

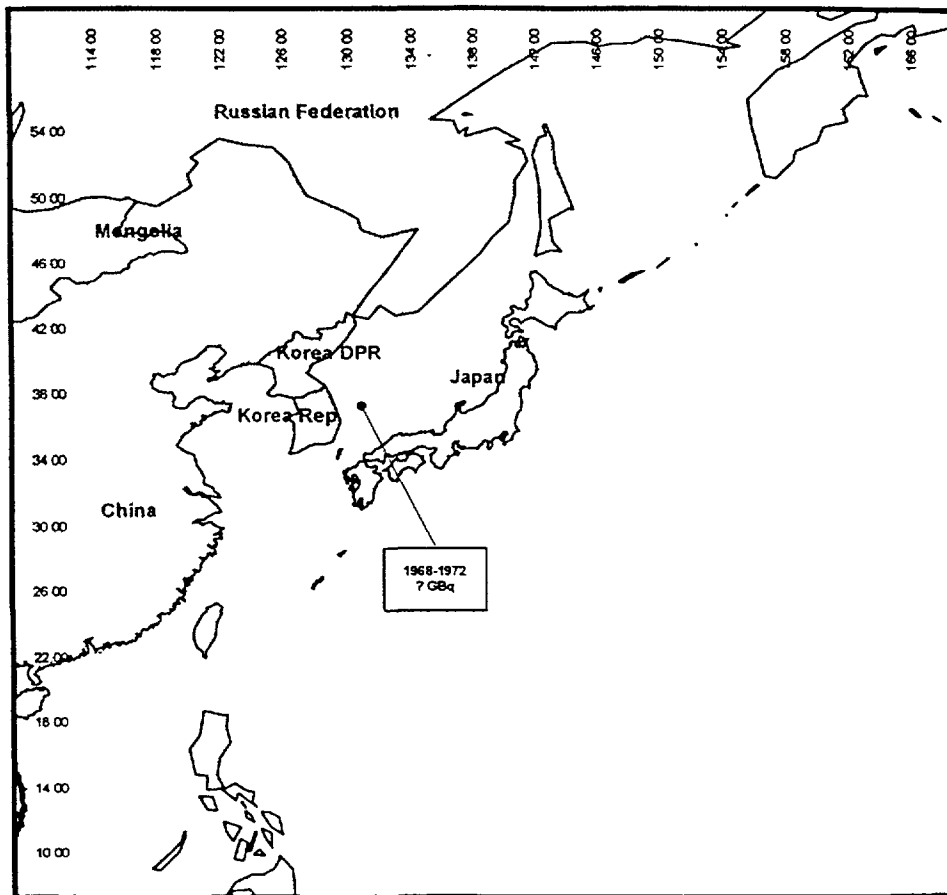


FIG. A.6. Geographical position of the dump site and disposal period.

DATE	CO-ORDINATES		DEPTH	Package	CONTAINER			Total weight t	ACTIVITY		
	Latitude	Longitude	m		Number	Type*	Matrix		Total GBq	Alpha GBq	Beta-gamma GBq
1968	37 ° 20'N	130 ° 44'E	2192-2192	Yes	21	C.L.D.	Concrete	8	?	?	?
1969	37 ° 20'N	130 ° 44'E	2192-2192	Yes	21	C.L.D.	Concrete	8	?	?	?
1970	37 ° 20'N	130 ° 44'E	2192-2192	Yes	23	C.L.D.	Concrete	9	?	?	?
1971	37 ° 20'N	130 ° 44'E	2192-2192	Yes	25	C.L.D.	Concrete	10	?	?	?
1972	37 ° 20'N	130 ° 44'E	2192-2192	Yes	25	C.L.D.	Concrete	10	?	?	?
				Total:	115			45			

* Key for the type of container: C.L.D.: metal drum lined with concrete (200 l).

Annex A.7 NETHERLANDS

Disposal period: 1967–1982
Total number of years of disposal operations: 14
Total number of sites: 4
Total number of containers dumped: 28 428
Total weight of containers dumped: 19 162 tons
Total activity: 3.36×10^5 GBq (9×10^3 Ci)
Information provided to IAEA on: 22 June 1989

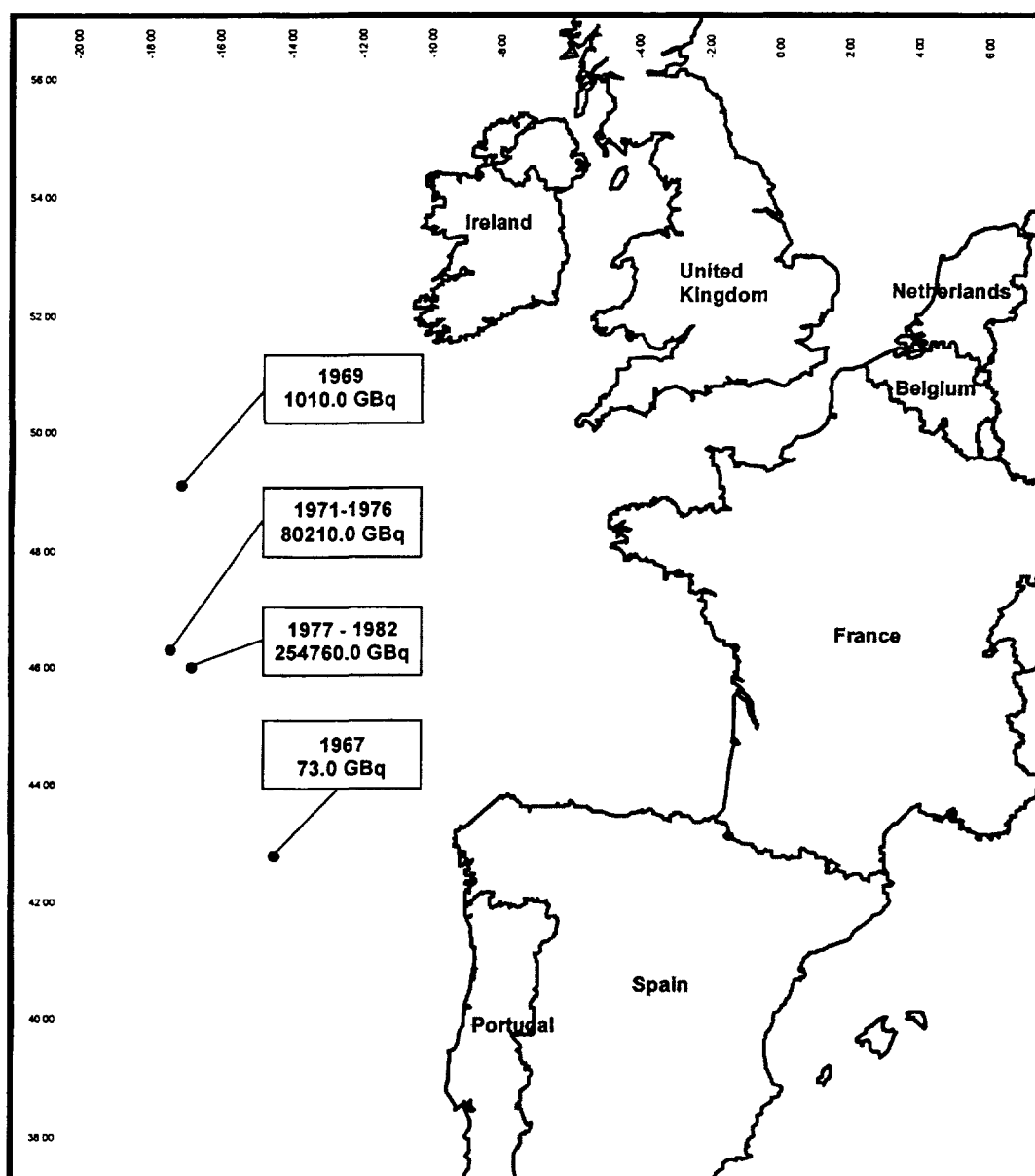


FIG. A.7. Geographical positions of the dump sites, disposal periods and total activity disposed.

DATE	CO-ORDINATES		DEPTH m	Package	CONTAINER			Total weight t	ACTIVITY			H-3 GBq
	Latitude	Longitude			Number	Type*	Matrix		Total GBq	Alpha GBq	Beta-gamma GBq**	
1967	42° 50'N	14° 30'W	5200	Yes	-	MLC/MC	C	207.0	73.0	3.0	70.0	-
1969	49° 05'N	17° 05'W	4000-4600	Yes	-	MLC/MC	C	303.0	1010.0	10.0	1000.0	-
1971	46° 15'N	17° 25'W	3200-4100	Yes	-	MLC/MC	C	360.0	750.0	10.0	740.0	-
1972	46° 15'N	17° 25'W	3200-4100	Yes	-	MLC/MC	C	626.0	2030.0	-	2030.0	-
1973	46° 15'N	17° 25'W	3200-4100	Yes	-	MLC/MC	C	657.0	1850.0	-	1850.0	-
1974	46° 15'N	17° 25'W	3200-4100	Yes	1189	MLC/MC	C	501.0	21020.0	40.0	20980.0	20350.0
1975	46° 15'N	17° 25'W	3200-4100	Yes	2162	MLC/MC	C	901.0	18190.0	60.0	18130.0	14800.0
1976	46° 15'N	17° 25'W	3200-4100	Yes	4496	MLC/MC	C	1911.0	36370.0	40.0	36330.0	3700.0
1977	46° 00'N	16° 45'W	3200-4750	Yes	3812	MLC/MC	C	3015.0	22190.0	330.0	21860.0	7100.0
1978	46° 00'N	16° 45'W	3200-4750	Yes	2946	MLC/MC	C	1562.0	57060.0	190.0	56870.0	17460.0
1979	46° 00'N	16° 45'W	3200-4750	Yes	3393	MLC/MC	C	2122.0	31310.0	50.0	31260.0	11400.0
1980	46° 00'N	16° 45'W	3200-4750	Yes	2960	MLC/MC	C	1885.0	19960.0	20.0	19940.0	3850.0
1981	46° 00'N	16° 45'W	3200-4750	Yes	3015	MLC/MC	C	2063.0	68840.0	240.0	68600.0	3070.0
1982	46° 00'N	16° 45'W	3200-4750	Yes	4455	MLC/MC	C	3049.0	55400.0	120.0	55280.0	17700.0
				Total:	28428			19162.0	336053.0	1113.0	334940.0	99430.0
									(9 × 10 ³ Ci)			

* Key for the type of containers and matrix: MLC: metal drum lined with concrete
MCB: monolithic concrete block
C: concrete.

** Tritium activities are included in the beta-gamma figures.

Annex A.8
NEW ZEALAND

Disposal period: 1954–1976
Total number of years of disposal operations: 11
Total number of sites: 4
Total number of containers dumped: 9
Total volume of containers dumped: 0.62 m³ approx.
Total activity: 1.04 × 10³ GBq approx. (28.1 Ci)
Information provided to IAEA on: 23 March 1990

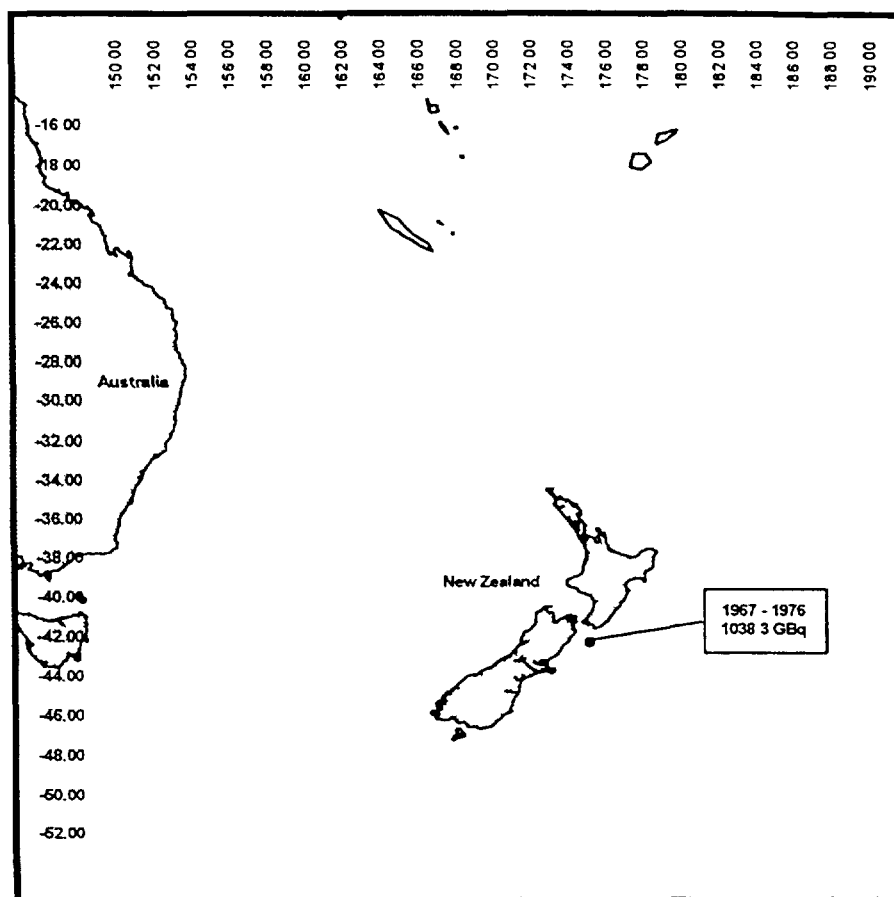


FIG. A.8. Geographical position of the dump site, disposal period and total activity disposed.

DATE	CO-ORDINATES		DEPTH m	Package	CONTAINER			Total volume l	ACTIVITY			Ra-226 GBq/mg	
	Latitude	Longitude			Number	Type	Matrix		Total GBq	Alpha GBq	Beta-gamma GBq		
1954	Site 1		18	Yes	4	Drum	-	-	-	-	-	-	
1955	Site 1		18	Yes	1	Barrel	-	-	-	-	-	-	
1956	Site 1		18	Yes	1	Barrel	-	-	-	-	-	-	
1956	Site 1		18	Yes	1	Barrel	-	-	-	-	-	-	
1961	Site 1		18	Yes	2	Drum	-	396	-	-	-	5 mg	
					2	Drum	-	180	-	-	-	-	-
					1	Wooden Box	-	-	-	-	-	-	-
1962	Site 2		549	Yes	2	Drum	-	396	0.7	-	-	0.74	
					1	Drum	-	-	-	-	-	-	-
1965	Site 3:												
	42 ° 13'S 176 ° 10'E		2600	No	4	Block	Concrete	-	-	-	-	4 mg	
1967	Site 4 (area A):												
	42 ° 15'S 175 ° 00'E		2834	Yes	1	Drum	Concrete	46.3	-	-	-	11 mg	
				No	1	Block	Concrete	-	-	-	-	-	
1972	42 ° 15'S 175 ° 00'E		2834	Yes	9	Drum	Concrete	46.3	117.0	-	-	2.22	
1973	42 ° 15'S 175 ° 00'E		2834	Yes	2	Drum	Concrete	22.5	444.0	-	-	-	
1976	42 ° 15'S 175 ° 00'E		2834	Yes	7	Drum	Concrete	22.5	477.3	-	-	8.14	
				Total:	39			1108.3	1039.0				
									(28.1 Ci)				

Keys for co-ordinates:

Site 1: Three miles north-north west of Lyttelton Heads.

Site 2: Six miles south of Baring Heads.

Site 3: At a bearing of 135°, at a distance of 50 miles from Cape Palliser; disposal from an aircraft.

Annex A.9
SWEDEN — ATLANTIC OCEAN

Disposal period: 1969
Total number of years of disposal operations: 1
Total number of sites: 1
Total number of containers dumped: 2895
Total weight of containers dumped: 1080.3 tons
Total activity: 3.24×10^3 GBq (86.9 Ci)
Information provided to IAEA on: 11 April 1990

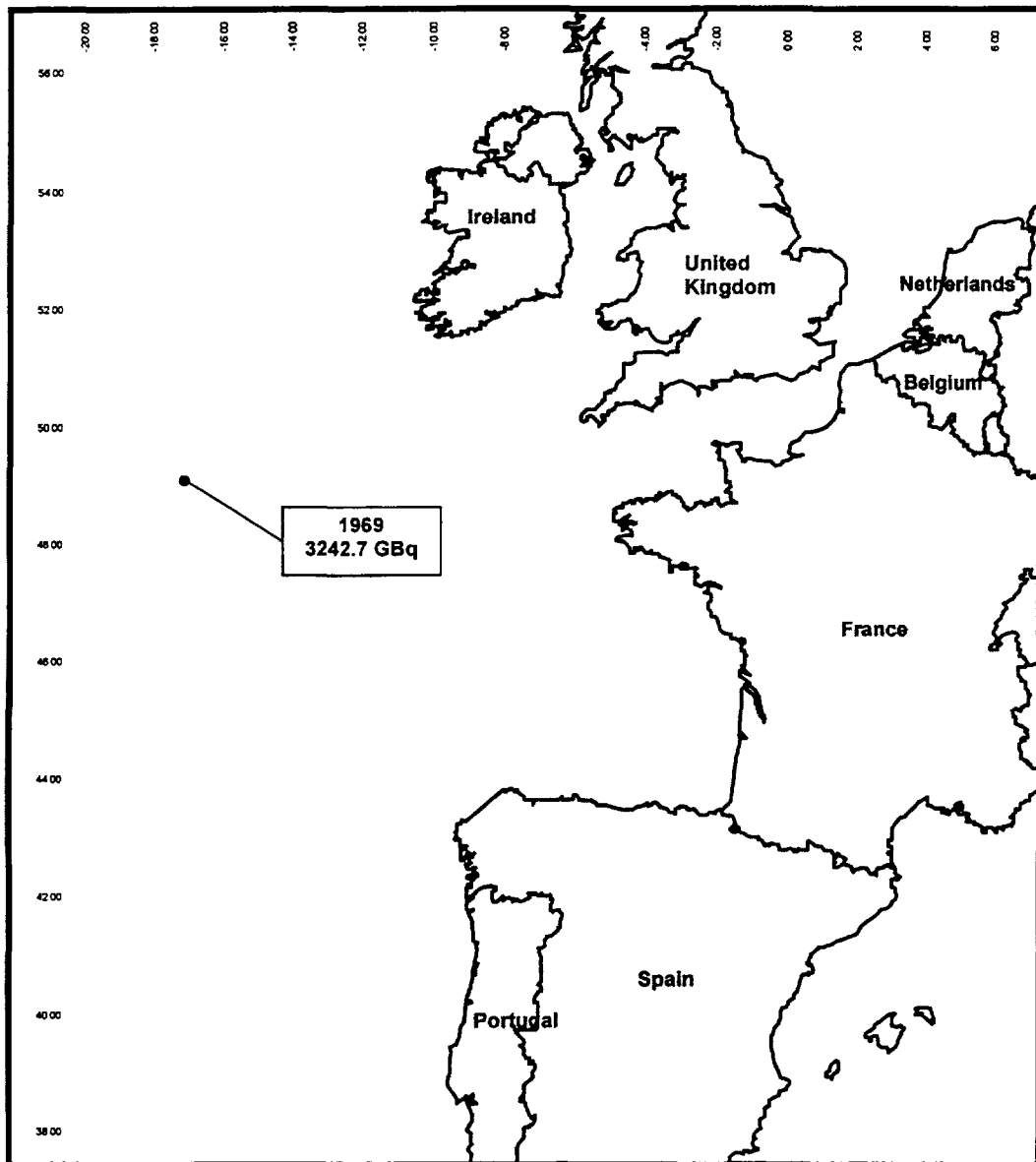


FIG. A.9. Geographical position of the dump site, disposal period and total activity disposed.

DATE	CO-ORDINATES		DEPTH	Package	CONTAINER			Total weight t	ACTIVITY		
	Latitude	Longitude	m		Number	Type*	Matrix		Total GBq	Alpha GBq	Beta-gamma GBq
1969	49 ° 05'N	17 ° 05'W	4000-4600	Yes	220	M 200 l	Concrete	82.0	259.0	74.0	185.0
				Yes	2645	M 200 l	Concrete	982.0	2701.0	851.0	1850.0
				Yes	3	M 200 l	Concrete	1.9	26.3	0.4	25.9
				Yes	14	M 200 l	Concrete	7.4	99.9	11.1	88.8
				Yes	13	M 200 l	Concrete	7.0	156.5	1.1	155.4
				Total	2895			1080.3	3242.7	937.6	2305.1
								(86.9 Ci)			

* Key for the type of containers: M: metal drum.

ANNEX A.10
SWEDEN — BALTIC SEA

Disposal period: 1959 and 1961
Total number of years of disposal operations: 2
Total number of sites: 1
Total number of containers dumped: 230
Total weight of containers dumped: 64 tons
Total volume of waste: 43.75 cubic metre
Total activity: 14.8 GBq (0.4 Ci)
Information provided to IAEA on: 23 September 1992

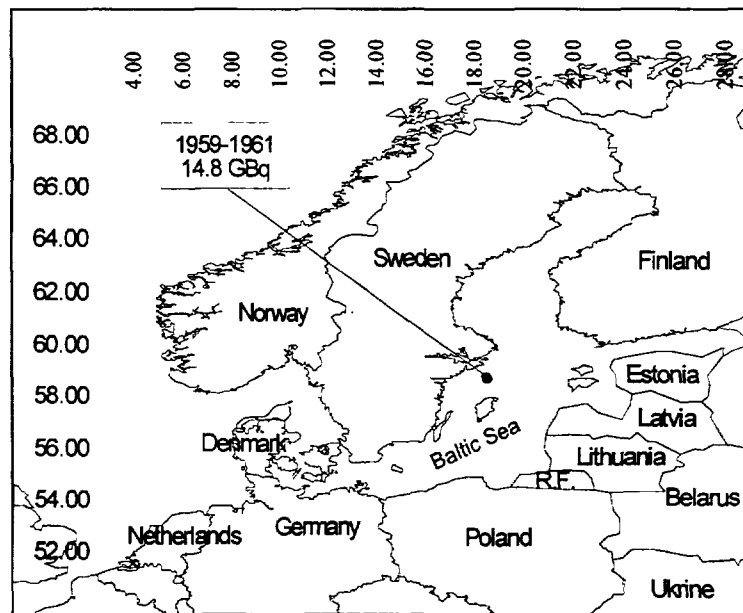


FIG. A.10. Approximate geographical position of the dump site, disposal period and total activity disposed in Baltic Sea.

DATE	CO-ORDINATES		DEPTH	Package	CONTAINER		Total Weight t	Total Volume m ³	ACTIVITY		
	Latitude	Longitude	m		Number	Type*			Total GBq	Alpha GBq	Beta-gamma GBq
1959	[About 30 km South East of Landsort]		About 400	Yes	200	M 200 I	60	40.000	4.4		
1961					30	M 200 I	4	3.750	10.4		
				Total	230		64	43.750	14.8 (0.4 Ci)		

* Key for the type of containers: M: metal drum.

Annex A.11 SWITZERLAND

Disposal period: 1969–1982
Total number of years of disposal operations: 12
Total number of sites: 3
Total number of containers dumped: 7420
Total weight of containers dumped: 5321 tons
Total activity: 4.42×10^6 GBq (11.94×10^4 Ci)
Information provided to IAEA on: 7 July 1989

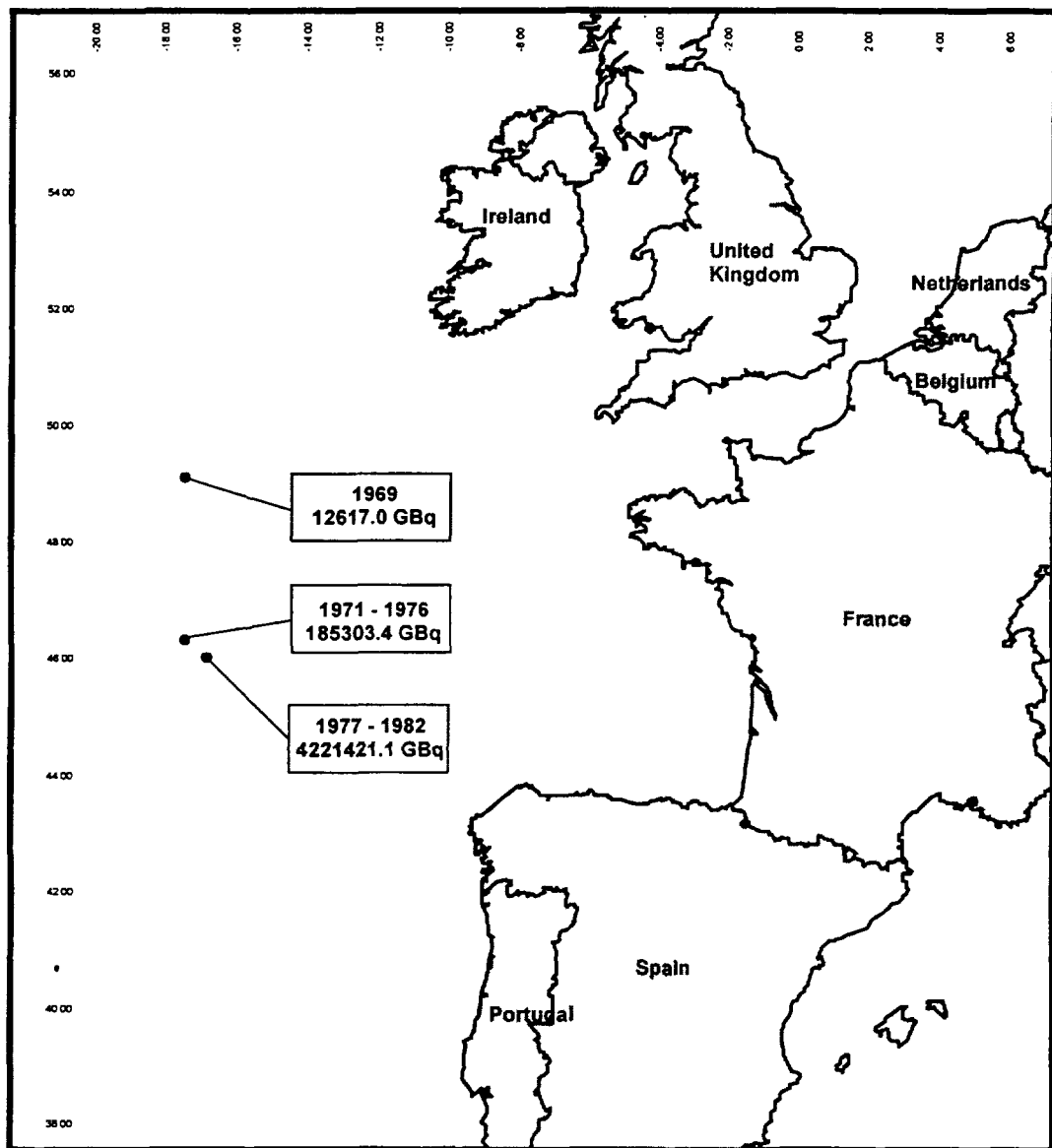


FIG. A.11. Geographical positions of the dump sites, disposal periods and total activity disposed.

DATE	CO-ORDINATES		DEPTH	Package	CONTAINER			Total weight t	ACTIVITY			H-3 GBq
	Latitude	Longitude	m		Number	Type*	Matrix		Total GBq	Alpha GBq	Beta-gamma GBq**	
1969	49 ° 05'	17 ° 25'W	4000-4600	Yes	100	MDLC	C	224	12617.0		12617.0	
1971	46 ° 15'N	17 ° 25'W	3600-4750	Yes	150	MD	C					
				Subtotal	128	MDLC	C					
				Subtotal	278			376	13242.3	70.3	13172.0	
1972	46 ° 15'N	17 ° 25'W	3600-4750	Yes	1075	MD	C	509	22237.0	259.0	21978.0	7104.0
				Subtotal	45	MDLC	C					
				Subtotal	1120							
1974	46 ° 15'N	17 ° 25'W	3600-4750	Yes	587	MD	C	509	79043.1	603.1	78440.0	67414.0
				Subtotal	121	MDLC	C					
				Subtotal	708							
1975	46 ° 15'N	17 ° 25'W	3600-4750	Yes	200	MD	C	203	43356.6	806.6	42550.0	15725.0
				Subtotal	55	MDLC	C					
				Subtotal	255							
1976	46 ° 15'N	17 ° 25'W	3600-4750	Yes	541	MD	C	349	27424.4	562.4	26862.0	17501.0
				Subtotal	59	MDLC	C					
				Subtotal	600							
1977	46 ° 00'N	16 ° 45'W	3900-4750	Yes	630	MD	C	457	35268.4	303.4	34965.0	13542.0
				Subtotal	82	MDLC	C					
				Subtotal	712							
1978	46 ° 00'N	16 ° 45'W	3900-4750	Yes	801	MD	C	733	166111.0	1017.5	165094.0	14430.0
				Subtotal	165	MDLC	C					
				Subtotal	966							

DATE	CO-ORDINATES		DEPTH	Package	CONTAINER			Total weight t	ACTIVITY			H-3 GBq
	Latitude	Longitude	m		Number	Type*	Matrix*		Total GBq	Alpha GBq	Beta-gamma GBq**	
1979	46 ° 00'N	16 ° 45'W	3900-4750	Yes	378	MD	C	409	63717.7	3.7	63714.0	58682.0
					4	MDLC	C					
				Subtotal	382							
1980	46 ° 00'N	16 ° 45'W	3900-4750	Yes	594	MD	C	301	1903960.0	14.8	1903946.0	1876307.0
					10	MDLC	C					
				Subtotal	604							
1981	46 ° 00'N	16 ° 45'W	3900-4750	Yes	671	MD	C	404	1405556.0	407.0	1405149.0	1332111.0
					39	MDLC	C					
				Subtotal	710							
1982	46 ° 00'N	16 ° 45'W	3900-4750	Yes	883	MD	C	847	646808.0	270.1	646538.0	499426.0
					152	MDLC	C					
				Subtotal	1035							
				Total:	7470			5321	4419341.5	4317.9	4415025.0	3902242.0
									(11.94 × 10 ⁴ Ci)			

* Key for the type of containers and matrix: MD: metal drum
MDLC: metal drum lined with concrete
C: concrete.

** Tritium activities are included in the beta-gamma figures.

Annex A.12 UNITED KINGDOM

Disposal period: 1949–1982
 Total number of years of disposal operations: 34
 Total number of sites: 15
 Total number of containers dumped: ?
 Total weight of containers dumped: 74 052 tons
 Total activity: 3.51×10^7 GBq (9.5×10^5 Ci)
 Information provided to IAEA on: 5 December 1989

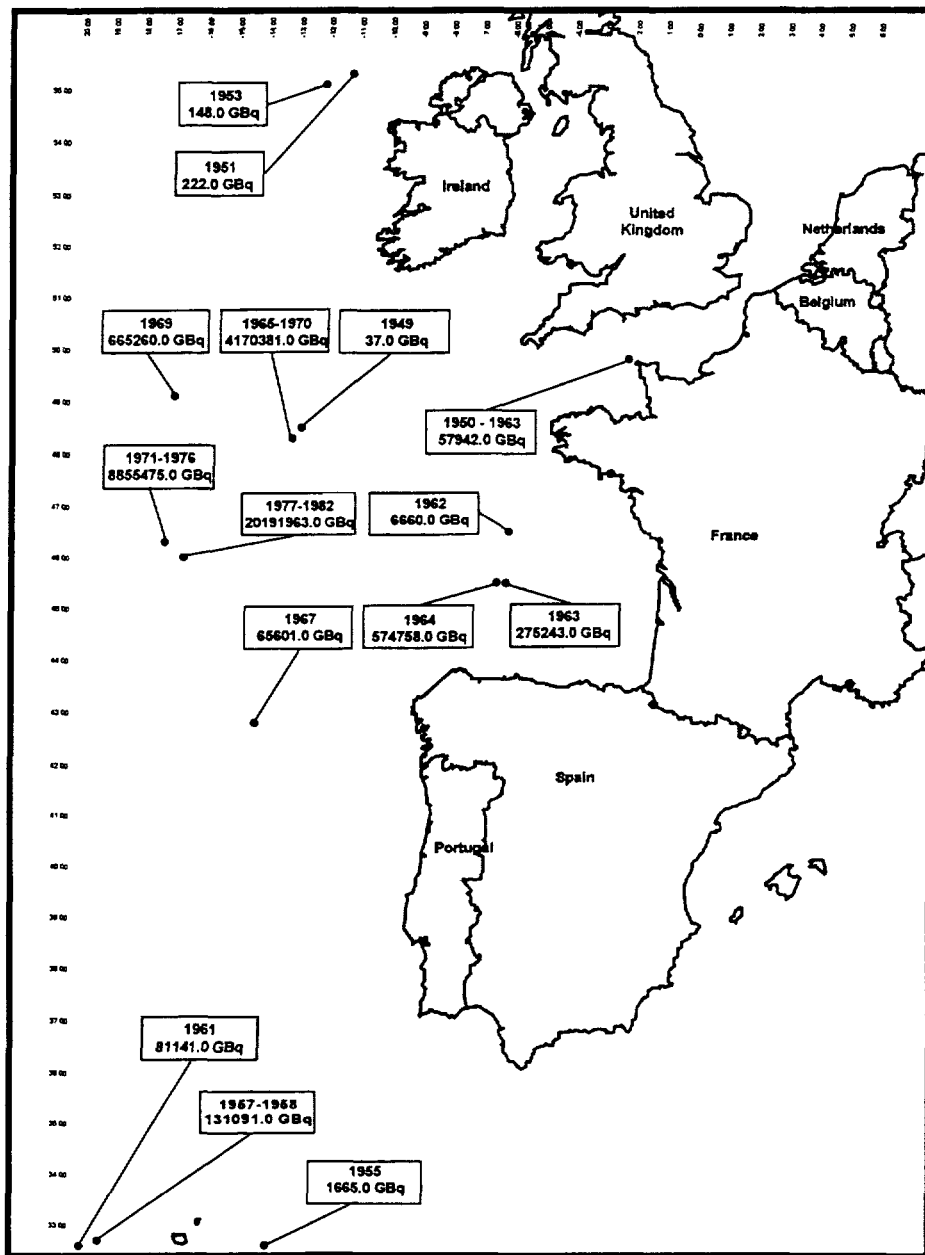


FIG. A.12. Geographical positions of the dump sites, disposal periods and total activity disposed.

DATE	CO-ORDINATES		DEPTH	Package*	Total weight t	ACTIVITY			H-3 GBq
	Latitude	Longitude	m			Total GBq	Alpha GBq	Beta-gamma GBq**	
1949	48 ° 30'N	13 ° 00'W	3600-4000	Yes	9	37.0	—	37.0	—
1950	49 ° 50'N	2 ° 18'W	65-160	Yes	350	814.0	74.0	740.0	—
1951	49 ° 50'N	2 ° 18'W	65-160	Yes	319	703.0	37.0	666.0	—
	55 ° 20'N	11 ° 20'W	2700-2700	Yes	33	222.0	37.0	185.0	—
1952	49 ° 50'N	2 ° 18'W	65-160	Yes	534	1147.0	74.0	1073.0	—
1953	55 ° 08'N	12 ° 10'W	2800-2800	Yes	57	148.0	74.0	74.0	—
	49 ° 50'N	2 ° 18'W	65-160	Yes	758	1813.0	370.0	1443.0	—
1954	49 ° 50'N	2 ° 18'W	65-160	Yes	1145	2886.0	851.0	2035.0	—
1955	49 ° 50'N	2 ° 18'W	65-160	Yes	1164	2923.0	1295.0	1628.0	—
	32 ° 37'N	14 ° 05'W	4000-4200	Yes	1453	1665.0	444.0	1221.0	—
1956	49 ° 50'N	2 ° 18'W	65-160	Yes	1038	2849.0	1628.0	1221.0	—
1957	49 ° 50'N	2 ° 18'W	65-160	Yes	1537	9990.0	4033.0	5957.0	—
	32 ° 42'N	19 ° 30'W	3600-4100	Yes	4404	65231.0	35335.0	29896.0	—

DATE	CO-ORDINATES		DEPTH	Package*	Total weight t	ACTIVITY			H-3 GBq
	Latitude	Longitude	m			Total GBq	Alpha GBq	Beta-gamma GBq**	
1958	32 ° 42'N	19 ° 30'W	3600-4100	Yes	2694	65860.0	25715.0	40145.0	-
	49 ° 50'N	2 ° 18'W	65-160	Yes	1011	4255.0	2146.0	2109.0	-
1959	49 ° 50'N	2 ° 18'W	65-160	Yes	1198	2886.0	148.0	2738.0	-
1960	49 ° 50'N	2 ° 18'W	65-160	Yes	2551	10804.0	2738.0	8066.0	-
1961	49 ° 50'N	2 ° 18'W	65-160	Yes	1967	12136.0	740.0	11396.0	-
	32 ° 38'N	20 ° 05'W	2100-4800	Yes	4360	81141.0	20831.0	60310.0	-
1962	46 ° 27'N	6 ° 10'W	4200-4600	Yes	253	6660.0	629.0	6031.0	-
	49 ° 50'N	2 ° 18'W	65-160	Yes	1444	2997.0	185.0	2812.0	-
1963	49 ° 50'N	2 ° 18'W	65-160	Yes	1543	1739.0	111.0	1628.0	-
	45 ° 27'N	6 ° 16'W	4100-4800	Yes	5809	275243.0	13616.0	261627.0	-
1964	45 ° 27'N	6 ° 36'W	4100-4800	Yes	4392	574758.0	16428.0	558330.0	-
1965	48 ° 20'N	13 ° 16'W	1900-4500	Yes	1759	513116.0	4218.0	508898.0	-

DATE	CO-ORDINATES		DEPTH	Package*	Total weight t	ACTIVITY			H-3 GBq
	Latitude	Longitude	m			Total GBq	Alpha GBq	Beta-gamma GBq**	
1966	48 ° 20'N	13 ° 16'W	1900-4500	Yes	1044	104340.0	2886.0	101454.0	-
1967	42 ° 50'N	14 ° 30'W	2500-5200	Yes	722	65601.0	3367.0	62234.0	-
1968	48 ° 20'N	13 ° 16'W	1900-4500	Yes	3164	2796016.0	27047.0	2768969.0	-
1969	49 ° 05'N	17 ° 05'W	4000-4600	Yes	1878	665260.0	14430.0	650830.0	-
1970	48 ° 20'N	13 ° 16'W	1900-4500	Yes	1674	756909.0	8621.0	748288.0	-
1971	46 ° 15'N	17 ° 25'W	3200-4100	Yes	1434	330785.0	12030.0	318755.0	-
1972	46 ° 15'N	17 ° 25'W	3200-4100	Yes	1885	729751.0	24938.0	704813.0	-
1973	46 ° 15'N	17 ° 25'W	3200-4100	Yes	1453	458763.0	27343.0	431420.0	-
1974	46 ° 15'N	17 ° 25'W	3200-4100	Yes	1256	3497425.0	14763.0	3482662.0	-
1975	46 ° 15'N	17 ° 25'W	3200-4100	Yes	1350	1967808.0	26048.0	1941760.0	956080.0

DATE	CO-ORDINATES		DEPTH	Package*	Total weight t	ACTIVITY			H-3 GBq
	Latitude	Longitude	m			Total GBq	Alpha GBq	Beta-gamma GBq**	
1976	46 ° 15'N	17 ° 25'W	3200-4100	Yes	2269	1870943.0	29193.0	1841750.0	693010.0
1977	46 ° 00'N	16 ° 45'W	3200-4750	Yes	2140	2803116.0	34410.0	2768706.0	1159136.0
1978	46 ° 00'N	16 ° 45'W	3200-4750	Yes	2080	2594478.0	30118.0	2564360.0	1209900.0
1979	46 ° 00'N	16 ° 45'W	3200-4750	Yes	2014	3051054.0	51097.0	2999957.0	1516667.0
1980	46 ° 00'N	16 ° 45'W	3200-4750	Yes	2693	3991190.0	66267.0	3924923.0	1486253.0
1981	46 ° 00'N	16 ° 45'W	3200-4750	Yes	2517	3949415.0	75184.0	3874231.0	1414991.0
1982	46 ° 00'N	16 ° 45'W	3200-4750	Yes	2697	3802710.0	46770.0	3755940.0	2345170.0
				Total:	74052	35077587.0 (9.5 × 10 ⁵ Ci)	626269.0	34451318.0	10781207.0

* Key for the type of containers and matrix:

most of the packages had an outer shell of steel,
a small minority were monolithic blocks;
most of the packages were lined with concrete.

** Tritium activities are included in the beta-gamma figures.

Annex A.12-a
UNITED KINGDOM — ADDITIONAL DISPOSAL OPERATIONS
RETRIEVED FROM ARCHIVE

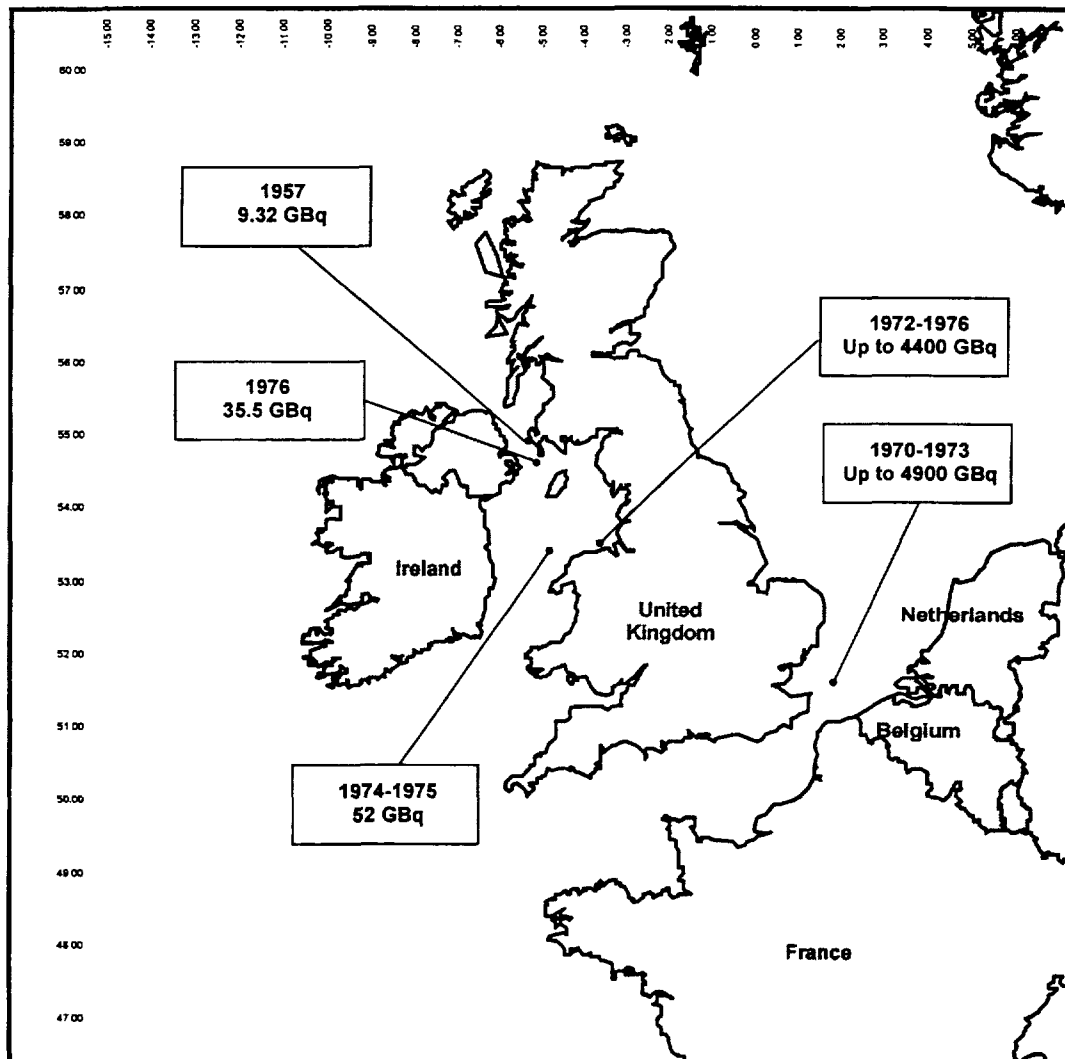
Disposal period: 1948–1976

Total number of years of disposal operations: 29

Total number of sites: 18

Total activity: $>9.397 \times 10^3$ GBq (253.97 Ci)

Information provided to IAEA on: 10 December 1997 and 27 November 1998



*FIG. A.12-a. Geographical positions of additional dump sites,
disposal periods and total activity disposed.*

DATE	CO-ORDINATES		DEPTH		Package *	Total weight t	ACTIVITY			H-3 GBq
	Latitude	Longitude	Min. m	Max. m			Total GBq	Alpha GBq	Beta-gamma GBq**	
1948-1951	Off Lowestoft (Outside herring fishing area)		25	40	Liquid waste from fish tolerance experiments. Poured from drums	7.3 maximum per disposal (exact number of disposals not known)	Not known	Not known	Not known	Not known
1949	Not known whether sea dumping actually took place. Advice was to dump at least 5 miles offshore (probably from the Tay Estuary) or to landfill.		Not known	If dumped at sea, probably less than 60 metres	35,000 faulty luminized dials possibly sealed in a drum or drums	Not known	Not known	Between 0.93 and 1.9 of radium 226 and progeny	Not known	Not known
1950-1957	Unknown - described as "well out to sea", probably from the Tay Estuary		Not known	Probably less than 60 metres	Considerable quantity of scrap radium luminized dials — type of packaging unknown	Not known	Not known	Radium 226 and progeny	Not known	Not known

DATE	CO-ORDINATES		DEPTH		Package *	Total weight t	ACTIVITY			H-3 GBq
	Latitude	Longitude	Min. m	Max. m			Total GBq	Alpha GBq	Beta-gamma GBq**	
1953– (number of disposals uncertain)	Beaufort's Dyke (exact dumpsite unknown)		Probably around 80 metres	Around 300 metres	1953 operation comprised two bins containing rubber gloves and broken glassware	Not known	Not known	Not known	Not certain but may have included Ca-45	Not known
1954–1956	Not known for certain. Thought to be in deep water close to Forth Rail Bridge at North Queensferry, Firth of Forth		Not known	Probably less than 40 metres	Scrap radio valves believed to be in perforated drums	Not known	Not known	Radium 226 and progeny. Estimated to be around 0.16 in the form of radium bromide every 6 months	Not known	Not known
1959	54 ° 54'N	05 ° 20'W	200		7 containers of waste from Scottish universities	0.5	Not known	Not known	Not known	Not known
1957	54 ° 56'N	05 ° 19'W	110		5 bins of waste from Edinburgh University	0.4	Not known	Not known	Not known	Not known

DATE	CO-ORDINATES		DEPTH		Package *	Total weight t	ACTIVITY			H-3 GBq
	Latitude	Longitude	Min. m	Max. m			Total GBq	Alpha GBq	Beta-gamma GBq**	
1957	54 ° 56'N	05 ° 19'W	110		Caesium contaminated solids and liquids in 4 steel containers	0.3	9.32	Not known	9.32	Not known
1957	54 ° 56'N	05 ° 19'W	110		Two galvanized cylinders containing luminized and other material	0.1	Not known	Not known	Not known	Not known
1957	54 ° 57'N	05 ° 21'W	192		1 large container of scrap radio valves	0.1	Not known	May have been radium bromide	Not known	Not known
1958	Beaufort's Dyke (exact location unknown)		Probably around 80 metres	Around 300 metres	Unknown. Presumed to be a batch of faulty luminized watch dials	Not known	Not known	Not known	Not known	Not known
1958	55 ° 37'N	04 ° 59'W	44	172	Unknown — 2 small antistatic devices thought to have been dumped in a container with other waste	Not known, but likely to have been fairly light (foil bonded to plastic)	Not known	Not known	Strontium 90	Not known

DATE	CO-ORDINATES		DEPTH		Package *	Total weight t	ACTIVITY			H-3 GBq
	Latitude	Longitude	Min. m	Max. m			Total GBq	Alpha GBq	Beta-gamma GBq**	
1963	55 ° 39'N	05 ° 0'W	Not known	Around 80	Loose rubble & soil	638	Not known	7.4 of radium 226	Not known	Not known
1966	Boundary 56 ° 10'N 56 ° 11'N	Boundary 02 ° 29'W 02 ° 31'W	54	69	Liquids & sludges	Not known	Not known	Not known	Chromium- 51, iron-55, iron-59 & cobalt-60	Not known
1970-1973	Boundary 51 ° 43'N 51 ° 42'N 51 ° 33'N 51 ° 31'N	Boundary 01 ° 48'W 01 ° 56'W 01 ° 43'W 01 ° 52'W	25	45	Liquid effluent poured into vessel wake	Not known	Up to 4900	0.0	Up to 4900	0.0
1972-1976	53 ° 31'N It is also possible that a small amount of this material could have been disposed of in the Morecambe Bay area	03 ° 35'W	20	30	Sludges poured direct into the sea from vessels	Up to 2240 (this is the maximum weight authorized for disposal — actual amount dumped unknown)	Up to 4400	Up to 4400	0.0	0.0

DATE	CO-ORDINATES		DEPTH		Package *	Total weight t	ACTIVITY			H-3 GBq
	Latitude	Longitude	Min. m	Max. m			Total GBq	Alpha GBq	Beta-gamma GBq**	
1974-1975	Boundary	Boundary	50	70	Co-60 in the form of a soluble salt contained in phials with soluble plugs	Not known	52	0.0	52	0.0
	53 ø 23'N	04 ø 48'W								
	53 ø 23'N	04 ø 45'W								
	53 ø 19'N	04 ø 45'W								
	53 ø 16'N	04 ø 48'W								
1976	Boundary	Boundary	160	200	Rubble & soil deposited from vessel	Around 9600	35.5	35.5	0.0	0.0
	54 ø 35'N	05 ø 04'W								
	54 ø 40'N	05 ø 10'W								

Total $>9.397 \times 10^3$ GBq (253.97 Ci)

* Most of the packages had an outer shell of steel,
a small minority were monolithic blocks;
most of the packages were lined with concrete.

** Tritium activities are included in the beta-gamma figures.

Annex A.13
UNITED STATES OF AMERICA — ATLANTIC OCEAN

Disposal period: 1949–1967
Total number of years of disposal operations: ?
Total number of sites: 11
Total number of containers dumped: 34 282
Total weight of containers dumped: ?
Total activity: 2.94×10^6 GBq (7.95×10^4 Ci)
Information provided to IAEA on: 27 October 1989

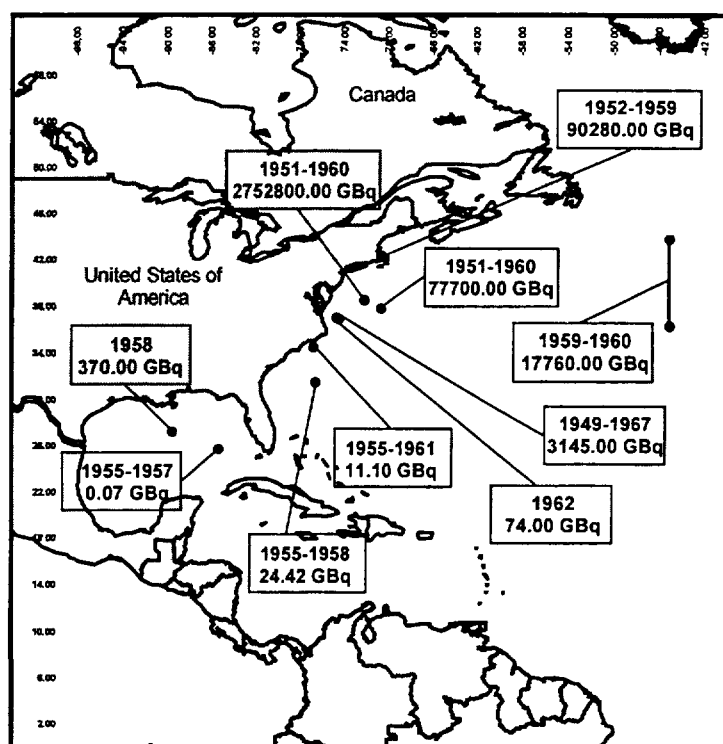


FIG. A.13. Geographical positions of the dump sites in the Atlantic Ocean, disposal periods and total activity disposed.

DATE		CO-ORDINATES		DEPTH	Package	CONTAINER	NATURE OF WASTE*			ACTIVITY
Start	End	Latitude	Longitude	m		Number	BPM	SM	SNM	Total GBq
1949	1967	36 ° 56'N	74 ° 23'W	1829-1967	Yes	834	Yes			3145.00
1951	1960	38 ° 30'N	72 ° 06'W	1829-2800	Yes	14301	Yes**			2752800.00
1951	1960	37 ° 50'N	70 ° 35'W	1829-3800	Yes	14500	Yes			77700.00
1952	1959	42 ° 25.5'N	70 ° 35'W	92	Yes	4008	Yes	Yes		90280.00
1955	1957	25 ° 40'N	85 ° 17'W	3110	Yes	78	Yes			0.07
1955	1960	off Sapelo Island		11	No-liquid		Yes			0.19
1955	1961	34 ° 32'N	76 ° 40'W	19	No		Yes			11.10
1955	1962	31 ° 32'N	76 ° 30'W	915-3660	Yes	119	Yes			24.42
1958	1958	27 ° 14'N	89 ° 33'W	1829	Yes	1	Yes			370.00

DATE		CO-ORDINATES		DEPTH	Package	CONTAINER Number	NATURE OF WASTE*			ACTIVITY Total GBq
Start	End	Latitude	Longitude	m			BPM	SM	SNM	
1959	1960	36 ° 20'N	45 ° 00'W	3660-5289	Yes	432	Yes			17760.00
1959	1960	43 ° 49'N	45 ° 00'W							
1962		37 ° 00'N	74 ° 37'W	421	Yes	9	Yes			74.00
					Subtotal:	34282				2942164.78 (7.95 × 10 ⁴ Ci)
					Totals (Atlantic + Pacific):	90543				3496411.83 (9.45 × 10 ⁴ Ci)

Keys to table:

*BPM = byproduct materials; SM = source materials; SNM = special nuclear materials.

** = includes the Seawolf submarine reactor shell, dumped in 1959; estimated activity 1221 TBq (33000 Ci).

N.B.: Radioactivity is the estimated activity at the time of packaging.

Annex A.14
UNITED STATES OF AMERICA — PACIFIC OCEAN

Disposal period: 1946–1970
 Total number of years of disposal operations: ?
 Total number of sites: 18
 Total number of containers dumped: 56 261
 Total weight of containers dumped: ?
 Total activity: 5.54×10^5 GBq (1.50×10^4 Ci)
 Information provided to IAEA on: 27 October 1989

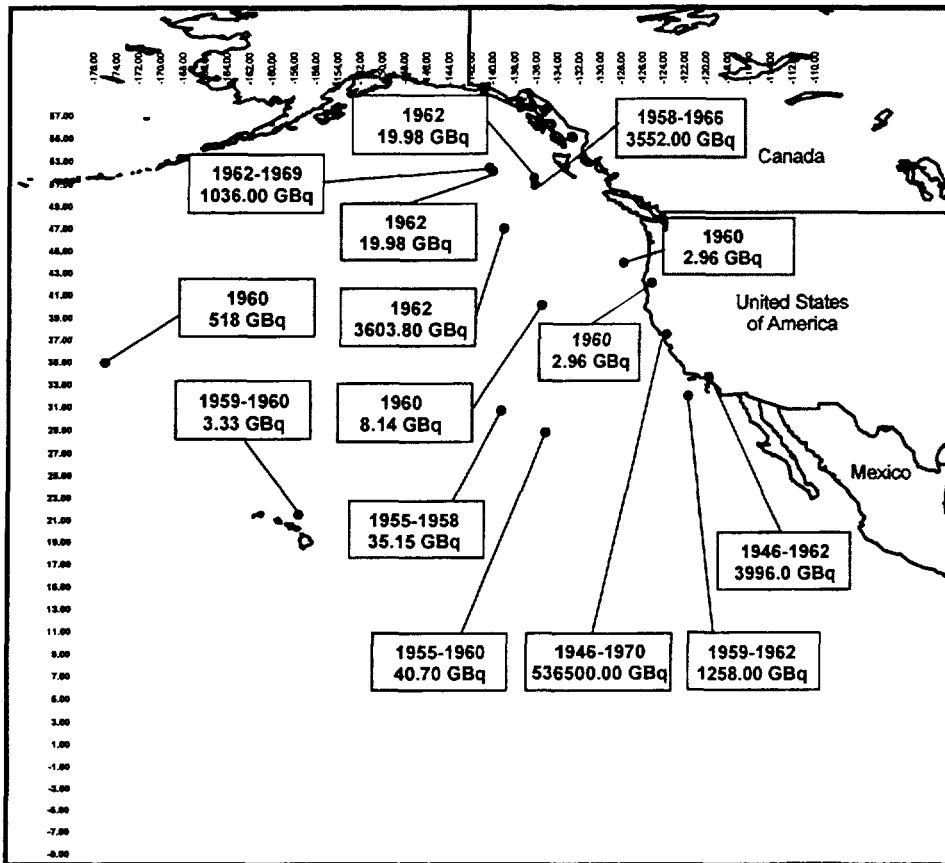


FIG. A.14. Geographical positions of the dump sites in the Pacific Ocean, disposal periods and total activity disposed.

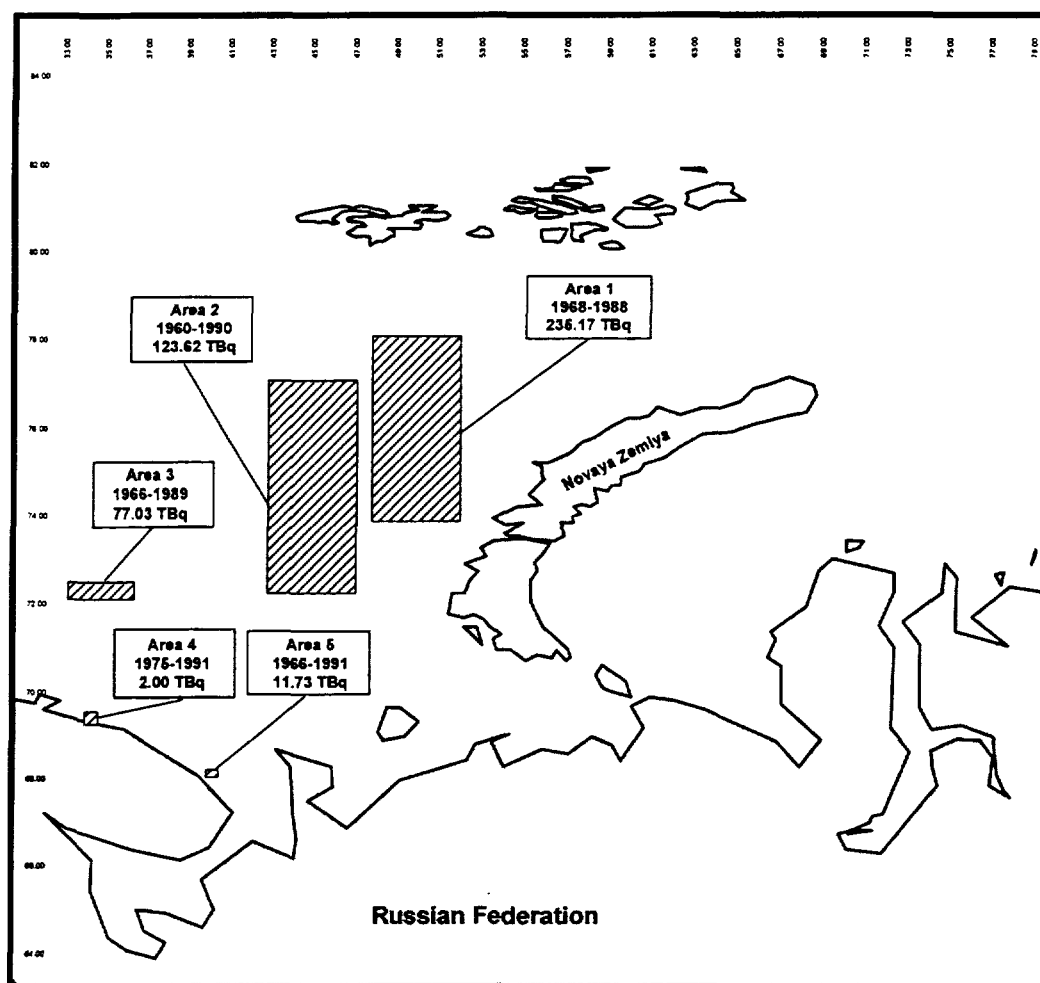
DATE		CO-ORDINATES		DEPTH	Package	CONTAINER Number	NATURE OF WASTE*			ACTIVITY
Start	End	Latitude	Longitude	m			BPM	SM	SNM	Total GBq
1946	1962	33 ° 40'N	119 ° 35'W	1829 – 1940	Yes	3114	Yes	Yes		3996.00
	1962	51 ° 30'N	136 ° 10'W	– –	Yes	38	–	–	–	19.98
	1962	52 ° 05'N	140 ° 00'W	– –	Yes	41	–	–	–	19.98
	1962	47 ° 00'N	138 ° 54'W	– –	Yes	361	–	–	–	3603.80
	1962	–	–	1830	Yes	37	–	–	–	44.40
	1962	–	–	–	Yes	231	–	–	–	3570.50
1946	1970	37 ° 27'N	123 ° 37'W	896 – 1700	Yes	47500	Yes	Yes	Yes	536500.00
1955	1958	42 ° 12'N	129 ° 31'W	3292 <	Yes	26	Yes			35.15
1955	1958	30 ° 43'N	139 ° 05'W	3658 – 4560	Yes	26	Yes			35.15
1955	1960	28 ° 47'N	135 ° 00'W	3477 <	Yes	29	Yes			40.70
1958	1966	50 ° 56'N	136 ° 03'W	3292 <	Yes	197	Yes	Yes		3552.00
1959	1960	21 ° 28'N	157 ° 25'W	3456 <	Yes	39	Yes			3.33
1959	1962	32 ° 00'N	121 ° 30'W	2210 – 3658	Yes	4415	Yes	Yes	Yes	1258.00
	1960	34 ° 58'N	174 ° 52'W	5487 <	Yes	7	Yes			518.00
	1960	43 ° 52'N	127 ° 44'W	2926 <	Yes	4	Yes			2.96
	1960	42 ° 04'N	125 ° 01'W	1000 – 4097	Yes	4	Yes			2.96
	1960	40 ° 07'N	135 ° 24'W	1829 – 1990	Yes	29	Yes	Yes		8.14
1962	1969	52 ° 25'N	140 ° 20'W	3294 <	Yes	163	Yes	Yes		1036.00
Subtotal:						56261				554247.05 (1.50 × 10 ⁴ Ci)
Total (Atlantic + Pacific):						90543				3496411.83 (9.45 × 10 ⁴ Ci)

Keys: *BPM = byproduct materials; SM = source materials; SNM = special nuclear materials.
– = no data available

N.B.: Total activity is the estimated activity at the time of packaging.

ANNEX A.15
FORMER SOVIET UNION — DISPOSAL OF LIQUID RADIOACTIVE WASTE
(LRW) IN THE ARCTIC SEAS

Disposal period: 1959–1991
 Total number of disposal operations: 98
 Total number of sites: 5
 Total volume of liquid radioactive waste disposed: 190 334 cubic metres
 Total activity: 764 TBq (20.650 kCi)
 Information provided to IAEA on: 21 May 1993



N.B. Discharge outside areas 1–5 (co-ordinates not available) = 314.5 TBq (8.5 kCi).

FIG. A.15. Geographical positions of the dump sites in the Arctic Seas, disposal period and total activity disposed.

SUMMARY

AREA	CO-ORDINATES		DEPTH m	ACTIVITY		GEOGRAPHICAL LOCATION
	Latitude	Longitude		TBq	Ci	
1	78 ° 0'N	48 ° 0'E	180-300	235.17	6356.00	Barents Sea (open sea)
	78 ° 0'N	52 ° 0'E				
	74 ° 0'N	48 ° 0'E				
	74 ° 0'N	52 ° 0'E				
2	77 ° 0'N	43 ° 0'E	200-300	123.62	3341.00	Barents Sea (open sea)
	77 ° 0'N	47 ° 0'E				
	72 ° 30'N	43 ° 0'E				
	72 ° 30'N	47 ° 0'E				
3	72 ° 45'N	33 ° 30'E	200-300	77.03	2082.00	Barents Sea (open sea)
	72 ° 45'N	36 ° 30'E				
	72 ° 15'N	33 ° 30'E				
	72 ° 15'N	36 ° 30'E				
4	69 ° 51'N	34 ° 15'E	100-200	2.00	54.00	Barents Sea (coastal)
	69 ° 51'N	34 ° 51'E				
	69 ° 34'N	34 ° 15'E				
	69 ° 34'N	34 ° 51'E				
5	68 ° 18'N	40 ° 13'E	50-100	11.73	317.00	Barents Sea (coastal)
	68 ° 18'N	40 ° 36'E				
	68 ° 10'N	40 ° 13'E				
	68 ° 10'N	40 ° 36'E				
Outside Areas 1-5	Total Areas 1-5			449.55	12150.00	
				314.50	8500.22	Baltic Sea; Kara Sea
	Grand total			764.05	20650.22	
			≅ 764	20650		

DATE	CO-ORDINATES		DEPTH	VOLUME m ³	ACTIVITY	
	Latitude	Longitude	m		TBq	Ci
Area 1	78 ° 0'N	48 ° 0'E	180-300			
	78 ° 0'N	52 ° 0'E				
	74 ° 0'N	48 ° 0'E				
	74 ° 0'N	52 ° 0'E				
	Barents Sea (open Sea)					
1968				353.0	0.10	2.81
1969				316.0	4.05	109.51
1970				2703.0	2.42	65.42
1972				850.0	0.22	5.90
1973				882.0	0.81	22.00
1975				1947.0	15.91	430.00
1976				1800.0	2.33	63.00
1977				1500.0	2.53	68.32
1978				340.0	1.12	30.19
1979				604.0	0.44	12.01
1980				650.0	1.00	27.06
1982				1250.0	6.25	169.00
1983				685.0	2.68	72.41
1988				364.5	195.30	5278.51
			Total	14244.0	235.17	6356.00

DATE	CO-ORDINATES		DEPTH	VOLUME m ³	ACTIVITY	
	Latitude	Longitude	m		TBq	Ci
Area 2	77 ° 0'N	43 ° 0'E	200-300			
	77 ° 0'N	47 ° 0'E				
	72 ° 30'N	43 ° 0'E				
	72 ° 30'N	47 ° 0'E				
	Barents Sea (open Sea)					
1960				760.0	0.01	0.22
1961				930.0	0.61	16.50
1962				850.0	0.17	4.61
1963				1054.0	13.25	358.15
1964				910.0	5.67	153.11
1965				6520.0	35.65	963.62
1966				3540.0	13.57	366.84
1967				144.0	1.12	30.17
1969				3416.0	1.92	51.88
1971				2371.0	0.76	20.65
1972				930.0	0.72	19.50
1973				4057.0	2.83	76.60
1974				8645.0	9.83	265.70
1975				4720.0	2.04	55.27
1976				6229.0	2.81	75.90
1977				4150.0	1.75	47.35
1980				3405.0	0.83	22.32
1981				2146.0	9.93	268.27

DATE	CO-ORDINATES		DEPTH	VOLUME m ³	ACTIVITY	
	Latitude	Longitude	m		TBq	Ci
Area 2 (contd.)						
1982				1745.4	0.41	11.08
1983				1772.1	9.82	265.34
1984				5125.4	8.22	222.13
1986				900.0	0.39	10.59
1987				1740.0	1.29	34.80
1990				751.0	0.03	0.85
			Total	66811.0	123.62	3341.00
Area 3	72 ø 45'N	33 ø 30'E	200-300			
	72 ø 45'N	36 ø 30'E				
	72 ø 15'N	33 ø 30'E				
	72 ø 15'N	36 ø 30'E				
	Barents Sea (open Sea)					
1966				1220.0	0.22	5.97
1967				530.0	0.08	2.20
1968				1357.0	0.02	0.51
1969				1290.0	0.01	0.29
1970				4370.0	3.56	96.14
1971				1096.0	0.13	3.63
1972				4101.0	3.75	101.33

DATE	CO-ORDINATES		DEPTH	VOLUME m ³	ACTIVITY	
	Latitude	Longitude	m		TBq	Ci
Area 3 (contd.)						
1973				3872.0	4.79	129.36
1974				3155.0	11.89	321.30
1975				851.0	0.57	15.30
1976				2788.0	30.01	811.19
1977				860.0	0.06	1.50
1978				5170.0	3.34	90.25
1979				7286.0	2.90	78.42
1980				3957.0	1.39	37.67
1981				2130.0	7.44	201.06
1982				1476.6	0.69	18.52
1983				472.0	0.41	11.06
1984				820.0	0.22	5.99
1985				2376.6	2.44	65.85
1986				870.0	1.09	29.49
1987				780.0	0.54	14.70
1989				2472.0	1.47	39.76
			Total	53300.0	77.03	2082.00

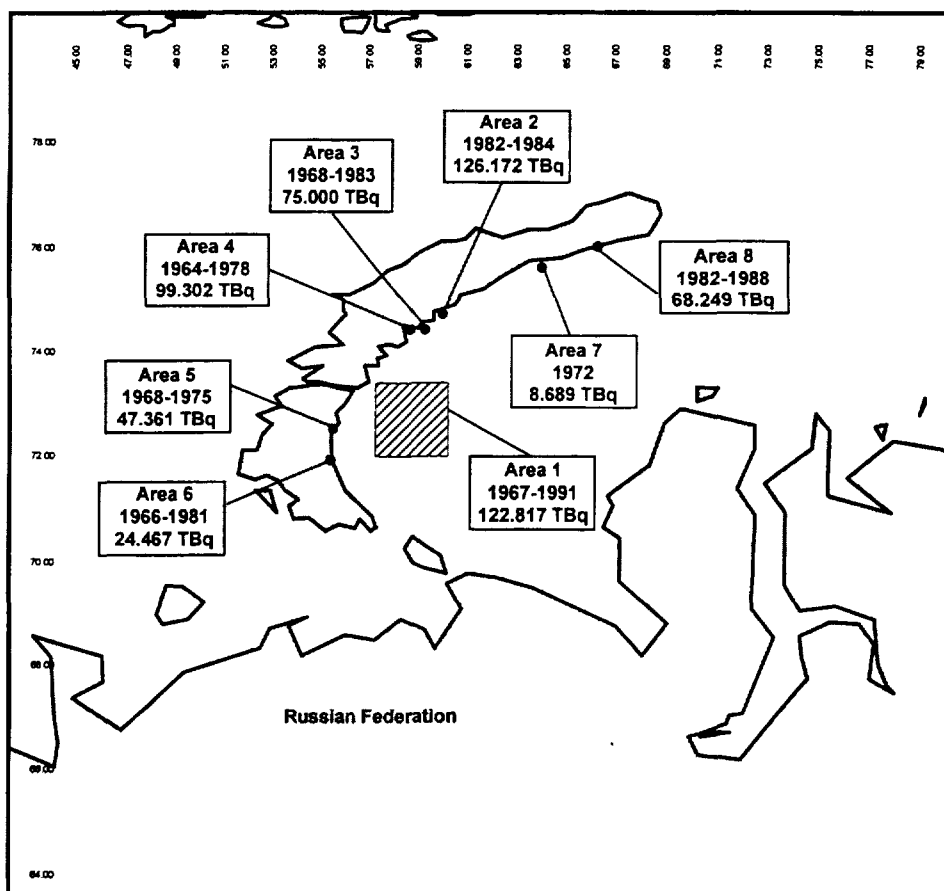
DATE	CO-ORDINATES		DEPTH	VOLUME m ³	ACTIVITY				
	Latitude	Longitude	m		TBq	Ci			
Area 4	69 ° 51'N	34 ° 15'E	100-200						
	69 ° 51'N	34 ° 51'E							
	69 ° 34'N	34 ° 15'E							
	69 ° 34'N	34 ° 51'E							
	Barents Sea (coastal)								
	1975						835.0	0.23	6.35
	1981						906.0	0.15	3.99
	1984						740.0	0.10	2.78
	1986						1410.0	0.21	5.74
	1987						2211.0	0.83	22.38
1989		875.0	0.05	1.41					
1990		1267.0	0.26	7.12					
1991		263.2	0.15	4.00					
		Total	8507.0	2.00	54.00				
Area 5	68 ° 18'N	40 ° 13'E	50-100						
	68 ° 18'N	40 ° 36'E							
	68 ° 10'N	40 ° 13'E							
	68 ° 10'N	40 ° 36'E							
	Barents Sea (coastal)								
1966		449.0	0.04	1.02					
1967		2000.0	0.10	2.69					
1968		1400.0	0.06	1.53					
1969		750.0	0.02	0.41					

DATE	CO-ORDINATES		DEPTH	VOLUME m ³	ACTIVITY	
	Latitude	Longitude	m		TBq	Ci
Area 5 (contd.)						
1970				2257.0	0.02	0.56
1971				1549.0	0.05	1.41
1972				2560.0	0.31	8.40
1973				885.0	0.15	4.00
1974				838.0	0.03	0.80
1975				1610.0	0.30	8.16
1976				830.0	0.41	11.20
1977				870.0	0.32	8.70
1980				800.0	0.30	8.00
1981				2755.0	0.78	21.14
1982				1855.0	0.36	9.70
1983				3247.0	0.83	22.34
1984				1614.8	1.90	51.38
1985				3980.5	0.81	21.90
1986				3410.0	0.88	23.73
1987				2063.0	0.76	20.61
1989				2752.0	0.41	11.10
1990				5913.6	2.18	59.04
1991				2382.8	0.73	19.61
			Total	46772.0	11.73	317.00
			Total Areas 1-5	189634.0	449.55	12150.00

DATE	CO-ORDINATES		DEPTH	VOLUME m ³	ACTIVITY	
	Latitude	Longitude	m		TBq	Ci
Discharge outside Areas 1-5						
1959	65 ° 44'N Baltic Sea	35 ° 54'E,		600.0	0.00	0.02
1960	Near Gogland Island, Baltic Sea			100.0	0.01	0.20
1976	Kara Sea, LRW from nuclear icebreaker "Lenin"			?	314.50	8500.00
				700.0 +?	314.50	8500.22
			Grand total	190334.0	764.05	20650.22
				+?	≅ 764	≅ 20650

ANNEX A.16
FORMER SOVIET UNION — DISPOSAL OF LOW AND INTERMEDIATE LEVEL
SOLID WASTE IN THE ARCTIC SEAS

Disposal period: 1964–1991
 Total number of disposal operations: 46
 Total number of sites: 8 + 3*
 Total number of containers dumped: 6508 (excluding dumping of unpackaged objects and ships)
 Total volume of solid radioactive waste dumped: 31 654 cubic metre
 Total activity: >585 TBq (>15.902 kCi)
 Total number of vessels dumped: 18
 Total number of unpackaged big size objects dumped: 153
 Information provided to IAEA on: 21 May 1993



* Disposal sites outside areas 1–8, activity discharged: 13.28 TBq (440 Ci).

FIG. A.16. Geographical positions of the dump sites in the Arctic Seas, disposal periods and total activity disposed.

SUMMARY

AREA	CO-ORDINATES		DEPTH	ACTIVITY		GEOGRAPHICAL LOCATION
	Latitude	Longitude	m	TBq	Ci	
1	72 ° 5'N 73 ° 17'N	57 ° 30'E 60 ° 0'E	380	122.817	3320.00	Kara Sea Novaya Zemlya Depression
2	74 ° 40'N 74 ° 42'N	59 ° 53'E 60 ° 17'E	13-33	126.172	3410.00	Sedov Inlet east coast of Novaya Zemlya
3	74 ° 35'N 74 ° 7'N	59 ° 18'E 59 ° 12'E	24	75.000	2027.00	Oga Inlet east coast of Novaya Zemlya
4	74 ° 22'N 74 ° 22'N	58 ° 42'E 58 ° 41'E	56-135	99.302	2684.00	Tsivolka Inlet east coast of Novaya Zemlya
5	72 ° 33'N 72 ° 32'N	55 ° 34'E 55 ° 23'E	25-27	47.361	1280.00	Stepovoy Inlet east coast of Novaya Zemlya
6	71 ° 56'N 71 ° 56'N	55 ° 22'E 55 ° 19'E	12-20	24.467	661.00	Abrosimov Inlet east coast of Novaya Zemlya
7	75 ° 40'N	63 ° 59'E	13-16	8.689	235.00	Blagopoluchiye Inlet east coast of Novaya Zemlya
8	75 ° 58'N 75 ° 59'N	66 ° 20'E 66 ° 18'E	Up to 50	68.249	1845.00	Techeniye Inlet east coast of Novaya Zemlya
Outside Areas 1-8	-		-	> 13.280	> 440.00	Northwest of Kolguyev Island; Barents Sea; Chernaya Bay; west coast of Novaya Zemlya
			Total	> 585.337	> 15902.00	
				> 585	> 15902	

DATE	CO-ORDINATES		DEPTH m	VOLUME m ³	ACTIVITY		FORM OF DISPOSAL		
	Latitude	Longitude			TBq	Ci	Containers	Ships	Unpackaged
Area 1, Kara Sea (Novaya Zemlya Depression)			380						
1967	73 ° 17'N	59 ° 54'E		212.00	1.306	35.30			3 pumps of icebreaker "Lenin"
1967	72 ° 21'N	57 ° 50'E		910.00	13.283	359.00		m/v "Diaz"	
1968	73 ° 06'N	59 ° 10'E		150.00	0.207	5.60		Barge No. 3	
1969				144.80	5.890	159.20	?	?	?
1970	73 ° 11'N	59 ° 54'E		144.00	0.207	5.60	?	?	?
1972	72 ° 24'N	57 ° 55'E		?	5.920	160.00		Lighter Sayany	
1973	72 ° 23'N	58 ° 0'E		?		?		Tanker TNT15	
1974	72 ° 11'N	57 ° 40'E		?		?		Tanker "Goryn"	
1975	72 ° 38'N	58 ° 20'E		5000.00	1.110	30.00		Lighter Oma	
1977	72 ° 19'N	57 ° 46'E		600.00	0.022	0.60		Lighter L-3	
1980	72 ° 18'N	57 ° 36'E		243.00	4.381	118.40		m/v-801250	
1980	72 ° 15'N	57 ° 35'E		?		?	?	?	?

DATE	CO-ORDINATES		DEPTH m	VOLUME m ³	ACTIVITY		FORM OF DISPOSAL		
	Latitude	Longitude			TBq	Ci	Containers	Ships	Unpackaged
Area 1, Kara Sea (contd.)									
1984	72 ° 15'N	57 ° 30'E		295.10	9.176	248.00	Containers (V*+)		
1984	72 ° 15'N	57 ° 30'E		4.00	0.215	5.80			Class III furfurool — acetone resin (V+)
1984	72 ° 15'N	57 ° 30'E		3.00	0.548	14.80			Primary loop circulating pump
1985	72 ° 21'N	57 ° 50'E		5182.10	27.315	738.24	1027		1 large object
1985	73 ° 06'N	59 ° 10'E		693.26	18.759	506.99	535		
1986	72 ° 21'N	57 ° 50'E		419.40	5.803	156.83	321		
1987	73 ° 07'N	59 ° 10'E		1302.30	23.241	628.14	847		Steam generator, primary loop circulating pump
1989	73 ° 06'N	59 ° 10'E		370.26	3.223	87.10	256		
1989	72 ° 21'N	57 ° 50'E		142.00	0.895	24.18	57		
1991	73 ° 17'N	59 ° 54'E		264.40	0.764	20.66	131		1 large object
1991	73 ° 17'N	59 ° 54'E		54.50	0.552	14.92			
		Total		16134.00	122.817	3320.00	3174	8	9

* V is designated as vessel.

DATE	CO-ORDINATES		DEPTH m	VOLUME m ³	ACTIVITY		FORM OF DISPOSAL		
	Latitude	Longitude			TBq	Ci	Containers	Ships	Unpackaged
Area 2, Sedov Inlet (east coast of Novaya Zemlya)			13-33						
1982	74 ° 40'N	59 ° 55'E		?	3 700	100 00			
1982	74 ° 40'N	59 ° 55'E		2357 6	63 573	1718 20	298		91 4K-650 B bundles
1982	74 ° 42'N	69 ° 56'E		218 4	2 353	63 56	182		
1982	74 ° 41'N	59 ° 53'E		276 0	4 378	118 32	230		
1983	74 ° 40'N	59 ° 56'E		280 5	41 493	1121 44	231		
1984	74 ° 41'N	60 ° 17'E		136 5	6 394	172 80	108		
1984	74 ° 41'N	60 ° 17'E		3 0	0 222	6 00			6 filters
1984	74 ° 41'N	60 ° 17'E		10 5	1 943	52 50			7 pcs primary loop circulating pumps
1984	74 ° 41'N	60 ° 17'E		150 9	2 117	57 21	59		1 steam generator
		Total		3433 0	126 172	3410 00	1108		105

DATE	CO-ORDINATES		DEPTH	VOLUME	ACTIVITY		FORM OF DISPOSAL		
	Latitude	Longitude	m	m ³	TBq	Ci	Containers	Ships	Unpackaged
Area 3, Oga Fjord (east cost of Novaya Zemlya)			24						
1968	74 ° 07'N	59 ° 12'E		400.0	0.148	4.00		Barge SB-5	1 large object
1976	74 ° 35'N	59 ° 15'E		560.0	34.373	929.00			
1978	74 ° 17'N	58 ° 18'E		170.0	0.574	15.50			1 large object
1980	74 ° 35'N	59 ° 14'E		287.0	10.151	274.35			1 large object
1980	74 ° 35'N	59 ° 14'E		500.0	2.191	59.21	?		
1981	?	?		?	12.915	349.06	Containers, ?		1 large object
1983	74 ° 35'N	59 ° 13'E		540.0	7.597	205.32	212		
1983	74 ° 35'N	59 ° 13'E		580.0	7.052	190.60	260		
		Total		3028.0	75.000	2027.00	472+?	1	4

DATE	CO-ORDINATES		DEPTH m	VOLUME m ³	ACTIVITY		FORM OF DISPOSAL		
	Latitude	Longitude			TBq	Ci	Containers	Ships	Unpackaged
Area 4, Tsivolka Fjord (east coast of Novaya Zemlya)			56-135						
1964	74 ° 22'N	58 ° 41'E		640 0	36 163	977 37	1600	Lighter "N Bauman"	1 large object
1965	74 ° 22'N	58 ° 41'E		266 0	16 612	448 96			1 large object
1966	74 ° 22'N	58 ° 41'E		446 0	19 764	534 17			1 large object
1967	74 ° 22'N	58 ° 42'E		240 0	13 874	374 97			1 large object
1967	74 ° 22'N	58 ° 41'E		25 2	1 060	28 64			1 large object
1967	74 ° 23'N	58 ° 42'E		72 2	2 856	77 20			1 large object
1976	74 ° 22'N	58 ° 42'E		1233 0	0 444	12 00		Lighter "Kolezhma"	
1978	74 ° 22'N	58 ° 41'E		438 0	8 529	230 50	?		
		Total		3360 0	99 302	2684 00	1600+?	2	6

DATE	CO-ORDINATES		DEPTH	VOLUME	AVTIVITY		FORM OF DISPOSAL		
	Latitude	Longitude	m	m ³	TBq	Ci	Containers	Ships	Unpackaged
Area 5, Stepovoy Fjord (east coast of Novaya Zemlya)			25-27						
1968	72 ° 32'N	55 ° 33'E		185.2	6.837	184.78			1 large object from ice breaker Lenin
1970	72 ° 33'N	55 ° 29'E		243.0	13.727	371.00			1 large object
1972	72 ° 33'N	55 ° 26'E		242.0	7.844	212.00			1 large object
1973	72 ° 33'N	55 ° 23'E		532.0	12.034	325.24			1 large object
1975	72 ° 33'N	55 ° 24'E		445.0	6.919	187.00			1 large object
		Total		1647.0	47.361	1280.00			5

DATE	CO-ORDINATES		DEPTH	VOLUME	ACTIVITY		FORM OF DISPOSAL		
	Latitude	Longitude	m	m ³	TBq	Ci	Containers	Ships	Unpackaged
Area 6, Abrosimov Fjord (east coast of Novaya Zemlya)			12-20						
1966	71 ° 56'N	55 ° 19'E		?		?		Barge	
1967	71 ° 56'N	55 ° 21'E		?	0.010	0.28		Barge MNN 231500	
1967	71 ° 56'N	55 ° 21'E		?	1.110	30.00		Barge MSN-378250	1 large object
1974	71 ° 56'N	55 ° 21'E		520.0	8.473	229.00			
1977	71 ° 55'N	55 ° 22'E		254.0	14.319	387.00	8		
1980	71 ° 56'N	55 ° 21'E		750.0	0.370	10.00		Lighter L-8711	5 steam generators 1 large object
1981	71 ° 56'N	55 ° 21'E		392.0	0.185	5.00	?		
		Total		1917.0	24.467	661.00	8 + ?	4	7

DATE	CO-ORDINATES		DEPTH	VOLUME	ACTIVITY		FORM OF DISPOSAL		
	Latitude	Longitude	m	m ³	TBq	Ci	Containers	Ships	Unpackaged
Area 7, Blagopoluchiye Inlet (east coast of Novaya Zemlya)			13-16						
1972	75 ° 40'N	63 ° 39'E		331.0	8.689	234.84			1 large object from "Lenin"
		Total		331.0	8.689	235.00			1
Area 8, Techeniye Inlet (east coast of Novaya Zemlya)			Up to 50						
1982	76 ° 58'N	66 ° 20'E		91.2	1.086	29.34	76		
1982	76 ° 58'N	66 ° 20'E		84.0	0.148	4.00	70		
1988	73 ° 59'N	66 ° 18'E		229.0	67.015	1811.21		Lighter No. 4	
		Total		404.0	68.249	1845.00	146	1	
Outside Areas 1-8									
1978	69 ° 34'2"N 47 ° 56'5"E (20 miles to north-west of Kolguyev Island)			1100.0	1.480	40.00		Lighter "Nikel"	7 leads of reactor, 5 steam generators, 2 steam reductors, 1 steam tube
1991	Chernaya Bay (Novaya Zemalya)			-	11.100	300.00		1 LO (Ship)	
?	Barents Sea			-	> 3.7	> 100			Barge with solid RW in welded hold
		Total		1100.0	> 13.280	> 440.0			
		Grand total		31654	> 585.337	> 15902	6508	2	16
					≥ 585			18	153

Annex A.17
FORMER SOVIET UNION — OBJECTS WITH SPENT NUCLEAR FUEL
DUMPED IN THE ARCTIC SEAS

Disposal period: 1965–1981

Total number of disposal operations:

Total number of sites: 4

Total number of objects: 5 objects (6 reactors and special container with spent nuclear fuel)

Total weight: Not available

Total activity: 36.876 PBq (996.6 kCi)

(Revised information - Annex A.17-b.)

[86.9 PBq (2350 kCi) — initial information, Annex A.17-a]

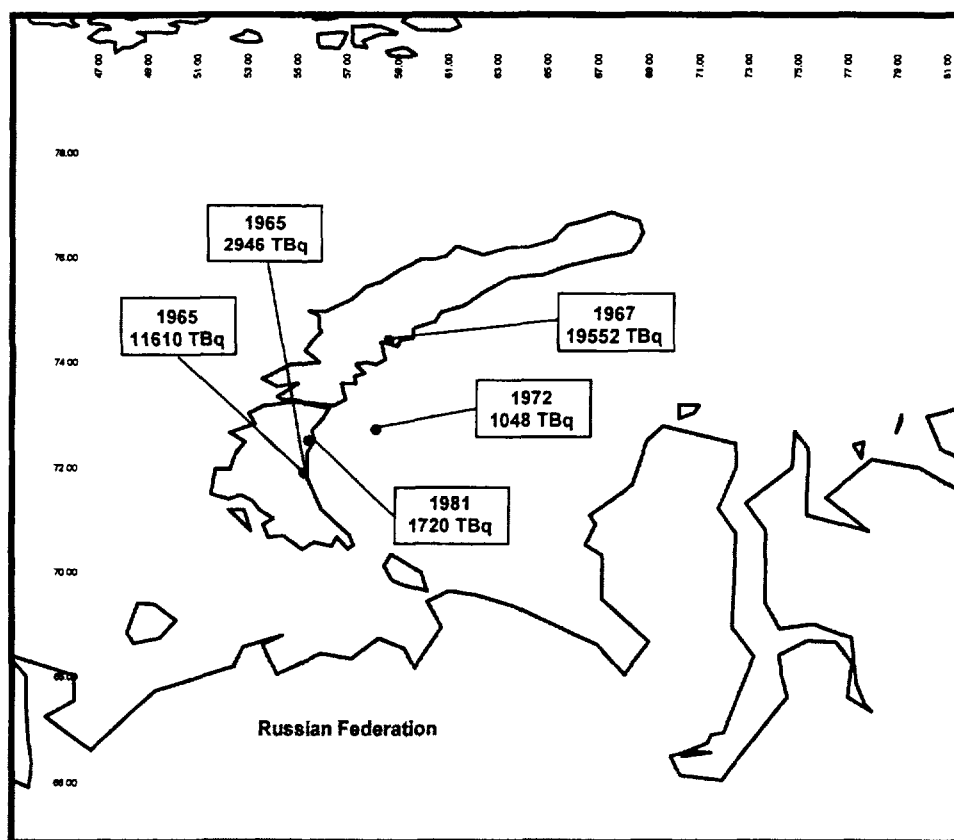


FIG. A.17. Geographical positions of the dump sites in the Arctic Seas, disposal periods and total activity disposed based on IAEA, IASAP study (1996).

Annex A.17-a
FORMER SOVIET UNION — OBJECTS WITH SPENT NUCLEAR FUEL
DUMPED IN THE ARCTIC SEAS¹: INITIAL INFORMATION

Object	Co-ordinates, ² year	Depth, metres	Total activity, (max.) PBq ³	Radionuclide content	Description of protective barriers
Compartment of NS Number 285 with 2 reactors (one reactor containing SNF)	71°56'2" N, 55°18'5" E, Abrosimov Fjord, 1965	20	29.6 (800 kCi)	Fission products	Reactor compartment and interior structures filled with furfurool mixture
Compartment of NS Number 901 (with 2 reactors containing SNF)	71°56'2" N, 55°18'9" E, Abrosimov Fjord, 1965	20	14.8 (400 kCi)	Fission products	Reactor compartment and interior structures filled with furfurool mixture
Shielding assembly of reactor from nuclear icebreaker <i>Lenin</i> with residual SNF (60% of original UO ₂ fuel charge)	74°22'1" N, 58°42'2" E, Tsivolka Fjord, 1967	49	5.5 (150 kCi)	¹³⁷ Cs (1.85 PBq), ⁹⁰ Sr (1.85 PBq), ²³⁸ Pu, ²⁴¹ Am, ²⁴⁴ Cm (0.07 PBq)	SNF residue bound by furfurool mixture, shielding assembly placed in reinforced concrete container and metal shell
Reactors of NS Number 421 (containing SNF)	72°40' N, 58°10' E, Novaya Zemlya Trough, 1972	300	29.6 (800 kCi)	Fission products	Metal container with lead shell dumped along with barge
NS Number 601 (with 2 reactors containing SNF)	72°31'15" N, 55°30'15" E, Stepovoy Fjord, 1981	50	7.4 (200 kCi)	Fission products	Reactor compartment and interior structures filled with furfurool mixture
Total: 5 objects with 7 reactors containing SNF	1965-1981		86.9 (2350 kCi)		

¹ Information from [Ref. 29] and 1993 White Book [Ref. 30]. For revised information see Annex A.17-b.

² These are the co-ordinates given in the official information provided by the Russian Federation (White Book) [30]. The joint Russian-Norwegian investigations in the dumping areas [52] showed that a number of the co-ordinates of dumped objects cited in the "White Book" are inaccurate. Thus in Abrosimov Fjord, two reactor compartments were discovered at point 71°56'44"N 55°18'81"E; one reactor compartment at point 71°56'50"N 55°18'71"E; a submarine in Stepovoy Fjord was found at 72°31'33"N 55°33'50"E. Work on establishing which nuclear submarines (factory numbers) these reactor compartments belong to is yet to be completed.

³ Expert estimates were made at the time of dumping, based on power generated by NS reactors (12.5 GW. day).

NS = nuclear submarine.

SNF = spent nuclear fuel.

Annex A.17-b
FORMER SOVIET UNION — OBJECTS WITH SPENT NUCLEAR FUEL
DUMPED IN THE ARCTIC SEAS: REVISED INFORMATION DEVELOPED IN
1996 BY THE IAEA, IASAP STUDY

Object	Co-ordinates ¹ and year	Depth, metres	Total activity, PBq	Radionuclide content	Reference ²
Compartment of NS Number 285 with 2 reactors, (one reactor containing SNF)	71°56'2" N, 55°18'5" E, Abrosimov Fjord, 1965	20	11.610 (313.8 kCi)	Fission products, activation products and actinides	Table 9, IASAP-5
Compartment of NS Number 901 (with 2 reactors containing SNF)	71°56'2" N, 55°18'9" E, Abrosimov Fjord, 1965	20	2.946 (79.6 kCi)	Fission products, activation products and actinides	Table 18, IASAP-5
Shielding assembly of reactor from nuclear icebreaker <i>Lenin</i> with residual SNF (60% of original UO ₂ fuel charge)	74°22'1" N, 58°42'2" E, Tsvolka Fjord, 1967	49	19.552 (528.4 kCi)	Fission products, activation products and actinides	Table 4, IASAP-1
Reactors of NS Number 421 (containing SNF)	72°40' N, 58°10' E, Novaya Zemlya Trough, 1972	300	1.048 (28.3 kCi)	Fission products, activation products and actinides	Table 12, IASAP-5
NS Number 601 (with 2 reactors containing SNF)	72°31'15" N, 55°30'15" E, Stepovoy Fjord, 1981	50	1.720 (46.5 kCi)	Fission products, activation products and actinides	Table 13, IASAP-6
Total: 5 objects (6 reactors and special container with SNF)	1965-1981		36.876 (996.6 kCi)		

¹ These are the co-ordinates given in the official information provided by the Russian Federation (White Book) [30]. The joint Russian-Norwegian investigations in the dumping areas [52] showed that a number of the co-ordinates of dumped objects cited in the "White Book" are inaccurate. Thus in Abrosimov Fjord, two reactor compartments were discovered at point 71°56'44"N 55°18'81"E; one reactor compartment at point 71°56'50"N 55°18'71"E; a submarine in Stepovoy Fjord was found at 72°31'33"N 55°33'50"E. Work on establishing which nuclear submarines (factory numbers) these reactor compartments belong to is yet to be completed.

² Reference [57] and IAEA-IASAP-1, 5 and 6. Working material of the International Arctic Seas Assessment Project (IASAP).

NS = nuclear submarine.

SNF = spent nuclear fuel.

Annex A.18
FORMER SOVIET UNION — OBJECTS WITHOUT SPENT NUCLEAR FUEL
DUMPED IN THE ARCTIC SEAS

Disposal period: 1965–1988

Total number of disposal operations:

Total number of sites: 5

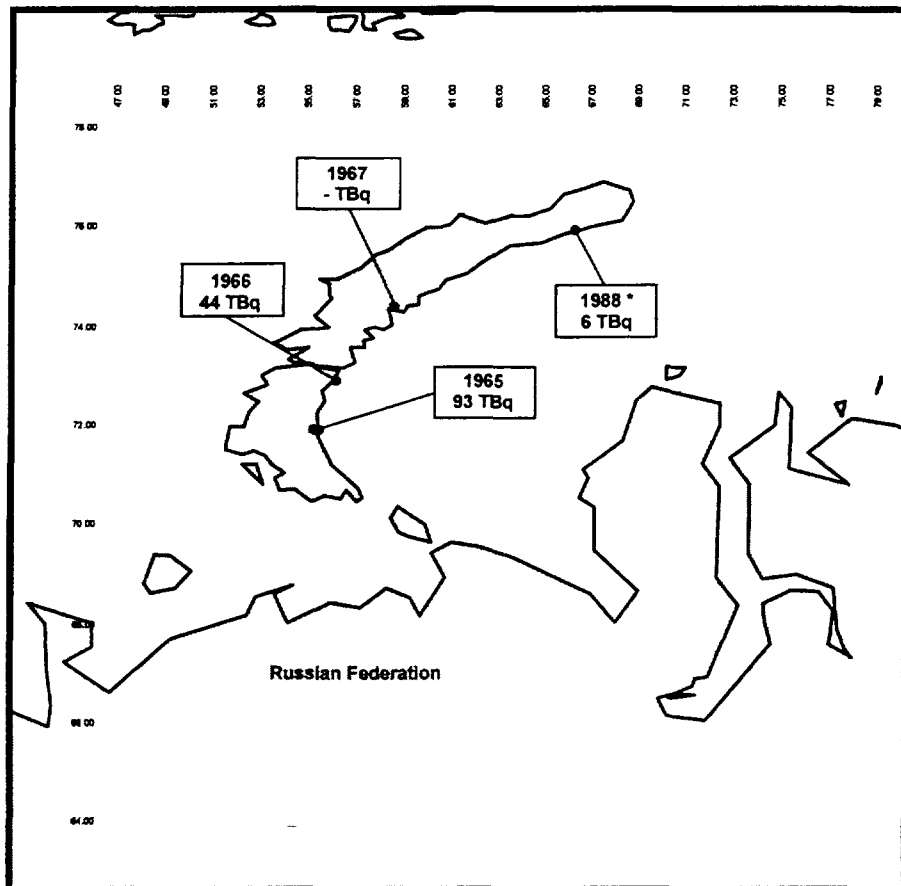
Total number of objects: 5 objects with 10 reactors without spent nuclear fuel

Total weight: Not available

Total activity: 0.143 PBq (3.9 kCi)

(Revised information — Annex A.18-b)

[3.7 PBq (100 kCi) - initial information, Annex A.18-a]



* Co-ordinates cited in the "White Book" are not correct. Approximate location of the dump site Techeniye Fjord is as shown here.

FIG. A.18. Geographical positions of the dump sites in the Arctic Seas, disposal periods and total activity disposed based on IAEA, IASAP study (1996).

Annex A.18-a
FORMER SOVIET UNION — OBJECTS WITHOUT SPENT NUCLEAR FUEL
DUMPED IN THE ARCTIC SEAS¹: INITIAL INFORMATION

Object	Co-ordinates ² year	Depth, metres	Total activity PBq ³	Radionuclide content	Description of protective barriers
Reactor compartment of NS Number 285 with 2 reactors (one reactor without SNF)	71°56'2" N, 55°18'5" E, Abrosimov Fjord, 1965	20	Requires special analysis	Unclear	Reactor compartment structures
Reactor compartment of NS Number 254 (with 2 reactors without SNF)	71°55'13" N, 55°32'32" E, Abrosimov Fjord, 1965	20	Requires special analysis	Unclear	Reactor compartment structures
Reactor compartment of NS Number 260 (with 2 reactors without SNF)	72°56'2" N, 55°18'5" E, Abrosimov Fjord, 1966	20	Requires special analysis	Unclear	Reactor compartment structures
Steam generating installation of icebreaker <i>Lenin</i> (comprising 3 reactors without SNF and with primary loop pipelines and water tight stock equipment)	74°26'4" N, 58°37'3" E, Tsivolka Fjord, 1967	50	~ 1.9 (50 kCi)	Mainly ⁶⁰ Co	Biological shielding unit (B-300 steel + concrete)
Reactor compartment of NS Number 538 (with 2 reactors without SNF)	73°59' N, 66°18' E, Techeniye Fjord, 1988	35-40	Requires special analysis	Unclear	Metal container with lead shell
Total: 5 objects with 10 reactors without SNF	1965-1988		Requires special analysis (possibly up to 3.7 PBq (100 kCi) at time of dumping)		

¹ Information from 1993 White Book [30]. For revised information see Annex A.18-b.

² These are the co-ordinates given in the official information provided by the Russian Federation (White Book) [30]. The joint Russian-Norwegian investigations in the dumping areas [52] showed that a number of the co-ordinates of dumped objects cited in the "White Book" are inaccurate. Thus in Abrosimov Fjord, two reactor compartments were discovered at point 71°56'44"N 55°18'81"E; one reactor compartment at point 71°56'50"N 55°18'71"E; a submarine in Stepovoy Fjord was found at 72°31'33"N 55°33'50"E. Work on establishing which nuclear submarines (factory numbers) these reactor compartments belong to is yet to be completed. It is obvious that the coordinate of Techeniye Fjord are wrong in "White Book". Approximate co-ordinates of the dump site Techeniye Fjord are 75°59' N, 66°18' E.

³ Expert estimates were made at the time of sinking, based on power generated by NS reactors (12.5 GW. day).

NS = nuclear submarine.

SNF = spent nuclear fuel.

Annex A.18-b
FORMER SOVIET UNION — OBJECTS WITHOUT SPENT NUCLEAR FUEL
DUMPED IN THE ARCTIC SEAS: REVISED INFORMATION DEVELOPED IN
1996 BY THE IAEA, IASAP STUDY

Object	Co-ordinates ¹ and year	Depth, metres	Total activity, PBq	Radionuclide content	Reference ²
Reactor compartment of NS Number 285 with 2 reactors (one reactor without SNF)	71°56'2" N, 55°18'5" E, Abrosimov Fjord, 1965	20			
Reactor compartment of NS Number 254 (with 2 reactors without SNF)	71°55'13" N, 55°32'32" E, Abrosimov Fjord, 1965	20	0 093 (2 5 kCi)	Activation Products	Table 3, IASAP-5
Reactor compartment of NS Number 260 (with 2 reactors without SNF)	72°56'2" N, 55°18'5" E, Abrosimov Fjord, 1966	20	0 044 (1 2 kCi)	Activation Products	Table 6, IASAP-5
Steam generating installation OK-150 of icebreaker <i>Lenin</i> (comprising 3 reactors without SNF and with primary loop pipelines and water tight stock equipment)	74°26'4" N, 58°37'3" E, Tsvolka Fjord, 1967	50			
Reactor compartment of NS Number 538 (with two reactors without SNF)	73°59' N, 66°18' E, Techeniye Fjord, 1988	35-40	0 006 (0 2 kCi)	Activation Products	Table 15, IASAP-5
Total 5 objects with 10 reactors without SNF	1965-1988		0 143 (3 9 kCi)		

¹ These are the co-ordinates given in the official information provided by the Russian Federation (White Book) [30]. The joint Russian-Norwegian investigations in the dumping areas [52] showed that a number of the co-ordinates of dumped objects cited in the "White Book" are inaccurate. Thus in Abrosimov Fjord, two reactor compartments were discovered at point 71°56'44"N 55°18'81"E, one reactor compartment at point 71°56'50"N 55°18'71"E, a submarine in Stepovoy Fjord was found at 72°31'33"N 55°33'50"E. Work on establishing which nuclear submarines (factory numbers) these reactor compartments belong to is yet to be completed. Approximate co-ordinates of the dump site Techeniye Fjord are 75°59' N, 66°18' E.

² Reference [57] - and IAEA-IASAP-5 Working material of the International Arctic Seas Assessment Project (IASAP).

NS = nuclear submarine

SNF = spent nuclear fuel

ANNEX A.19
FORMER SOVIET UNION — DISPOSAL OF LIQUID WASTE IN THE PACIFIC

Disposal period: 1966–1992
Total number of disposal operations: 61+
Total number of sites: 9
Total volume of liquid radioactive waste dumped: 123497 cubic metre
Total activity: 456 TBq (12.337 kCi)
Information provided to IAEA on: 21 May 1993

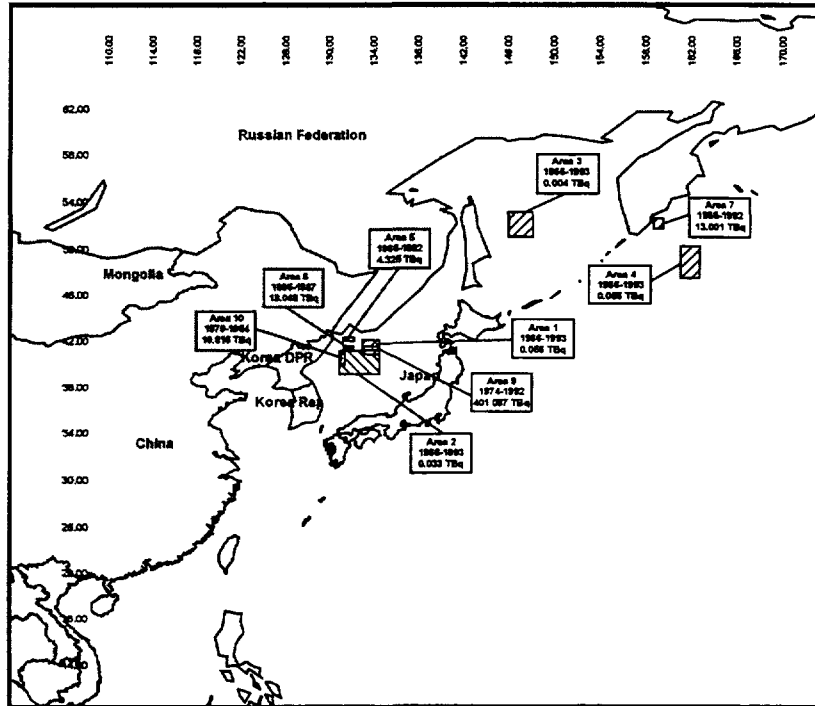


FIG. A.19. Geographical positions of the dump sites in the Pacific, disposal periods and total activity disposed.

SUMMARY

AREA	CO-ORDINATES		DEPTH	ACTIVITY		GEOGRAPHICAL LOCATION
	Latitude	Longitude	m	TBq	Ci	
1	42 ° 0'N	133 ° 10'E	3250-3700	0.056	1.50	Sea of Japan
	42 ° 0'N	134 ° 30'E				
	41 ° 0'N	133 ° 10'E				
	41 ° 0'N	134 ° 30'E				
2	41 ° 10'N	131 ° 10'E	2900-3300	0.033	0.90	Sea of Japan
	41 ° 10'N	134 ° 30'E				
	39 ° 30'N	131 ° 10'E				
	39 ° 30'N	134 ° 30'E				
3	53 ° 0'N	148 ° 10'E	?	0.004	0.10	Pacific Ocean (east coast of Kamchatka)
	53 ° 0'N	146 ° 40'E				
	51 ° 20'N	148 ° 10'E				
	51 ° 20'N	146 ° 40'E				
4	50 ° 0'N	162 ° 45'E	?	0.007	0.20	Pacific Ocean (east coast of Kamchatka)
	50 ° 0'N	161 ° 35'E				
	48 ° 0'N	162 ° 40'E				
	48 ° 0'N	161 ° 35'E				
5	42 ° 26'N	131 ° 37'E	1100-1500	4.325	116.86	Sea of Japan
	42 ° 26'N	132 ° 20'E				
	42 ° 17'N	131 ° 37'E				
	42 ° 17'N	132 ° 20'E				

AREA	CO-ORDINATES		DEPTH	ACTIVITY		GEOGRAPHICAL LOCATION
	Latitude	Longitude	m	TBq	Ci	
6	41 ° 55'N	131 ° 47'E	1900-3300	18.084	489.00	Sea of Japan
	41 ° 55'N	132 ° 13'E				
	41 ° 45'N	131 ° 47'E				
	41 ° 45'N	132 ° 13'E				
7	52 ° 28'N	159 ° 02'E	1400-1500	13.001	352.00	Pacific Ocean (east coast of Kamchatka)
	52 ° 28'N	159 ° 12'E				
	52 ° 40'N	159 ° 02'E				
	52 ° 40'N	159 ° 12'E				
9	41 ° 36'N	133 ° 22'E	3250-3700	401.087	10840.00	Sea of Japan
	41 ° 36'N	134 ° 42'E				
	41 ° 46'N	133 ° 22'E				
	41 ° 46'N	134 ° 42'E				
10	40 ° 10'N	131 ° 15'E	2900-3300	19.816	536.00	Sea of Japan
	41 ° 10'N	131 ° 15'E				
	40 ° 10'N	131 ° 35'E				
	41 ° 10'N	131 ° 35'E				
			Total	456.413	12336.56	
				≅ 456	≅ 12337	

DATE	CO-ORDINATES		DEPTH	VOLUME	ACTIVITY	
	Latitude	Longitude	m	m ³	TBq	Ci
*	Area 1		3250-3700	16250.00	0.056	1.500
	42 ° 0'N	133 ° 10'E				
	42 ° 0'N	134 ° 30'E				
	41 ° 0'N	133 ° 10'E				
	41 ° 0'N	134 ° 30'E				
*	Area 2		2900-3300	3156.00	0.033	0.900
	41 ° 10'N	133 ° 10'E				
	41 ° 10'N	134 ° 30'E				
	39 ° 30'N	133 ° 10'E				
	39 ° 30'N	134 ° 30'E				
*	Area 3		?	1513.00	0.004	0.100
	53 ° 0'N	148 ° 10'E				
	53 ° 0'N	146 ° 40'E				
	51 ° 20'N	148 ° 10'E				
	51 ° 20'N	146 ° 40'E				

DATE	CO-ORDINATES		DEPTH	VOLUME	ACTIVITY	
	Latitude	Longitude	m	m ³	TBq	Ci
	Area 4		?			
*	48 ° 0'N	161 ° 35'E		4803.00	0.007	0.200
	50 ° 0'N	162 ° 40'E				
	Area 5		1100-1500			
1966	42 ° 26'N	131 ° 37'E		?	0.005	0.123
	42 ° 26'N	132 ° 20'E				
1967	42 ° 17'N	131 ° 37'E		?	0.006	0.160
	42 ° 17'N	132 ° 20'E				
1968				?	0.115	3.109
1969				?	0.033	0.892
1970				?	0.067	1.800
1971				?	0.057	1.500
1972				?	1.197	32.353
1973				2930.00	0.867	23.400
1974				900.00	1.036	28.000
1986				33.00	0.006	0.150
1986				223.00	–	0.007
1988				1808.00	0.692	18.700
1990				133.00	–	0.070
1991				900.00	0.196	5.300
1992				906.00	0.048	1.300
			Total	7836.00	4.325	116.895

* For areas 1-4, year by year breakdown not available.

DATE	CO-ORDINATES		DEPTH	VOLUME m ³	ACTIVITY	
	Latitude	Longitude	m		TBq	Ci
	Area 6		1900-3300			
1986	41 ø 55'N	131 ø 47'E		824.00	11.772	318.152
	41 ø 55'N	132 ø 13'E				
1987	41 ø 45'N	131 ø 47'E		872.00	2.072	56.000
	41 ø 45'N	132 ø 13'E				
1987				904.00	1.765	47.700
1987				664.00	1.865	50.400
1987				904.00	0.514	13.900
1987				904.00	0.096	2.600
			Total	5072.00	18.084	489.000
	Area 7		1400-1500			
1966	52 ø 58'N	159 ø 02'E		800.00	0.004	0.098
	52 ø 58'N	159 ø 12'E				
1967	52 ø 40'N	159 ø 02'E		900.00	0.001	0.022
	52 ø 40'N	159 ø 12'E				
1968				900.00	0.002	0.052
1969				1200.00	0.008	0.205
1970				?	0.009	0.240
1971				?	0.044	1.180
1972				2100.00	0.006	0.172
1973				3700.00	0.189	5.098
1974				?	0.002	0.050

DATE	CO-ORDINATES		DEPTH	VOLUME	ACTIVITY	
	Latitude	Longitude	m	m ³	TBq	Ci
	Area 7 (contd.)					
1975				856.00	-	0.009
1977				1517.00	0.035	0.950
1978				2334.00	0.196	5.290
1980				2335.00	0.011	0.290
1981				3530.00	0.103	2.797
1982				2960.00	5.546	149.880
1983				1730.00	1.056	28.542
1984				526.00	0.708	19.140
1985				305.00	0.474	12.810
1986				2550.00	0.979	26.446
1987				780.00	1.180	31.902
1988				1230.00	1.587	42.900
1989				1660.00	0.402	10.860
1990				890.00	0.048	1.300
1991				580.00	0.369	9.980
1992				906.00	0.048	1.300
				Total		
				34289.00	13.001	352.000
				+?		

DATE	CO-ORDINATES		DEPTH	VOLUME m ³	ACTIVITY	
	Latitude	Longitude	m		TBq	Ci
	Area 9		3250-3700			
1974	41 ø 36'N	133 ø 22'E		2835.00	0.822	22.212
	41 ø 36'N	134 ø 42'E				
1975	41 ø 46'N	133 ø 22'E		2028.00	0.128	3.450
	41 ø 46'N	134 ø 42'E				
1976				3630.00	0.483	13.057
1977				2210.00	0.014	0.376
1978				4124.00	0.739	19.966
1984				1500.00	0.121	3.270
1985				2997.50	7.048	190.490
1986				3698.74	379.264	10250.370
1987				2710.00	8.044	217.400
1988				720.00	0.387	10.450
1989				1807.00	3.289	88.900
1990				902.00	0.312	8.440
1991				2034.00	0.155	4.178
1992				1774.00	0.281	7.600
			Total	32970.00	401.087	10840.000

DATE	CO-ORDINATES		DEPTH	VOLUME	ACTIVITY	
	Latitude	Longitude	m	m ³	TBq	Ci
	Area 10		2900-3300			
1979	40 ø 10'N 41 ø 10'N	131 ø 15'E 131 ø 15'E		3140.0	15.208	411.037
1980	40 ø 10'N 41 ø 10'N	131' ø 35'E 131 ø 35'E		3545.0	1.926	52.051
1981				929.0	0.148	3.998
1982				2840.0	0.502	13.570
1983				3553.6	0.754	20.387
1984				3600.0	1.278	34.550
			Total	17608.0	19.816	536.000
			Grand total Areas (1-10)	123497.0	456.413	12336.564
					≅ 456	≅ 12337

ANNEX A.20
FORMER SOVIET UNION — DISPOSAL OF SOLID
RADIOACTIVE WASTE IN THE PACIFIC

Disposal period: 1968–1992
Total number of disposal operations: 152
Total number of sites: 4
Total number of containers dumped: 6642
Total number of vessels dumped: 39
Total number of unpackaged big size objects dumped: 100+
Total volume of solid radioactive waste dumped: 21 880 cubic metres
Total activity: 418 TBq (11.297 kCi)
Type of container: Metallic box with/without matrix
Information provided to IAEA on: 21 May 1993

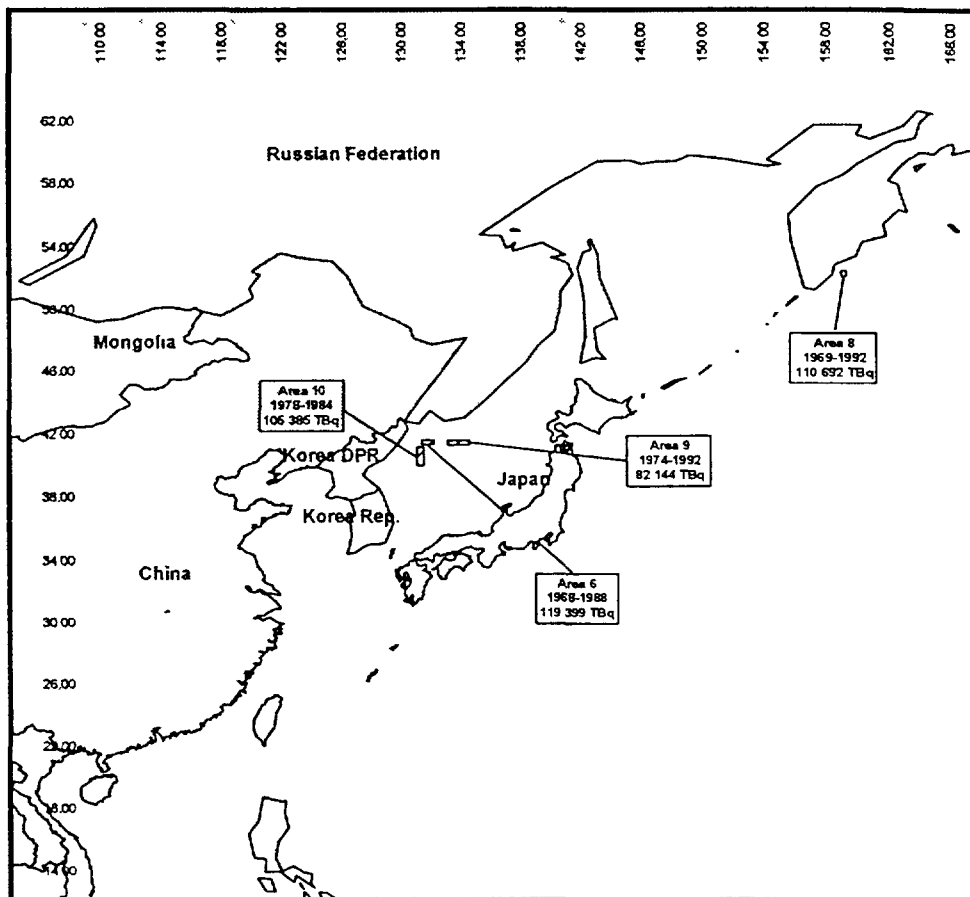


FIG. A.20. Geographical positions of the dump sites in the Pacific, disposal periods and total activity disposed.

SUMMARY

AREA	CO-ORDINATES		DEPTH m	ACTIVITY		GEOGRAPHICAL LOCATION
	Latitude	Longitude		TBq	Ci	
6	41 ° 55'N	131 ° 47'E	1900–3300	119.399	3227.00	Sea of Japan
	41 ° 55'N	132 ° 13'E				
	41 ° 45'N	131 ° 47'E				
	41 ° 45'N	132 ° 13'E				
8	52 ° 28'N	159 ° 06'E	2000–2570	110.692	2991.65	Pacific Ocean (east coast of Kamchatka)
	52 ° 28'N	159 ° 11'E				
	52 ° 34'N	159 ° 02'E				
	52 ° 34'N	159 ° 11'E				
9	41 ° 36'N	133 ° 22'E	3250–3700	82.144	2230.00	Sea of Japan
	41 ° 36'N	134 ° 42'E				
	41 ° 46'N	133 ° 22'E				
	41 ° 46'N	134 ° 42'E				
10	40 ° 10'N	131 ° 15'E	2900–3300	105.385	2848.00	Sea of Japan
	41 ° 10'N	131 ° 15'E				
	40 ° 10'N	131 ° 35'E				
	41 ° 10'N	131 ° 35'E				
			Total	417.62	11296.65	
				≅ 418	≅ 11297	

DATE	CO-ORDINATES		DEPTH	VOLUME m ³	ACTIVITY		FORM OF DISPOSAL		
	Latitude	Longitude	m		ΓBq	Ci	Containers	Ships	Unpackaged
	Area 6		1900-3300						
1968	No data			136 0	0 777	21 00	136		
1969	No data			1145 0	7 733	209 00	1145		
1970	No data			693 0	0 814	22 00	693		
1971	41 ° 55'N	131 ° 47'E	2000		43 309 43 941	1170 50 1187 60			{ NS No 143 RB and { NS No 143 LB Nuclear Submarine reactors without SNF *
1971	No data			481 0	4 107	111 00	481		
1973	No data			241 0	4 514	122 00	241		
1973	No data			550 0	2 146	58 00		m/v "Lity"	
1973	No data			70 0	0 111	3 00		Floating crane	
1986	41 ° 50'N	131 ° 30'E		59 0	2 664	72 00	52		
1986	41 ° 50'N	131 ° 30'E		40 0	0 148	4 00	40		
1986	41 ° 50'N	132 ° 0'E		371 0	0 407	11 00		Fishing vessel "Indra"	
1986	41 ° 51'N	132 ° 0'E		180 0	4 255	115 00		f/v "Kapitan Aron"	
1987	41 ° 50'N	132 ° 0'E		21 0	1 591	43 00			Part of a crane

* Ref [32] Svintsev, Y, and Kiknadze, O, "Inventory of Radionuclides in the Ship Nuclear Reactors Dumped in the Sea of Japan", Proceedings of Part 2 of an International Symposium on Radionuclides in the Oceans (RADOc 96-97), April 7-11, 1997, Norwich (1998)

DATE	CO-ORDINATES		DEPTH	VOLUME	ACTIVITY		FORM OF DISPOSAL		
	Latitude	Longitude	m	m ³	TBq	Ci	Containers	Ships	Unpackaged
	Area 6 (contd.)								
1987	41 ° 50'N	132 ° 0'E		200.0	0.629	17 00		Barge	
1987	41 ° 50'N	132 ° 0'E		95.0	0.518	14.00	44		
1987	41 ° 50'N	132 ° 0'E		16.0	0.037	1 00			Metal
1987	41 ° 50'N	132 ° 0'E		37.0	1 258	34.00	37		
1987	41 ° 50'N	132 ° 0'E		48.0	0.185	5 00	32		
1988	41 ° 50'N	132 ° 0'E		26.0	0.255	6.90	14		
				4409.0	119 399	3227.00	2915	6	4
	Area 8		2000-2570						
1969	No data			61 0	4 921	133 00	61		
1970	No data			20 0	0 518	14 00	20		
1970	52 ° 28'N	159 ° 6'E		16 0	0 518	14 00	16		
1970	52 ° 28'N	159 ° 11'E		4 0	0 222	6 00	4		
1970	52 ° 34'N	159 ° 2'E		4 0	0.189	5 10	4		
1970	52 ° 34'N	159 ° 11'E		16 0	0.592	16 00	18		

DATE	CO-ORDINATES		DEPTH	VOLUME	ACTIVITY		FORM OF DISPOSAL		
	Latitude	Longitude	m	m ³	TBq	Ci	Containers	Ships	Unpackaged
	Area 8 (contd.)								
1970	No data			16.0	2.331	63.00	16		
1971	No data			20.0	0.333	9.00	20		
1971	No data			5.0	2.590	70.00	5		
1972	No data			300.0	0.141	3.80		m/v "Sungay"	
1972	No data			14.0	0.118	3.20	14		
1973	No data			60.0	0.962	26.00	60		
1974	No data			56.0	0.178	4.80	56		
1975	No data			64.0	1.739	47.00	64		
1976	No data			27.0	0.629	17.00	27		
1977	No data			25.0	1.517	41.00	25		
1978	No data			50.0	1.332	36.00	50		
1980	54 ° 34'N	159 ° 2'E		94.0	0.999	27.00	94		
1981	52 ° 28'N	159 ° 11'E		48.0	0.999	27.00	48		
1982	54 ° 34'N	159 ° 11'E		95.0	8.954	242.00	95		
1983	52 ° 28'N	159 ° 2'E		60.0	1.628	44.00	60		
1985	52 ° 30'N	159 ° 4'E		82.0	56.869	1537.00	51		
1986	52 ° 31'N	159 ° 9'E		47.0	0.407	11.00	41		

DATE	CO-ORDINATES		DEPTH	VOLUME	ACTIVITY		FORM OF DISPOSAL		
	Latitude	Longitude	m	m ³	TBq	Ci	Containers	Ships	Unpackaged
	Area 8 (contd.)								
1986	52 ° 30'N	159 ° 8'E		15.0	0.296	8.00	15		
1986	52 ° 31'N	159 ° 8'E		8.0	1.443	39.00			50 pumps
1986	52 ° 31'N	159 ° 8'E		105.0	1.665	45.00	105		
1987	52 ° 31'N	159 ° 8'E		50.0	1.517	41.00	50		
1987	52 ° 32'N	159 ° 8'E		51.0	1.480	40.00	50		
1988	52 ° 30'N	159 ° 8'E		2.7	0.296	8.00			1 pump
1988	52 ° 30'N	159 ° 9'E		70.0	2.183	59.00			10 steam generators
1988	52 ° 30'N	159 ° 9'E		97.0	1.369	37.00	97		
1989	52 ° 30'N	159 ° 9'E		46.0	0.481	13.00	46		
1989	52 ° 30'N	159 ° 9'E		7.0	2.590	70.00			1 protective screen
1989	52 ° 30'N	159 ° 9'E		3.7	0.031	0.85			1 pump
1989	52 ° 30'N	159 ° 9'E		30.0	0.629	17.00	30		
1989	52 ° 30'N	159 ° 9'E		14.0	0.130	3.50			Gas bags
1989	52 ° 30'N	159 ° 9'E		56.0	0.311	8.40	56		

DATE	CO-ORDINATES		DEPTH	VOLUME	ACTIVITY		FORM OF DISPOSAL		
	Latitude	Longitude	m	m ³	TBq	Ci	Containers	Ships	Unpackaged
	Area 8 (contd.)								
1990	52 ° 30'N	159 ° 9'E		72.0	0.481	13.00	72		
1990	52 ° 30'N	159 ° 9'E		600.0	5.106	138.00		Barge	
1990	52 ° 30'N	159 ° 9'E		55.0	1.073	29.00	50		
1991	52 ° 30'N	159 ° 9'E		41.0	0.481	13.00	41		
1992	52 ° 30'N	159 ° 9'E		46.0	0.444	12.00	41		
				2553.0	110.692	2991.65	1502	2	62+

DATE	CO-ORDINATES		DEPTH	VOLUME	ACTIVITY		FORM OF DISPOSAL		
	Latitude	Longitude	m	m ³	ΓBq	Ci	Containers	Ships	Unpackaged
	Area 9		3250-3700						
1974	41 ° 40'N	133 ° 30'E		14	0 222	6 0	14		
1974	41 ° 45'N	134 ° 41'E		32	0 629	17 0	32		
1974	41 ° 44'N	134 ° 2'E		28	0 074	2 0	28		
1974	41 ° 36'N	133 ° 22'E		132	1 221	33 0		Seiner No 100	
1975	41 ° 41'N	133 ° 40'E		40	1 332	36 0	40		
1975	41 ° 40'N	134 ° 1'E		4	0 814	22 0	4		
1975	41 ° 40'N	134 ° 1'E		40	10 952	296 0	40		
1975	41 ° 39'N	134 ° 10'E		18	1 036	28 0	18		
1975	41 ° 40'N	133 ° 30'E		22	0 311	8 4	22		
1975	41 ° 40'N	133 ° 30'E		20	0 962	26 0	20		
1975	41 ° 36'N	132 ° 22'E		130	0 592	16 0		Seiner No 5	
1975	41 ° 36'N	132 ° 22'E		63	0 148	4 0	63		
1975	41 ° 36'N	132 ° 22'E		230	0 740	20 0		Seiner No 6	
1975	41 ° 36'N	132 ° 22'E		204	0 703	19 0		Seiner No 4	
1975	41 ° 41'N	134 ° 41'E		196	0 962	26 0		Seiner No 2	
1975	41 ° 41'N	134 ° 41'E		154	0 592	16 0		Seiner No 3	
1975	41 ° 41'N	134 ° 41'E		36	0 133	3 6	36		

DATE	CO-ORDINATES		DEPTH	VOLUME	ACTIVITY		FORM OF DISPOSAL		
	Latitude	Longitude	m	m ³	TBq	Ci	Containers	Ships	Unpackaged
	Area 9 (contd.)								
1976	41 ° 41'N	133 ° 30'E		40.0	0.592	16.00	40		
1977	41 ° 42'N	133 ° 30'E		46.0	6.068	164.00	46		
1977	41 ° 41'N	133 ° 22'E		62.0	0.111	3.00	38		
1977	41 ° 37'N	133 ° 42'E		174.0	0.222	6.00		Seiner	
1977	41 ° 37'N	133 ° 42'E		160.0	0.222	6.00		Seiner	
1978	41 ° 40'N	133 ° 40'E		29.0	0.407	11.00	29		
1978	41 ° 40'N	133 ° 40'E		13.0	0.666	18.00	13		
1978	41 ° 40'N	133 ° 40'E		23.0	0.126	3.40	23		
1978	41 ° 43'N	133 ° 35'E		28.0	0.091	2.50	28		
1978	41 ° 41'N	133 ° 31'E		39.0	2.516	68.00	39		
1978	41 ° 40'N	133 ° 31'E		36.0	0.278	7.50	36		
1978	41 ° 38'N	133 ° 41'E		33.0	0.185	5.00	33		
1978	41 ° 37'N	133 ° 42'E		235.0	0.555	15.00		Seiner	
1978	41 ° 37'N	133 ° 42'E		178.0	0.407	11.00		Seiner	
1978	41 ° 44'N	133 ° 26'E		29.0	0.074	2.00	27		
1978	41 ° 44'N	133 ° 26'E		321.0	0.185	5.00	321		

DATE	CO-ORDINATES		DEPTH	VOLUME	ACTIVITY		FORM OF DISPOSAL		
	Latitude	Longitude	m	m ³	TBq	Ci	Containers	Ships	Unpackaged
	Area 9 (contd.)								
1984	41 ° 41'N	134 ° 2'E		34 0	8 732	236 00	34		
1984	41 ° 39'N	133 ° 30'E		29 0	0 315	8 50	29		
1985	41 ° 38'N	133 ° 30'E		36 0	0 307	8 30	31		
1985	41 ° 39'N	133 ° 30'E		60 0	0 359	9 70	60		
1985	41 ° 40'N	133 ° 23'E		201 0	0 518	14 00		m/v Ungur	
1985	41 ° 37'N	134 ° 0'E		80 0	0 796	21 50	80		
1985	41 ° 41'N	134 ° 1'E		50 0	3 330	90 00	50		
1985	41 ° 38'N	133 ° 25'E		58 0	0 122	3 30	58		
1986	41 ° 40'N	134 ° 10'E		38 0	2 590	70 00	37		
1986	41 ° 40'N	134 ° 18'E		31 0	0 555	15 00	31		
1986	41 ° 46'N	134 ° 10'E		20 0	0 185	5 00	18		
1987	41 ° 40'N	134 ° 20'E		31 0	0 962	26 00	34		
1987	41 ° 46'N	134 ° 30'E		41 0	3 145	85 00	28		
1987	41 ° 36'N	133 ° 22'E		474 0	0 499	13 50		Seiner	
1987	41 ° 36'N	134 ° 30'E		42 0	0 296	8 00	28	Seiner	
1988	41 ° 36'N	134 ° 30'E		208 0	0 296	8 00			
1988	41 ° 46'N	134 ° 30'E		50 0		10	34		

DATE	CO-ORDINATES		DEPTH m	VOLUME m ³	ACTIVITY		FORM OF DISPOSAL		
	Latitude	Longitude			TBq	Ci	Containers	Ships	Unpackaged
	Area 9 (contd.)								
1988	41 ° 40'N	134 ° 30'E		1665.0	0.629	17.00		Tanker-4	
1988	41 ° 40'N	134 ° 18'E		362.0	1.332	36.00		f/v-8	
1988	41 ° 42'N	134 ° 30'E		56.0	2.294	62.00	56		
1988	41 ° 40'N	134 ° 18'E		110.0	0.303	8.20		f/v-427	
1989	41 ° 40'N	134 ° 0'E		35.0	0.518	14.00	35		
1989	41 ° 40'N	134 ° 0'E		360.0	13.801	373.00		Barge	
1990	41 ° 40'N	134 ° 0'E		114.0	3.811	103.00		Seiner Taezhny	
1991	41 ° 40'N	134 ° 0'E		18.0	0.052	1.40	14		
1991	41 ° 40'N	134 ° 0'E		15.0	0.241	6.50			5 steam generators
1991	41 ° 40'N	134 ° 0'E							21 pumps
1991	41 ° 40'N	133 ° 30'E		124.0	1.461	39.50		f/s Otvazhny	
1992	41 ° 40'N	133 ° 30'E		2640.0	0.537	14.50		Tanker-11	
1992	41 ° 40'N	133 ° 30'E		55.0	0.029	0.80	41		
		Total		9846.0	82.144	2230.00	1689	20	26

DATE	CO-ORDINATES		DEPTH	VOLUME	ACTIVITY		FORM OF DISPOSAL		
	Latitude	Longitude	m	m ³	TBq	Ci	Containers	Ships	Unpackaged
	Area 10		2900-3300						
1978	40 ° 10'N	131 ° 15'E		31	1.702	46			Submarine reactor tank (2 pcs.)
1979	40 ° 10'N	131 ° 15'E	3000		37.622 41.100	1016.8 1110.8			{ NS No. 172 RB and { NS No. 172 LB Nuclear submarine reactors without SNF *
1979	41 ° 30'N	131 ° 35'E		60	4.625	125			Tanks of reservoir for spent process channels (2 pcs.)
1979	40 ° 10'N	131 ° 15'E		162	0.340	9.2			Fishing ship
1979	41 ° 23'N	131 ° 25'E		50	0.155	4.2	42		
1979	40 ° 10'N	131 ° 15'E		800	0.766	20.7	21		
1980	41 ° 05'N	131 ° 30'E		68	2.689	72.7	68		
1980	41 ° 25'N	131 ° 20'E		65	0.035	0.95	53		
1980	40 ° 10'N	131 ° 15'E		200	0.081	2.2			Fishing ship Tedzhem
1980	40 ° 10'N	131 ° 15'E		240	0.111	3			Fishing ship Taus
1980	41 ° 29'N	131 ° 18'E		34	0.007	0.2	34		
1980	40 ° 10'N	131 ° 18'E		284	0.133	3.6			RS-309
1981	40 ° 10'N	131 ° 18'E		165	0.093	2.5			Fishing ship Tekeli

* Ref [32] Sivintsev, Y and Kiknadze, O., "Inventory of Radionuclides in the Ship Nuclear Reactors Dumped in the Sea of Japan", Proceedings of Part 2 of an International Symposium on Radionuclides in the Oceans (RADOc 96-97), April 7-11, 1997, Norwich (1998).

DATE	CO-ORDINATES		DEPTH m	VOLUME m ³	ACTIVITY		FORM OF DISPOSAL		
	Latitude	Longitude			TBq	Ci	Containers	Ships	Unpackaged
	Area 10 (contd.)								
1981	41 ° 20'N	131 ° 26'E		183	5.347	144.5	188		
1981	41 ° 00'N	131 ° 26'E		74	0.019	0.5	48		
1981	40 ° 00'N	131 ° 15'E		472	0.280	7.3	-	Seiner "Tagil"	
1981	40 ° 10'N	131 ° 15'E		217	0.104	2.8	-	fs-300	
1982	41 ° 20'N	131 ° 26'E		40	1.421	38.4	40		
1982	41 ° 05'N	31' ° 30'E		36	0.866	23.4	36		
1982	40 ° 10'N	131 ° 15'E		255	0.263	7.1		Fishing ship Troitsk	
1982	41 ° 29'N	131 ° 26'E		31	0.004	0.12	31		
1982	41 ° 25'N	131 ° 21'E		42	0.013	0.35	38		
1982	40 ° 10'N	131 ° 15'E		450	0.407	11		Fishing ship Kosmonavt Yegorov	
1983	41 ° 20'N	131 ° 26'E		107	3.415	92.3	83		Reactor lid (8 pcs.)
1983	41 ° 25'N	131 ° 25'E		47	0.087	2.35	47		
1983	41 ° 25'N	131 ° 25'E		405	0.392	10.6		Medium fishing trawler/refrigerator ship	

DATE	CO-ORDINATES		DEPTH m	VOLUME m ³	ACTIVITY		FORM OF DISPOSAL		
	Latitude	Longitude			TBq	Ci	Containers	Ships	Unpackaged
	Area 10 (contd.)								
1983	40 ° 30'N	131 ° 35'E		436	0 459	12 4		Seiner "Izvolta"	
1984	40 ° 20'N	131 ° 20'E		118	2 849	77	119		
		Total		5072	105 385	2848 0	848	11	14
		Subtotal (Areas 6-10)		21880	417 620	11296 65	6642	39	100+
					≅ 418	≅ 11297			

Annex A.21
RUSSIAN FEDERATION — DISPOSAL OF LIQUID RADIOACTIVE WASTE
IN THE BARENTS SEA AND FAR EASTERN SEAS IN 1992

Disposal area (co-ordinates)	Type of dumping	Activity	
		TBq	Ci
Barents Sea			
Area 5 ¹ (coastal)	3066 m ³ LRW	0.666	18
Far Eastern Seas			
Area 5 ² , Sea of Japan	906 m ³ LRW	0.048	1.3
Area 7 ² , east coast of Kamchatka	906 m ³ LRW	0.048	1.3
Area 9 ² , Sea of Japan	1774 m ³ LRW	0.281	7.6
Area 8 ³ , 52°30' N, 159°9' E, east coast of Kamchatka	46 m ³ SRW, 41 containers	0.444	12.0
Area 9 ² , 41°40' N, 133°30' E, Sea of Japan	2640 m ³ SRW, tanker <i>TNT-11</i>	0.534	14.5
Area 9 ² , 41°40' N, 133°30' E, Sea of Japan	55 m ³ SRW, 41 containers	0.019	0.5
Total by type	6652 m ³ LRW 2741 m ³ SRW	1.043 0.997	28.2 27.0
Total activity		2.040	55.2

¹ Ref. Annex A.15, Area 5 (coastal).

² Ref. Annex A.19, Area 7 and 9.

³ Ref. Annex A.20, Area 8.

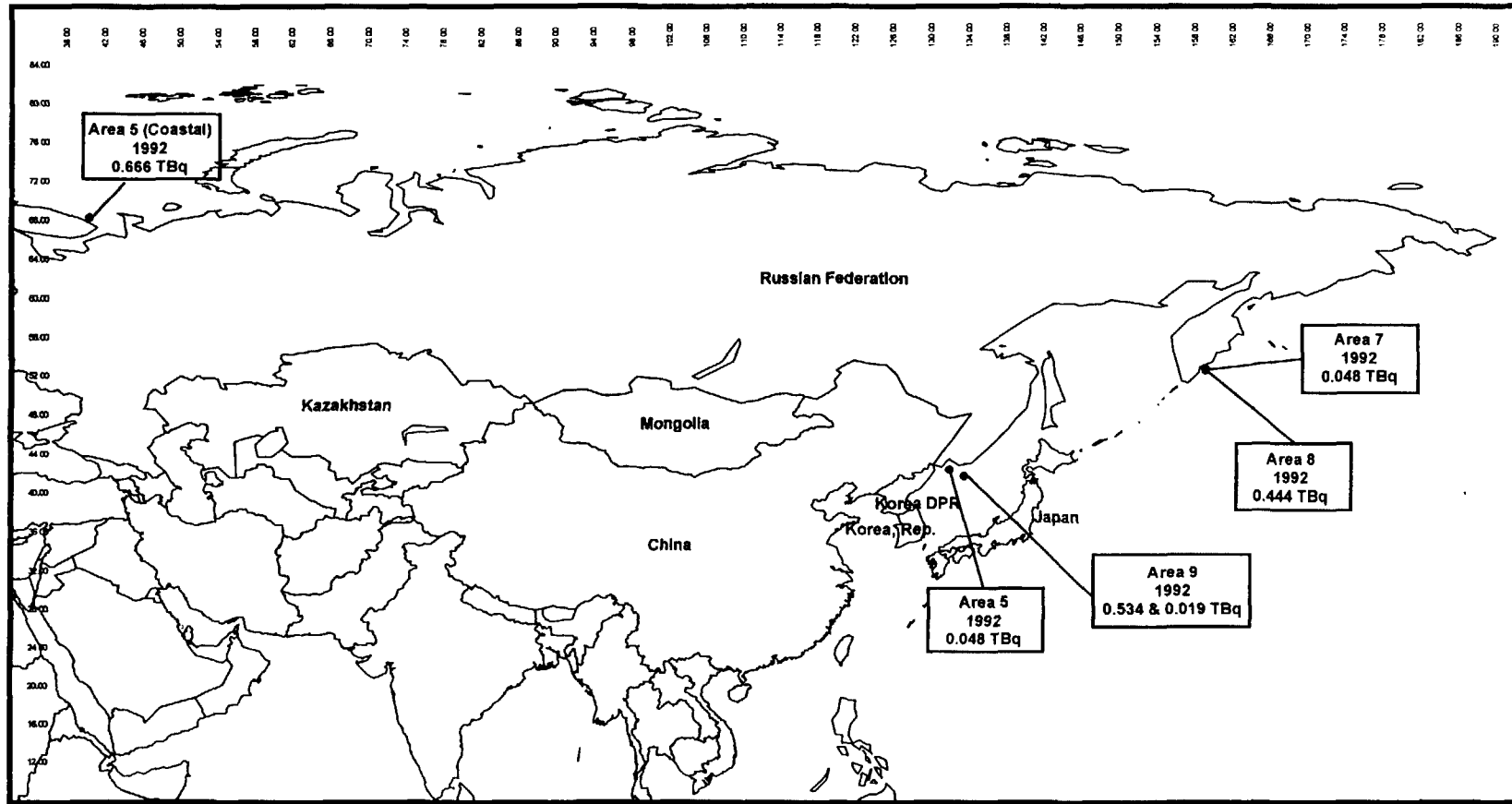


FIG. A21. Geographical positions of the dump sites and activity of liquid radioactive waste disposed in 1992 by the Russian Federation in the Barents Sea and Far Eastern Seas.

Annex A.22
RUSSIAN FEDERATION — DISPOSAL OF LIQUID RADIOACTIVE WASTE
IN THE SEA OF JAPAN IN 1993

Disposal area (co-ordinates)	Type of dumping	Radionuclides**	Concentration		Total activity	
			Bq/L	Ci/L	GBq	Ci
Area 6 41°46' - 42°36' N, 133°26' - 134°42' E	discharge of liquid radioactive waste	Cs-137	12029	3.25×10^{-7}	10.73	0.293
		Sr-90	3318	8.97×10^{-8}	2.96	0.081
		Co-60	83	2.24×10^{-9}	0.074	0.002

Total activity = 13.912 GBq (0.376 Ci)
 \cong 0.0139 TBq

* Based on LC 16/J/4 statement Ref. [31] made on 10 November 1993 by Mr. V.I. Danilov-Danilyan, Minister of Environmental Protection and National Resources, Russian Federation, at the 16th Consulative Meeting of the London Convention 1972.

** SIVINTSEV, Y., DANILYAN, V., VYSOTSKIY, V., "Environmental Impact of Liquid Radioactive Releases into the Sea of Japan", Environmental Impact of Radioactive Releases (Proc. Int. Symp. Vienna, 1995), IAEA, Vienna (1995) 820-821.

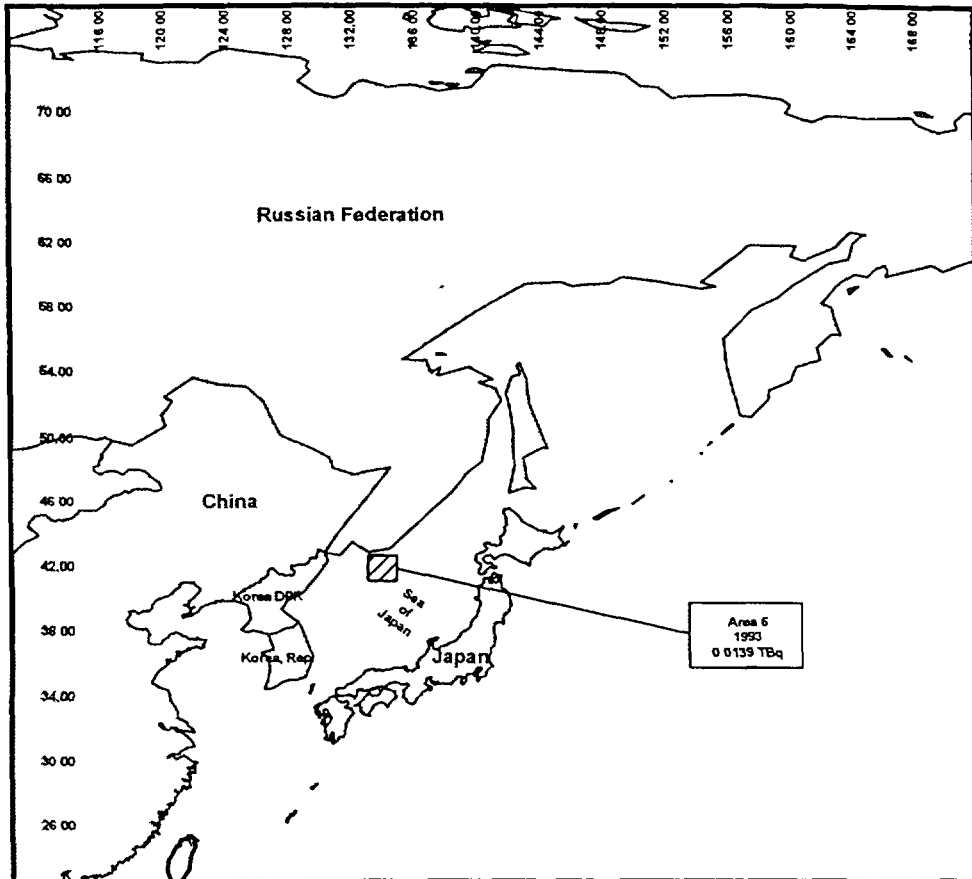


FIG. A22. Geographical position of the dump site and activity of liquid radioactive waste disposed in 1993 by the Russian Federation in the Sea of Japan

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Consultants Meetings

Vienna, Austria: 14–18 June 1993, 4–8 November 1996, 16–20 June 1997

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