Inventory of radioactive material entering the marine environment

To help assess the impact of past and present waste management practices, an information base is being developed

by Dominique Calmet and Kirsti-Liisa Sjöblom

The development of nuclear energy and its application to electrical power generation, and to medicine and research through the use of radioisotopes, has brought with it the creation of radioactive wastes. Some of these wastes have entered the marine environment. Five main categories of human activities leading to contamination of the marine environment can be distinguished:

- the explosion of nuclear weapons, either in the atmosphere or during underwater testing;
- the controlled release of low-level radioactive liquid effluents from nuclear power plants, reprocessing plants, industry, hospitals, scientific research centres, and nuclear weapons facilities;
- the disposal on the ocean floor of low-level radioactive waste, usually packaged, originating at any of the previously mentioned facilities;
- the Chernobyl accident, which caused a direct deposition of radionuclides into local seas or a deposition on their catchment areas; and
- marine accidents involving radioactive materials, for example, the loss of a vessel such as a nuclear-powered submarine or a ship carrying nuclear fuel, the loss of an aeroplane carring nuclear weapons, or the re-entry of a satellite containing nuclear materials.

The concern of many nations to prevent radioactive pollution in the marine environment is expressed in many international conventions, such as the Law of the Sea Convention, the London Dumping Convention (LDC), and the Code of Safety for Nuclear Merchant Ships. *(See box, page 26.)* The conventions have entrusted the IAEA with specific responsibilities to carry out studies and give definitions and recommendations concerning the prevention of radioactive contamination of the seas.

Recently, the LDC requested the IAEA to develop an inventory of radioactive wastes entering the marine environment from all sources. The rationale for creating the inventory is to establish an information base which can be used to provide accurate data for assessing the impact of any waste management practice which releases radioactive waste into the sea. The inventory would also serve as a deterrent against the disposal of more waste than recommended into a single oceanic basin.

The inventory database

A programme to develop such an inventory has been started at the IAEA. The system has been planned so that it has the capacity for:

- storage of information on past practices and accidents, inclusion of future information; and
- accessibility of the information needed in impact assessment, calculations, and comparisons.

A computerized database has been established with three modules.

- sea disposal operations of low-level radioactive wastes;
- accidents and losses at sea which may lead to a direct release of radionuclides into the sea; and
- controlled low-level radioactive liquid releases into coastal waters from nuclear plants.

Each database module has been established separately for the storage and rapid retrieval of specific information requested for each source. A system which functions as a memory automatically corrects the data for radioactive decay.

The availability of information on radionuclide inputs arising from different practices varies greatly. Thus, the information on inputs due to the atmospheric and underwater nuclear weapons tests is limited due to the confidentiality of the data, whereas their consequences in

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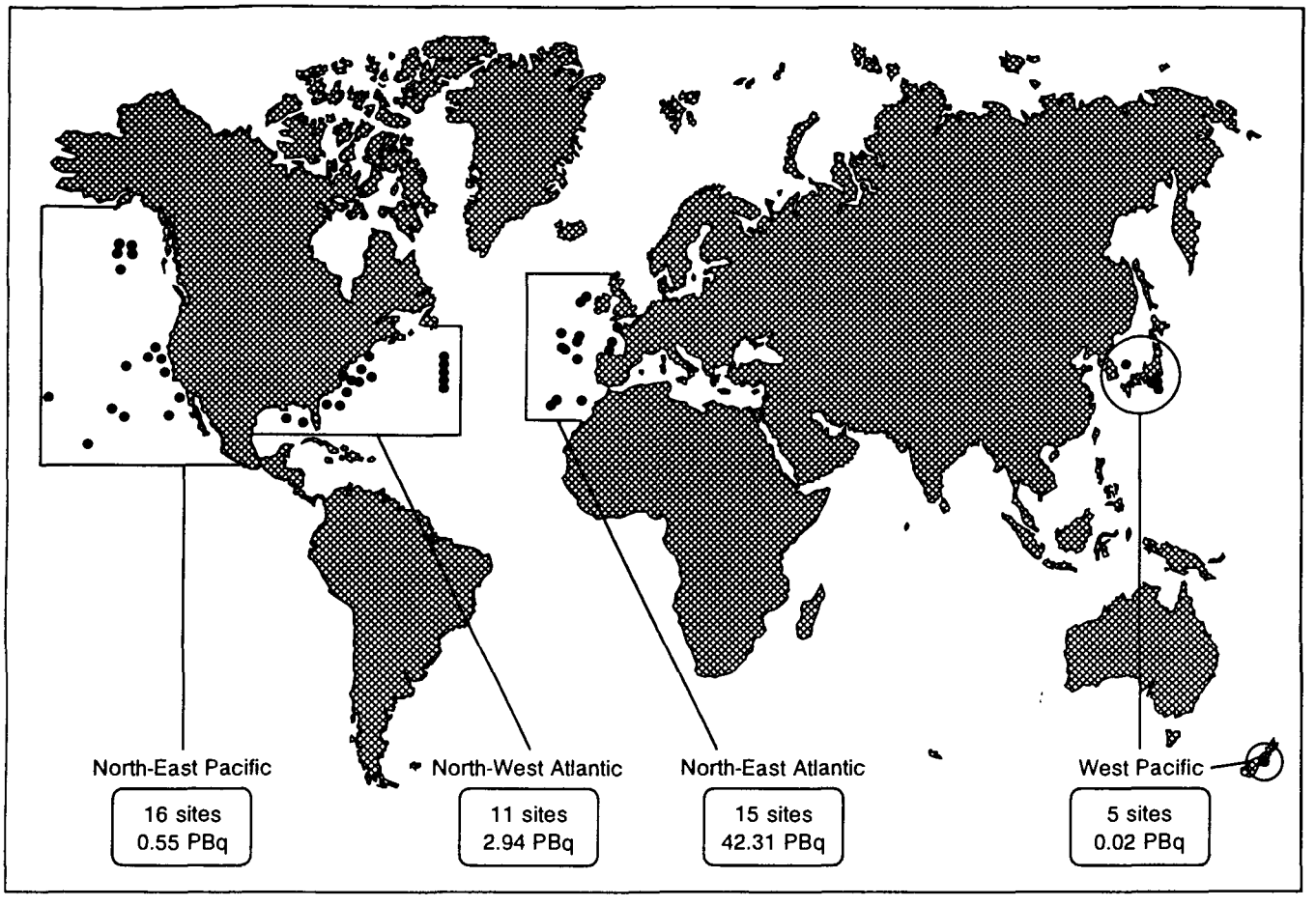


Worldwide distribution of reported sea sites used for disposal of low-level radioactive waste

the marine environment are well known. The controlled releases of low-level radioactive liquid effluents from civilian nuclear facilities are well documented by national authorities.

The United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) periodically reviews the data on radioactive contamination of the environment. In its reports, data on liquid effluent releases and the results of radiological impact assessments associated with these practices are presented, as well as those connected with the nuclear weapon tests and, more recently, the Chernobyl accident. The UNSCEAR documents can be of direct use for comparative purposes in relation to the various releases from the nuclear fuel cycle.

Because the sources of marine contamination due to "sea disposal operations" and "accidents and losses at sea" are most closely related to the objectives of the LDC, the eleventh consultative meeting (1988) of the Convention gave priority to the establishment by the IAEA of the databases on these sources. This article presents a summary of the data collected on low-level radioactive waste disposed of at sea and on the accidents and losses at sea reported by Member States of the IAEA.

Sea disposal of low-level waste

As the first output of the inventory database the IAEA in 1991 published the document *Inventory of Radioactive Material Entering the Marine Environment: Sea Disposal of Radioactive Waste.** It was presented during the 14th Consultative Meeting of the Contracting Parties to the LDC in 1991. This document provides on a country-by-country basis the information on the disposal sites and the yearly amounts of radionuclides disposed of at these locations.

Many different kinds of waste have been disposed of in the sea. Various amounts of low-level radioactive waste have been disposed of at more than 50 sites in the northern part of the Atlantic and Pacific oceans. The first sea disposal operation took place in 1946 at a site in the North-East Pacific Ocean, about 80 km off the coast of California. The last officially known disposal operation was in 1982, at a site about 550 km off the European continental shelf in the Atlantic Ocean. *(See map.)*

* IAEA TEC-DOC 588, Vienna (1991).

International legal framework

The international legal framework related to radioactive waste practices at sea includes:

Law of the Sea:

The first United Nations Conference on the Law of the Sea in 1958 recommended specifically that "the IAEA should pursue whatever studies and take whatever action is necessary to assist States in controlling the discharge or release of radioactive materials to the sea, in promulgating standards, and in drawing up internationally acceptable regulations to prevent pollution of the sea by radioactive materials in amounts which would adversely affect man and his marine resources".

London Dumping Convention:

The Convention for the Prevention of Marine Pollution by Dumping of Wastes and Other Matter (London Dumping Convention, LDC) entered into force in 1975. The LDC prohibits, *inter alia*, the dumping of high level wastes and requires that low-level wastes be dumped only after a special permit has been issued. A record must be kept of the nature and quantities of the matter dumped and the location, time, and method of dumping.

The LDC entrusted the IAEA with specific responsibilities, especially to evolve a definition of high-level radioactive wastes unsuitable for disposal at sea, and to make recommendations to national authorities on the issue of special permits for ocean disposal of low-level radioactive wastes. The IAEA was mandated to keep its definitions and recommendations to limit the impact of the disposal operation under review.

Voluntary moratorium on disposal:

In 1983, during the 7th Consultative Meeting of the Contracting Parties to the LDC, concern was expressed about possible damage to the marine resources due to the dumping of low-level wastes, mainly by countries that did not have a direct share in the benefits of nuclear energy. An amendment to the LDC annexes was proposed to prohibit the disposal of all radioactive waste at sea, and a resolution calling for suspension of all disposal of radioactive wastes was adopted. The Contracting Parties finally agreed on a voluntary non-binding moratorium on ocean disposal of low-level wastes while awaiting the conclusions of an inter-governmental panel of experts to consider the wider scientific as well as political, legal, economic, and social aspects of sea disposal of low-level wastes.

Safety Code for Nuclear Merchant Ships:

The International Convention for the Safety of Life at Sea containing safety recommendations applicable to nuclear merchant ships was signed in London in 1960. Safety requirements for nuclear ships came under the responsibility of the International Maritime Organization (IMO) in 1974. The IMO Subcommittee on Ship Design and Equipment put extensive and detailed work into the preparation of a Safety Code for Nuclear Merchant Ships which was published in 1981.

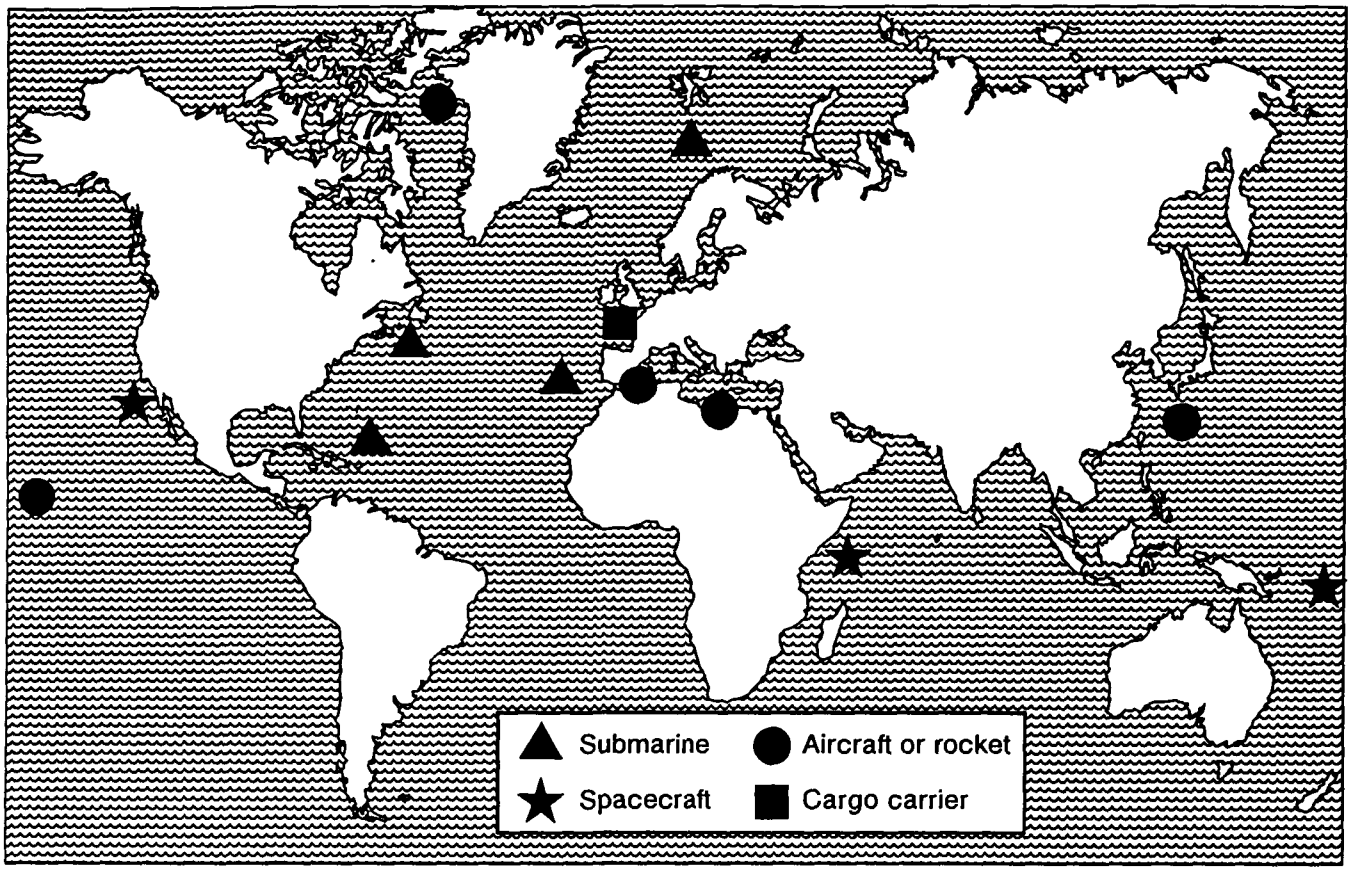
During these years, an estimated 46 PBq (1.7 MCi) of radioactive waste originating from research, medicine, nuclear industry, and military activities were packaged, usually in metal drums lined with a concrete or bitumen matrix, and disposed of at sea. The inventory also includes some unpackaged waste and liquid waste which was disposed of between 1950 and 1960. Beta-gamma emitters represented more than 98% of the total radioactivity of the waste. There were fission and activation products, such as tritium, carbon-14, iron-55, cobalt-58 and 60, strontium-90, and caesium-137. Of these, tritium alone represents one-third of the total amount of disposed radionuclides. The waste also contained low amounts of alpha-emitting nuclides, with plutonium and americium representing 96% of the alpha emitters present.

Until 1977, sea disposal operations were performed under national authority. In 1977 the Council of the Organisation for Economic Co-operation and Development (OECD) started to co-ordinate ocean disposal operations of its Member States and set up a Co-ordinated Research and Environmental Surveillance Programme (CRESP) to keep the suitability of disposal sites under review. As a result, the North-East Atlantic dumping site, which was used until 1982, was surveyed on a yearly basis. A radiological survey of the Pacific and North-West Atlantic Ocean sites is carried out from time to time by the US and Japanese environmental protection agencies. So far, samples of sea water, sediments, and deep sea organisms collected on the various sites have not shown any excess in the levels of radionuclides above those due to fallout from nuclear weapon tests, except during certain occasions when caesium and plutonium were detected at elevated levels in samples taken close to packages at the disposal site.

Recently, there have been reports that radioactive waste dumping has occurred in the Arctic seas (Barents and Kara Seas). It is alleged that some of the wastes are high level and that dumping has occurred in recent years. An official request by the IAEA for information on the alleged disposal operations and a scientific cruise planned in the late summer of 1992 is expected to provide further details on this dumping activity.

Accidents and losses at sea

Various human activities may, due to accidents or loss at sea, lead to direct releases of



Locations of reported accidents at sea involving radioactive materials

radionuclides into the marine environment. These sources and applications can be divided into:

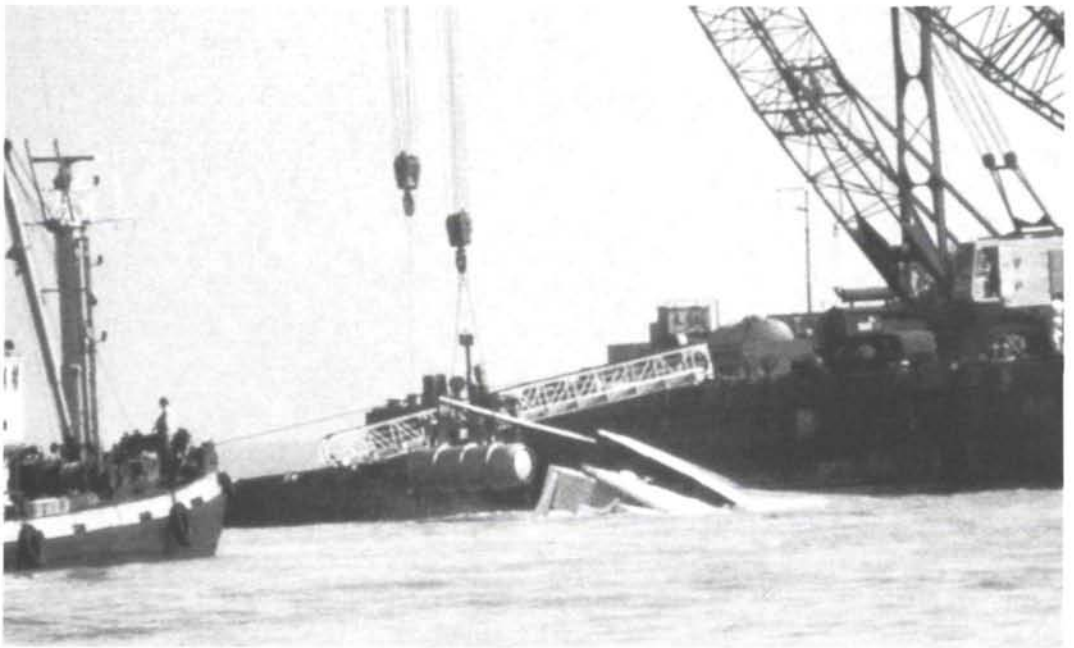
- nuclear reactors used for the propulsion of surface ships and submarines;
- nuclear weapons carried aboard surface ships, submarines, aircraft, and rockets;
- radioisotope thermoelectric generators (RTGs) used to generate electricity for marine navigation aids, unmanned weather stations, and spacecraft;
- sealed radioactive sources used in engineering, construction, oil and gas prospecting and extraction; and
- cargoes of radioactive materials in transit.

A detailed draft document entitled *Inventory of Radioactive Material Entering the Marine Environment: Accidents and Losses at Sea* was presented during the last consultative meeting of the LDC. It was based on open literature and some of the accidents reported have been confirmed officially by the Contracting Parties to the LDC. It will be finalized when supplementary information is received. The document presents a description of the accidents at sea including locations, quantities of radioactive material involved, and monitoring. *(See map.)*

The development of nuclear propulsion for seagoing vessels started in the 1950s, encouraged by the prospect of the durability and independence of the fuel capacity. In the event of an accident, a range of consequences can be postulated including the leakage of significant amounts of radionuclides and, in the worst case, the loss of a vessel along with its nuclear reactor on the sea floor.

No civilian losses of nuclear-powered vessels nor accidental leakage into the marine environment have been reported. However, for military vessels, four nuclear-powered submarines have been officially reported as being lost in various places in the Atlantic since 1963. The depth of the accident sites, below 1500 metres, and the technological difficulties involved have not yet permitted the recovery of the nuclear reactors. The airtight steel shell of the reactor vessels is designed to contain contamination from either normal or accidental operating conditions and is expected to limit the amount of radionuclides released into the marine environment. In addition to the four officially confirmed losses of nuclear submarines, several other losses have been reported, but not confirmed.

The number of nuclear weapons associated with the accidents stated above is unknown. However, nuclear materials used in nuclear weapons and nuclear weapons themselves have been officially reported lost at sea following the



The IAEA's database will include information about losses at sea. (Credit: CEA)

losses of military aircraft and rockets. One nuclear weapon has since been recovered, the others were lost at deep-sea sites and at sites for which only approximate coordinates are known.

Another type of accident which may lead to direct or indirect contamination of the marine environment is one involving spacecraft. Four nuclear-powered spacecraft have been lost over the sea. Three of these had RTGs on board containing plutonium-238. One RTG vaporized during re-entry, causing a widespread low-level contamination, and two fell into the sea. Of these, one was recovered without release to the environment and the other is still on the seabed. The fourth satellite, containing an enriched uranium (U-235) reactor, re-entered the earth's atmosphere due to a malfunction. It is likely that the reactor core broke into small fragments which fell into the South Atlantic Ocean.

Sealed radiation sources are commonly used for a variety of purposes in the offshore oil and gas industry, such as radiography and bore-hole logging, as well as marine navigation aids. Several losses of sealed sources have occurred as a result of shipping accidents, during transportation or in connection with damage of the drilling installations. In general, due to the packaging and the properties of the containment, the releases will take place over a long period and the radiological consequences of particular incidents will be relatively minor. In some cases, sources have been recovered intact although the recovery was not considered necessary by the national authorities.

Concern also has been expressed regarding the safe transport of radioactive materials. Since 1989, the IAEA has generated a computerized accident and incident reporting system, covering all shipments of radioactive materials. In the civilian surface ship category, a civilian carrier sank with its cargo of nuclear material in shallow water in 1984. However, it was rapidly recovered before any contamination of the environment occurred.

Radiological surveys including sampling of sea water, sediments, and deep sea organisms near the various sites of the past accidents, mainly those of the submarines, are carried out from time to time. So far, monitoring data has not shown any excess in the levels of radionuclides above those due to fallout from nuclear-weapons testing, except in certain samples collected close to the wreck.

Development of the inventory database

The IAEA will make every effort to respond to the request of the LDC to maintain an inventory of radioactive wastes entering the marine environment. The database on sea disposal operations of low-level radioactive wastes will be completed in the near future, if the alleged dumping operations in the Arctic Seas are confirmed. The development of the database on accidents and losses at sea needs a serious contribution from IAEA Member States. At present the inventory contains a great deal of data about accidents which have been publicly reported, but not officially confirmed. ❐