The International Arctic Seas Assessment Project: Progress report

Under an IAEA-supported study, experts are taking a close look at past radioactive waste dumping in the Kara and Barents seas

by Kirsti-Liisa Sjoeblom and Gordon S. Linsley

In 1992 the news that the former Soviet Union for over three decades had dumped large amounts of high-level radioactive wastes in the shallow waters of the Arctic Seas caused widespread concern, especially in countries with Arctic coastlines.

The IAEA responded by making a proposal for an international study to assess the health and environmental implications of the dumping. The proposal received support from the Contracting Parties to the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter (London Convention 1972). The study became known as the International Arctic Seas Assessment Project (IASAP) and was launched at a meeting jointly organized with the Norwegian and Russian Governments in Oslo in February 1993.

This article provides some background information on wastes dumped into the Arctic Seas and describes the progress made within the framework of IASAP.

International control of dumping

The first recorded sea disposal of radioactive wastes took place in 1946 at a site in the North-East Pacific Ocean, about 80 km off the coast of California. In subsequent years, as sea disposal became more widely used as a radioactive waste disposal option, the pressure for it to be controlled also increased. In response, the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter was established in 1972 and entered into force in 1975. (This convention became well-known as the London Dumping Convention but has recently been renamed the London Convention 1972.) The Convention is recognized as the main international mechanism for the control of waste dumping at sea.

The Convention in its original form prohibited, *inter alia*, the dumping of high-level radioactive wastes and required that low-level radioactive wastes were dumped only after a special permit was issued. The IAEA was requested to provide a definition of high-level wastes unsuitable for sea disposal and provide recommendations concerning disposal sites, packages etc. for low-level waste disposal. Three documents were prepared to address the request.*

In 1983, following the concerns of some of the Contracting Parties to the Convention over the possible health and environmental risks which could be produced by the radioactive waste disposal operations, a voluntary moratorium on radioactive waste dumping at sea was imposed pending a wide-ranging review of the issue. The IAEA provided technical input to aid this discussion. In 1993 Contracting Parties to the Convention reached the decision to prohibit the sea dumping of all types of radioactive waste. It was noted that the decision on total prohibition was not reached on the basis of scientific and technical considerations but rather on social, moral, and political grounds.

Sea dumping by the former Soviet Union

Information on the sea dumping practices of the former Soviet Union was first made public by a Russian non-governmental environmental group, Towards a New Earth. Greenpeace International, as observer to the London Convention,

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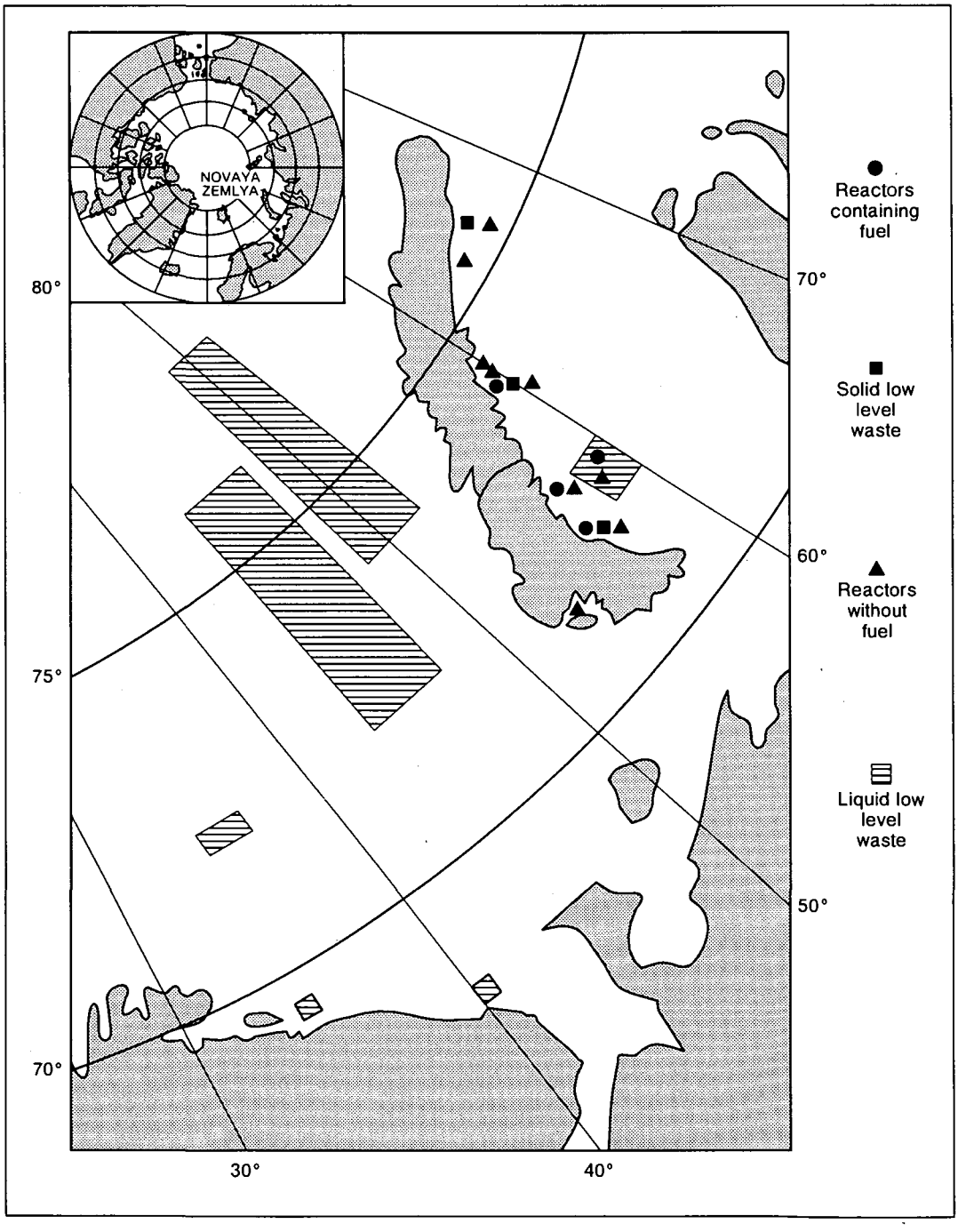
*For more information on sea disposal of radioactive wastes and the London Convention 1972, see articles in *IAEA Bulletin* editions Vol. 34, No.2 (1992) and Vol. 36, No. 2 (1994).

brought the issue to the attention of the Convention in 1991 and again in 1992. As a result, the Russian Federation was urged by Contracting Parties to the Convention to present complete information on the subject. The IAEA, in this period, developed plans to initiate a project for assessing the consequences of the dumping on human health and the environment and these were subsequently endorsed by the Contracting Parties to the Convention. The IAEA was requested to report the results of the assessment to the Convention.

In May 1993 the Russian Federation provided information to the IAEA about the high- and low-level radioactive waste dumped in the Arctic Seas and in the North-East Pacific during the years 1959-92. According to this report, the total amount of radioactivity dumped in the Arctic Seas was more than 90 PBq (90 x 10^{15} Bq or 2.4 x 10^{6} Ci). The items dumped included six nuclear submarine reactors and a shielding assembly from an icebreaker reactor containing spent fuel comprising a total of 85 PBq; ten reactors (without fuel) containing 3.7 PBq; liq-

Sea disposal of radioactive waste in the Arctic Seas by the former Soviet Union and Russia



uid low-level waste containing 0.9 PBq; and solid intermediate- and low-level waste containing 0.6 PBq. The packaged and unpackaged solid waste and the nuclear reactors were dumped in the Kara Sea, in the shallow bays of Novaya Zemlya. The depths of the dumping sites there range from 12 to 135 meters, and in the trough of Novaya Zemlya, 300 meters. The liquid low-level waste was discharged in the open Barents and Kara Seas. *(See table.)*

Arctic Sea dumping in perspective

Until its amendment in 1993, the London Convention prohibited the disposal at sea of high-level radioactive waste but allowed, under special permit, the dumping of other types of radioactive waste. Much of the material dumped in the Kara Sea falls into the category of high-level waste. However, most of the spent fuel was dumped in the years before the London Convention came into being (1972) and before the USSR became a Contracting Party to the Convention (1976). The radioactive waste disposal continued in the Arctic Seas until 1991.

The IAEA's Safety Series No. 78 (issued in 1986) specifies locations and depths below which the dumping of low-level wastes can be permitted, when appropriate environmental assessment and notification to the Secretariat of the Convention have been made. The Arctic dumping sites do not fit within these specifications and, in particular, many of the dumping sites are in very shallow waters. It may be noted here that, prior to the entry into force of the London Convention, the dumping of radioactive wastes had also been carried out in shallow coastal waters in other parts of the world and by other countries.

In 1992, the Joint Norwegian-Russian Expert Group was established to investigate radioactive contamination due to dumped nuclear waste in the Barents and Kara Seas. It arranged exploratory cruises to the dumping areas, with the participation of a scientist from the IAEA's Marine Environment Laboratory (IAEA-MEL) in 1992, 1993, and 1994. All four sites where reactors containing nuclear fuel were dumped have been visited by the cruises of the expert group, but only some of the objects have been successfully located. The group has taken samples, made measurements and used a side scanning sonar and video camera in an attempt to identify and examine the wastes. The results obtained during the cruises have not indicated any significant radioactive contamination at the dumping sites, although the levels near some dumped objects are slightly elevated compared with elsewhere.

While it appears that there are no significant regional and global effects at present from the

Data on the nuclear reactors dumped near Novaya Zemlya

Site	Year of dumping	Depth of dumping (meters)	Factory number	Dumped unit	Number of reactors		Total activity (PBq)		
					Without spent nuclear fuel	Containing spent nuclear fuel	Initial data	Further studies	
							At the time of dumping	At the time of dumping	1993/94
Abrosimov Fjord	1965	20 (10-15)	285	Reactor compartment	1	1	29.6	11.6	0.655
		20 (10-15)	901	Reactor compartment	-	2	14.8	2.95	0.727
		20	254	Reactor compartment	2	-	*	0.093	0.009
	1966	20	260	Reactor compartment	2	-	*	0.044	0.005
Tsivolka Fjord	1967	50	OK-150	Reactor compartment and a box containing fuel	3	0.6	* 3.7	19.5	2.2
East Novaya Zemlya Trough	1972	300	421	Reactor	-	1	29.6	1.05	0.293
Stepovoy Fjord	1981	50 (30)	601	Submarine	-	2	7.4	1.72	0.838
Techeniye Fjord	1988	35-40	538	Reactors	2	-	*	0.006	0.005
Total					10	6.6	89	37	4.7

Notes: The initial data on total activity were provided to the IAEA in May 1993 by the Russian Federation; the data were revised following further studies within the framework of IASAP. The data on depths of dumping were provided in May 1993 by the Russian Federation; the data in parenthesis were obtained during joint Norwegian-Russian scientific cruises in 1993 and 1994.

* Reactors without spent fuel, not more than 3.7 PBq total.

dumped wastes, the gradual deterioration of the waste containments could lead to future impacts. These could occur through contamination of the marine food chain, possibly resulting in the radiation exposure of humans through the consumption of fish and other marine foodstuffs. Since the wastes are lying in shallow waters, the possibility of radiation exposure by other routes — such as the movement and transport of the waste packages by natural events (ice or storm action), or deliberate human action — cannot be ruled out. The time scales for consideration are very long (tens of thousands of years) and, therefore, the possible impact of climatic change has also to be taken into account. In order to provide answers to these questions, it is necessary to have a thorough understanding of the present and future physical, chemical, and biological characteristics of the environment surrounding the wastes and of the wastes themselves.

Preliminary assessments have indicated that even under the most pessimistic release conditions, the wastes would not cause a significant global radiological impact. However, it was evident then that to evaluate the possible risks at the local and regional scales considerably more information would be needed than was generally available in 1992. The International Arctic Seas Assessment Project (IASAP) was established to answer these and other related questions.

Aims and implementation of IASAP

The objectives of IASAP take into account the requests of the Contracting Parties to the London Convention. They are to:

- assess the risks to human health and to the environment associated with the radioactive waste dumped in the Kara and Barents Seas; and
- examine possible remedial actions related to the dumped wastes and to advise on whether they are necessary and justified.

The results and conclusions of the project will be reported to the London Convention in 1996. The project is organized in five working areas: source terms; existing environmental concentrations; transfer mechanisms and models; impact assessment; and remedial measures.

The work is being carried out using normal IAEA mechanisms: consultants and advisory group meetings, a coordinated research programme, and research and technical contracts.

Progress of IASAP activities

Progress in all IASAP working areas is reviewed each year by a group of senior scientists.

Source term. The aim of the Source Term Working Group is to determine the information needed about the waste for use in impact assessment calculations. This involves having knowledge of the waste form and of its likely behaviour with time in the marine environment. The efforts of the Group have been focused on the dumped reactors containing spent fuel which obviously pose the highest potential risk. At a later stage, consideration will be given to the packaged and unpackaged low- and intermediate-level waste.

The official information on the dumped waste provided by the Russian Federation in May 1993 did not include information on the radionuclide composition of the waste nor on the characteristics of the fuel in the different types of dumped reactors. To obtain more detailed information, it has been necessary to investigate the archives of the former Soviet Union and to reconstruct the history of the reactor fuel prior to dumping.

As the first step, in January 1994, a detailed inventory of radionuclide composition and information on the structure of the dumped reactor containment of the commercial nuclear icebreaker *Lenin* was obtained (OK-150 in the table on page 27). Later, in July 1994, the Russian authorities declassified essential details of the structure, operational history, and characteristics of the fuel of the dumped submarine reactors. As a consequence, the corresponding radionuclide inventories of the lead bismuth cooled submarine reactors (No. 601 in table) and the water cooled submarine reactors (numbers 254, 260, 285, 421, 538 and 901 in table) were made available to IASAP.

The total activity of the dumped reactors (with and without nuclear fuel) at the time of dumping is now estimated to be about 37 PBq. This may be compared with the first estimate of 89 PBq provided in May 1993 by the Russian Federation. The reason for lower actual figures is that most of the reactors met with an accident after a very short period of operation. This was not taken into account in making the original estimates. Due to the radioactive decay, the total activity of the dumped reactors at the present time is about 4.7 PBq.

For impact assessment purposes, it is also necessary to have information on the protective barriers provided for the dumped reactors either by the initial construction or through preparations prior to dumping. This information has also been obtained through contracts placed in the Russian institutes.

Fuel was removed from ten of the reactors prior to dumping. Those dumped with spent fuel (six reactors) had usually met with an accident prior to the dumping in which the fuel was dam-

aged. The dumping of the reactors took place by four principal means: 1) Most of the submarine reactors were dumped contained in their reactor compartments. The reactors were filled with a special polymer, furfural; 2) In some cases the reactors were taken out of the compartment and filled with furfural prior to dumping; 3) In the case of the lead-bismuth cooled reactors, the submarine compartment was filled with furfural and bitumen and the whole submarine was dumped (No. 601 in table). In this case the solidified liquid metal coolant forms an additional protective barrier; 4) The dumped component of the nuclear icebreaker *Lenin* includes a reactor compartment with three reactor vessels from which the fuel was removed and which were filled with furfural. 57% of the fuel from one of the reactors was dumped in a separate metal-lined concrete box also filled with the sealant furfural.

On the basis of an analysis of the weak points of the protective barriers, the Source Term Working Group has prepared sets of possible time patterns of radionuclide release and release rates.

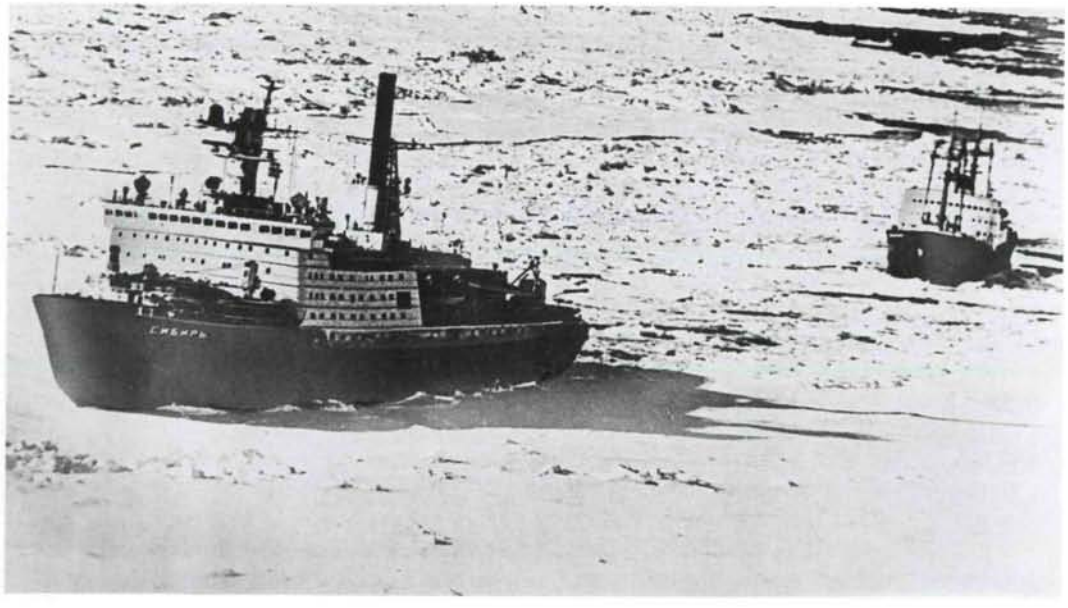
Further studies are expected to produce more accurate predictions of release. In this context, information on the physical and chemical characteristics of furfural and of its stability against radiation, heat, saline water, etc. would be valuable. In co-operation with IASAP, a study on the resistant properties of furfural was started early in 1995 as a Russian-US bilateral project.

The findings of the Norwegian-Russian exploratory cruises — for example, the results of visual investigation of reactors by means of underwater cameras; *in situ* radiometric measurements; and water and sediment sampling and analyses — are very important in the evaluation of the potential release rates. It is planned that the videotapes obtained during the exploratory cruises from the sunken objects will be carefully analyzed as a Norwegian-Russian co-operative project by experts on naval reactor and submarine design and on corrosion questions.

Existing environmental concentrations. Information on the levels of radioactive contamination in the target area and other areas of the Arctic seas is being collected as input to the Global Marine Radioactivity Data Base (GLOMARD) of IAEA-MEL. The database is designed to provide up-to-date information on radionuclide levels in seawater, sediment, and biota. It will enable the evaluation of nuclide ratios, identification of the different contributions to radioactivity in the region, the investigation of time trends, and the calculation of inventories. All available radionuclide data for the Arctic Seas have been entered into the database. The first report with a preliminary evaluation of existing radionuclide data will be available this year.

Transfer mechanisms and models. Laboratories in Denmark, Japan, the Netherlands, Russia, Switzerland, the United Kingdom, and IAEA-MEL are participating in the Co-ordinated Research Programme (CRP) entitled "Modelling of the Radiological Impact of Waste Dumping in the Arctic Seas". Its objective is to develop realistic and reliable assessment models for the Arctic Sea areas and to coordinate the efforts of different laboratories in the field. The final results of the modelling exercise will form the basis of the assessment for the London Convention.

A staged approach to the final modelling assessment is being taken. The participating modelling groups first analyzed scenarios based on assumed unit releases into a simplified environ-



The waste dumped in the Arctic Seas includes reactor compartments from a nuclear icebreaker such as the one shown here.

ment. At the first meeting of the CRP, the initial benchmark scenarios were supplemented with improved information on the oceanography and sedimentology of the Kara and Barents Seas, which was made available to the IASAP by Russian institutes. At the second meeting, fish and mammal catches from the target area and information on fish migration were included in the scenario.

At the same time, each modelling group participating in the CRP is in the process of developing and improving its models using the environmental information which is gradually becoming available from the target area. As the next step, release rates based on the results of the Source Term Working Group will be included in the scenario.

At the meetings of the CRP, the predictions of the different modelling groups for each benchmark scenario (i.e. concentrations of selected radionuclides in water and sediment in selected local and regional areas) are compared. This is done with a view to evaluating the sensitivity of the model results to the different modelling and transfer data assumptions.

Impact assessment. In 1995 and 1996, impact assessment calculations will be carried out on the basis of the concentration fields predicted by the Modelling Group and using appropriate environmental transfer factors and demographic data.

Radiation doses will be predicted at various times in the future for local, regional, and global populations. The predictions will take into account both the average consumers and those individuals whose diet consists of considerable amounts of seafood. The assessments will also include estimates of radiation dose to local fauna such as marine mammals.

Information on radionuclide concentration factors for biota and distribution factors between sediment and water relevant to the Arctic conditions is being acquired through projects of IAEA-MEL and other laboratories. The radiological, physical, and chemical measurements made on samples taken from the Arctic area are being analyzed and compiled and a literature review is being conducted. For nuclides and biological species on which appropriate local data is not available, the applicability of concentration and distribution factors derived at moderate latitudes will have to be considered. It is planned that the various sources of information will be evaluated by a small group of experts by the end of 1995.

Remedial measures. The Contracting Parties to the London Convention requested the IAEA to consider possible remedial actions in relation to the dumped wastes and to consider their feasibility. A group of technical experts was convened early in 1995 to consider possible remedial measures mainly from the standpoint of technical feasibility. While the findings of the group must be considered preliminary at this stage, certain general conclusions can be drawn:

- The objects which contain spent nuclear fuel should be considered as the prime potential subjects for remediation.
- Well-developed techniques are available for *in situ* remedial measures such as capping or underwater burial.
- If a remedial measure involving transport were to be chosen, underwater transport is a noteworthy option.

This subject will be discussed again at meetings in 1995 and the radiological impact of the various possible remedial options will be given special attention. One of the waste management options which has to be considered is leaving the wastes as they are without remediation. A decision to carry out remediation must be based, at least partly, on the judgment that potential future radiological risks from the dumped wastes are unacceptable.

Coordinating global efforts

One of the basic ideas in establishing IASAP was to provide a mechanism for coordinating international efforts in the field. The cooperation with the Norwegian-Russian expert group on investigation of dumping of radioactive waste in the Barents and Kara Seas is recognized as being essential to the IASAP project. A small coordination body comprising one member from Norway, Russia, and the IAEA has met three times.

Exchange of information is maintained between IASAP and other groups working in the area of radioactive contamination of the Arctic, notably with the Arctic Nuclear Waste Assessment Programme of the United States.

It has also been agreed that the results of the IASAP project will be made available to the Arctic Monitoring and Assessment Programme (AMAP). AMAP is a component of the Arctic Environmental Protection Strategy (AEPS) as adopted in 1991by Ministers of eight Arctic Nations in their Declaration on the Protection of the Arctic Environment. AMAP is conducting an overall review of the impact of all types of pollution on the Arctic Seas. ❐

See the following article for a report on the IASAP work of scientists from the IAEA's Marine Environment Laboratory in Monaco.