Deep-sea disposal: Scientific bases to control pollution

A status report on the technical work of the IAEA and NEA

by Amelia Hagen and B. Ruegger

Both the IAEA and the Nuclear Energy Agency of the Organisation for Economic Co-operation and Development (NEA/OECD) have significant roles to play in the disposal of radioactive waste at sea.

The IAEA has specific responsibilities under the 1972 Convention on the Prevention of Marine Pollution by Dumping of Wastes and other Matter (known as the London Dumping Convention, or LDC). The NEA, under its Multilateral Consultation and Surveillance Mechanism, oversees the dumping of wastes in the northeast Atlantic Ocean.*

Under the LDC, the IAEA's responsibilities are to:

- Define high-level radioactive waste that is prohibited from being dumped
- Make recommendations for the dumping of other radioactive waste.

The IAEA has recently completed a revision of its definition and recommendations, and it was approved in September 1985 by the Agency's Board of Governors. The NEA also has completed a review (required every 5 years under the Mechanism) of the dumping site, and the review found that from a radiological point of view the site is suitable for dumping over the next 5 years at specified rates.

Both exercises required a substantial scientific effort to provide a sound basis for their completion, and often times it was found that complementary exercises were being planned and that resources to achieve their objectives were being stretched. The IAEA had set up a series of scientific meetings and also had requested the scientific group GESAMP to advise it on suitable models for calculating concentrations of radionuclides above which sea-dumping would be prohibited.** The NEA had established in April 1981 a Co-ordinated Research and Environmental Surveillance Programme (CRESP) relevant to sea disposal for an initial period of 4 years.

Improving the scientific basis

- *Improving models.* In 1978, immediately after a revision of the definition and recommendations, the IAEA initiated a programme plan to ensure that the next revision would have a more sound scientific basis. One of the most important components of this effort was to improve the models used to calculate concentrations of radionuclides unsuitable for dumping at sea.

At the IAEA's request, the 11th meeting of GESAMP agreed to establish a working group on an "Oceanographic Model for the Dispersion of Wastes Disposed of in the Deep Sea". GESAMP recommended models for use in the near-field (the region in the vicinity of the release, where the concentration is significantly greater than the ocean average) and the far-field (the rest of the ocean).* (See accompanying table).

In reviewing the report, the Agency used two GESAMP models: one (Appendix VII) for calculating

Models recommended in the GESAMP report

Near-field:

- Simple finite ocean diffusive model (Appendix IV)
- Modified for finite source size and scavenging (Appendix VII)
- Plume solutions if the size of the near-field exceeds the scale K_H/U within which diffusion dominates (Appendix IV).

Far-field:

- Well-mixed box (for contaminants with a long residence time)
- One-dimensional scavenging models of Appendices VI and IX
- Simple 3-dimensional diffusive model with scavenging (Appendix VII)
- Medium-resolution box model
- Finite-difference models in 2- or 3-dimensions.

Ms Hagen is a staff member in the Agency's Division of Nuclear Fuel Cycle, and Mr Ruegger is with the Nuclear Energy Agency of the OECD, Paris.

* Currently there is a moratorium on sea dumping of radioactive wastes, pending further studies.

** GESAMP is the Joint Group of Experts on the Scientific Aspects of Marine Pollution of the International Maritime Organization (IMO), Food and Agriculture Organization (FAO), United Nations Educational, Scientific and Cultural Organization (UNESCO), World Meteorological Organization (WMO), World Health Organization (WHO), United Nations (UN), United Nations Environment Programme (UNEP), and the IAEA.

* *An Oceanographic Model for the Dispersion of Wastes Disposed of in the Deep Sea,* IMO/FAO/UNESCO/WMO/WHO/IAEA/UN/UNEP Joint Group of Experts on the Scientific Aspects of Marine Pollution – GESAMP, Reports and Studies No. 19, IAEA (1983).

concentrations in the near-field, and another (Appendix VI) for the far-field.* It was recognized that there could be some circumstances where the Appendix-VII model could predict water concentrations lower than those predicted by the Appendix-VI one. Therefore, it was decided that the model predicting the highest concentration for each nuclide would be used to calculate the release-rate limit.

It should be emphasized that the Agency uses generic models. Neither the models, nor the values of the parameters used, are necessarily applicable to specific dumping sites.

- *Sediment/water/biota concentration.* Both of the models used required parameters involving sediment/water interactions. In earlier models, the geochemical processes were not adequately represented and only rough approximations of parameters were used in the calculations. Little documentation was given for the values chosen; for sediment/water distribution coefficients; or for concentration factors in coastal sediments and biological materials. A recent IAEA report provides an approach for calculation of concentration factors based on stable element abundances, and reviews the literature in order to select the most appropriate concentration factors for radionuclides in marine biological materials based, whenever possible, on field data.** (The report's preparation was supported by the NEA. Data used in the model for reviewing the site's suitability are described later in this article.)
- *Environmental assessments.* The Agency also has issued a report to provide additional guidance regarding the preparation and evaluation of environmental assessments relevant to the issuance of special permits to dump radioactive waste not prohibited under Annex I of the Convention.*** The report describes the content of assessments prepared by national authorities to assist them in the decision-making process to determine how the option of sea disposal compares environmentally, technically, socially, and economically with other disposal options; and whether the impact of a proposed sea disposal option is acceptable.

Summary of major issues

During preparation of the IAEA revision of the LDC definition and recommendations, several major issues were addressed:

- *Dose limits.* There was considerable discussion on the dose limit to be used in the derivation of the quantitative definition (whether it should be 5 or 1 millisievert per year.) In addition, there was also considerable discussion as to whether the definition should be based on a dose upper-bound for the practice (that is, some value less than either 1 or 5 millisievert per year). The consensus was that the upper-bound concept belonged in the recommendations, since the definition was a level above which material may not be dumped and it gave no guidance as to what may be dumped. (The value of 1 millisievert per year was selected as the dose limit that is consistent with the latest recommendations of the International Commission on Radiological Protection.)
- *Dumping period.* The question of the dumping period to be assumed for the derivation of the quantitative definition also was a contentious issue. Calculations were carried out for dumping periods of 40 000 years and 1000 years. The 40 000-year period was used because it had been the basis of earlier calculations.* A 1000-year period was selected because it is more consistent with the time periods over which the use of nuclear power may be presumed to continue – for example, a period of 500 years is assumed in the latest report of the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR). The time also is long enough so that dumping of wastes, at the rate given in the definition, for even a few hundreds of years would not take up a significant fraction of the ocean's capacity to assimilate radioactive materials. The models used are not valid for the shorter periods (100 to 300 years) suggested by some experts as a basis for the definition.
- *Release rates versus concentration.* The models are used to calculate release-rate limits corresponding to a dose limit, and then to convert them to a limit on radionuclide concentration in wastes by assuming a mass-dumping rate (10^8 kg per year). Throughout the preparation of the revision, there was debate as to whether both release-rate limits and concentration limits should be included in the definition. Various suggestions were made as to how to include release-rate limits. Since it is much more difficult to demonstrate compliance with release-rate limits than with concentration limits, it was agreed that the quantitative definition should be in terms of concentration limits. These concentration limits, together with the limit on mass-dumping rate, set a cap on the total amount of activity that could ever be dumped per year in a single ocean basin.
- *Averaging mass.* The averaging mass given in 1978 was 1000 tonnes. In discussion, values smaller than this were suggested, ranging from averaging over the mass of a typical waste package to averaging over 100 tonnes. Larger values also were suggested, ranging from the size of a typical consignment of waste for sea dumping (a few thousand tonnes) up to 100 000 tonnes. With the addition of a qualitative definition – which prohibits the disposal of what is normally considered

* See *The Oceanographic and Radiological Basis for the Definition of High-Level Wastes Unsuitable for Dumping at Sea*, IAEA Safety Series No. 66 (1984).

** See *Sediment K_ds and Concentration Factors for Radionuclides in the Marine Environment*, IAEA Technical Reports Series No. 247 (1985).

*** *Environmental Assessment Methodologies for Sea Dumping of Radioactive Wastes*, IAEA Safety Series No. 65 (1984).

* INFCIRC/205/Add.1/Rev.1 (1978).

high-level waste (spent fuel and first-cycle reprocessing waste) – the consensus reached was that there were no overriding reasons to change the averaging mass from 1000 tonnes.

• *Source upper-bound.* Various suggestions were made as to the level of a dose upper-bound to be used in the recommendations.* No specific value for a dose upper-bound was selected, primarily because there has been no international discussion or agreement on principles to be used in establishing or applying upper-bounds for any source giving rise to doses to the world population. The types of sources to be considered include routine discharges from research establishments and nuclear fuel cycle facilities, particularly discharges to the sea and atmosphere of long-lived, globally dispersed radionuclides such as carbon-14 and iodine-129. It was felt that principles to be used in establishing and applying global upper-bounds in general should be agreed before proceeding to set a global upper-bound for dumping at sea.

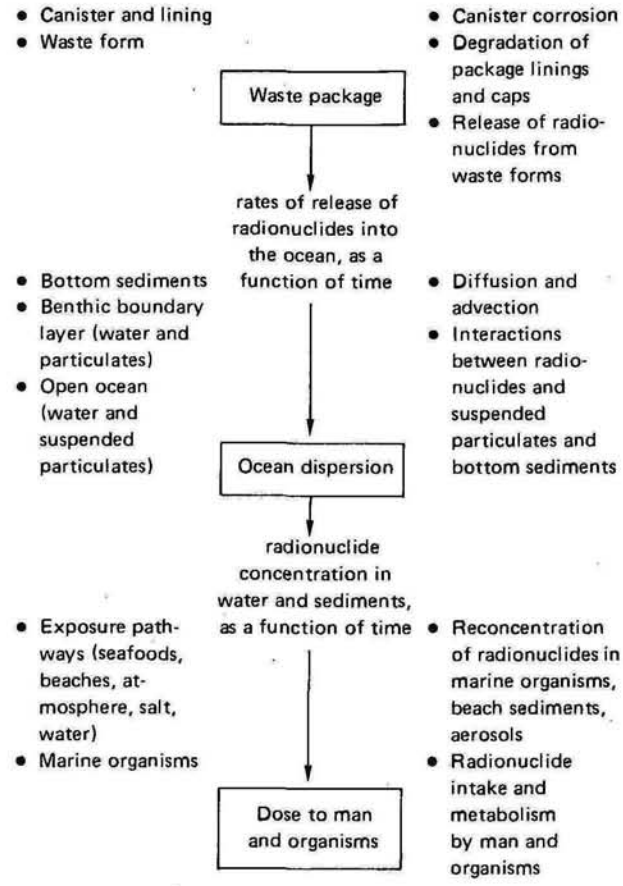
CRESP and the NEA review

The recent NEA site-suitability review drew extensively from the Co-ordinated Research and Environmental Surveillance Programme (CRESP), which was initiated in 1981 under the guidance of an executive group composed of representatives from participating countries and the IAEA. The work covered five subject areas: model development, physical oceanography, geochemistry, biology, and radiological surveillance.

• *Modelling.* The modelling task group had as its objective to develop site-specific models for calculating the dispersion of radioactivity from the dump site. A number of different models were developed within CRESP and consideration was given to the way the models should be used for a radiological assessment. (See accompanying figure for the modelling framework.) The group's work, particularly on sediment processes, was influenced by the GESAMP report. A number of benchmark calculations were made to compare two box models with a simple "ocean basin average" model from the GESAMP report. The calculations demonstrated that no one model would consistently give higher or lower values over all time and for all radionuclides.

• *Physical oceanography/geochemistry.* The physical oceanography and geochemistry task groups were combined because of complementary interests. Much of the new work has been published by the NEA.**

Modelling framework in the radiological assessment



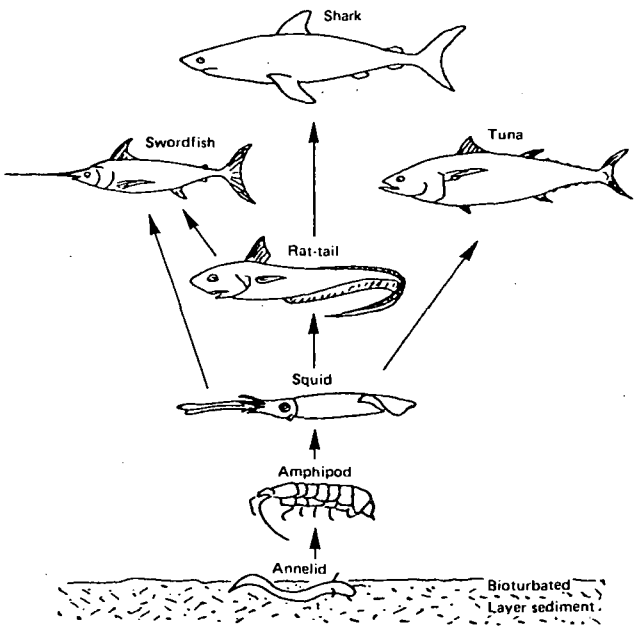
Current measurements have been taken within the site and across the eastern Atlantic and a deep, neutrally buoyant float experiment has been started. Water has been collected for measurement of the concentration of natural and man-made tracers and for measurement of particle concentrations in the benthic nepheloid layer. Sediment cores were collected to examine the sediment composition, particle-water interactions, and bioturbation processes.

• *Biology.* The main objective of the biology task group was to identify biological pathways back to humans, as well as to marine organisms. Much has been learned of the deep-sea biology of the site. It confirms that the biology is not unlike that in other parts of the North Atlantic Ocean. Experimental study of the colonization of dummy (non-radioactive) drums, and inspection of drums recovered by research vessels, have not indicated any evidence so far of activity. The group also looked at the potential transfer of radioactivity along a theoretical food chain. (See diagram, next page)

• *Radiological surveillance.* The radiological surveillance task group collected indicator materials, particularly sediments and biota; participated in inter-

* The lowest value suggested was 0.01 mSv a^{-1} and the highest 0.5 mSv a^{-1}. This range may not be as large as it appears because some dose levels were suggested as bounds for world-wide dumping practices, while others referred to dumping at a single site or in a single ocean basin.

** See *Interim Oceanographic Description of the Northeast Atlantic Site for the Disposal of Low-Level Radioactive Waste*, Vol. 2, OECD/NEA (1985), and *Review of the Continued Suitability of the Dumping Site for Radioactive Waste in the Northeast Atlantic*, OECD/NEA (1985).



A theoretical food chain studied by an NEA group to examine potential transfer of radioactivity.

calibration exercises between laboratories performing analyses of low-level samples; provided catch statistics for coastal fisheries; and examined the black scabbard fishery (with catches at depths up to 1500 meters).

Site suitability review. The work done through the co-ordinated research programme resulted in a greatly improved data base, a better understanding of deep ocean dynamics and transport, and more comprehensive and site-specific models for calculation of doses to people and the marine biota. This effort has formed the scientific basis for the site suitability review. The review concluded that, from a radiological protection point of view, the current site is suitable for the continued dumping of radioactive material for the next 5 years at rates no more than 10 times the average of 1978–82.

International rules and roles

The 1972 London Dumping Convention (LDC) lays down strict rules for sea disposal of all types of pollutants – both chemical and radioactive – and prohibits the dumping of a whole range of substances, including highly radioactive wastes. Dumping of other substances is allowed, subject to prior issuance of special or general permits by the responsible national authorities, who must comply with the LDC's criteria and conditions. A special permit is required to dump radioactive waste that is not prohibited.

In issuing permits, authorities must take account of the recommendations of the IAEA, which is given responsibility by the LDC for defining highly active wastes that are to be considered unsuitable for sea dumping, and for formulating recommendations concerning the conditions in which dumping of other radioactive wastes may take place. (The definition and recommendations were drawn up in 1974 and have been periodically revised, with the latest revision adopted by the IAEA Board of Governors in September 1985.)

The recommendations provide for detailed ecological and environmental assessments prior to dumping, and they set forth requirements for selection of dumping sites, for conditioning and packaging wastes, and for the ships themselves. They also provide for supervision of operations by the escorting officers on board.

To further the objectives of the LDC but separate from it, the Consultation and Surveillance Mechanism for Sea Dumping of Radioactive Waste of the Organisation for Economic Co-operation and Development (OECD) was set up in 1977. It provides for: (1) establishment of standards, guidelines, and recommendations concerning the scientific, technical, environmental, and operations aspects of sea dumping operations; (2) prior consultation amongst participating countries on the detailed conditions proposed by national authorities for a given dumping operation, to ascertain whether it conforms to established rules; (3) international surveillance of dumping operations by specifically appointed representatives of the Nuclear Energy Agency (NEA) carrying out their duties in co-operating with the national escorting officer; (4) international examination of the details of the execution of operations and recommended improvements as appropriate.

In recent years, countries party to the LDC have adopted non-binding resolutions calling for the suspension of sea dumping of radioactive wastes pending further scientific studies.

– Information drawn from *NEA Newsletter* (Fall 1985).