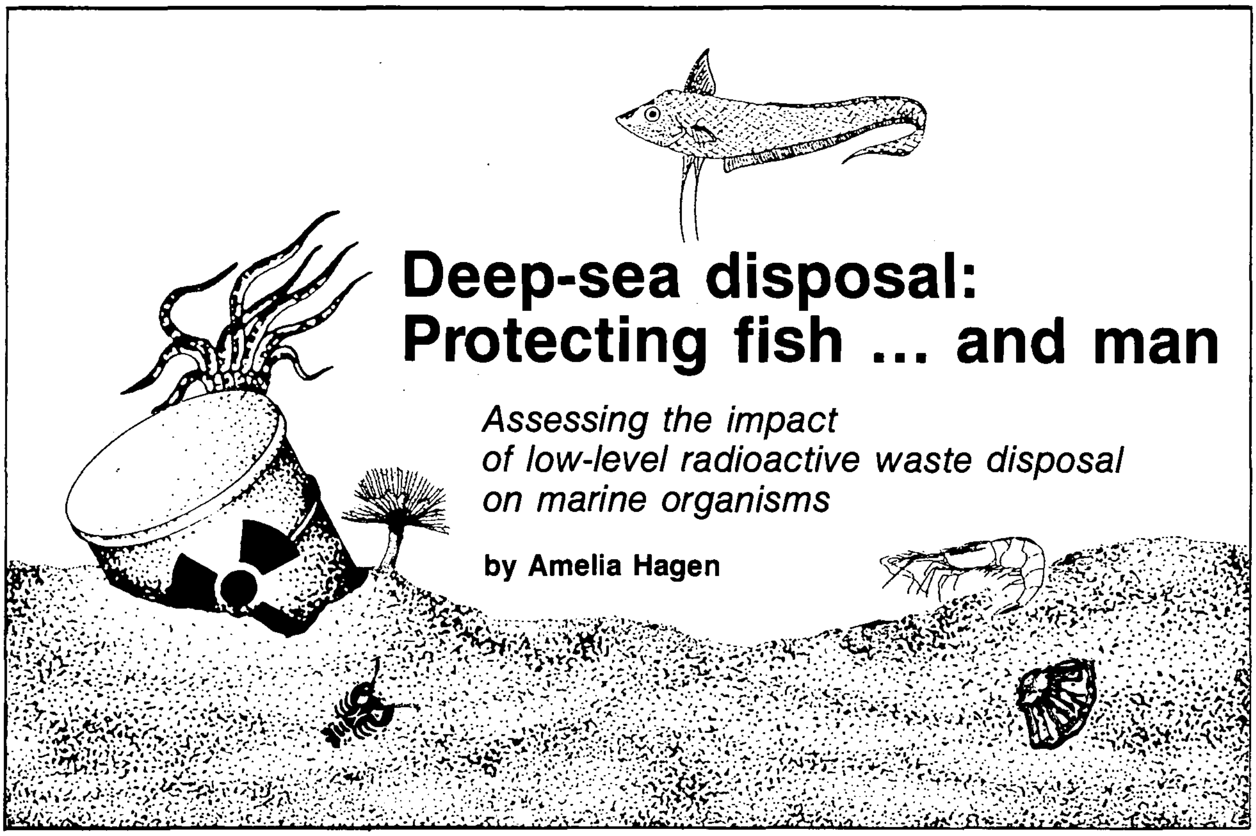

Deep-sea disposal: Protecting fish ... and man

Assessing the impact of low-level radioactive waste disposal on marine organisms

by Amelia Hagen

It is usually assumed that deliberate releases of radionuclides into the environment that are adequate for the protection of man are also adequate for the protection of species other than man. This is likely to be true for most situations. If radionuclides are released in a part of the biosphere in close proximity to human habitation, the limits adopted for human exposure are such that concentrations of radionuclides released to the environment will be very low. In the case of radioactive waste disposal into deep geologic formations, the disposal is into areas that are abiotic (lifeless). However, with disposal into the sea, it is possible that this generally held tenet will not hold. Dumping of low-level radioactive waste occurs at depths greater than 4000 metres resulting in spatial separation from pathways back to man and considerable dilution of the radioactive material. Unlike geological disposal, there are no impermeable barriers, and it is possible to postulate that deep sea marine organisms could sustain high levels of exposure from dumping onto the seabed, while levels to man are kept low.

The definition of radioactive waste unsuitable for dumping at sea prepared by the IAEA for the Convention on the Prevention of Marine Pollution by the Dumping of Waste and Other Matter, London 1972, is based on the protection of man.* It draws upon a large body of information from which estimates of dose-effect relationships and dose-risk estimates can be made. However, for the rest of the environment, there are no generally accepted dose limits that may be applied to individuals of a species, nor to whole populations, although it is generally protection at the population level that is aimed at with other species.

The development of criteria for assessing the impact on deep sea marine organisms at the population level has been attempted in a report recently published by the IAEA.** Information on the effects of radiation on aquatic organisms and on the deep sea environment, while far from complete, is sufficient to use along with models that predict potential radiation fields, and provide data and an approach to evaluate the possible environmental impact on deep sea disposal.

The report indicates that certain radionuclides may give rise to high dose rates to marine organisms if dump-

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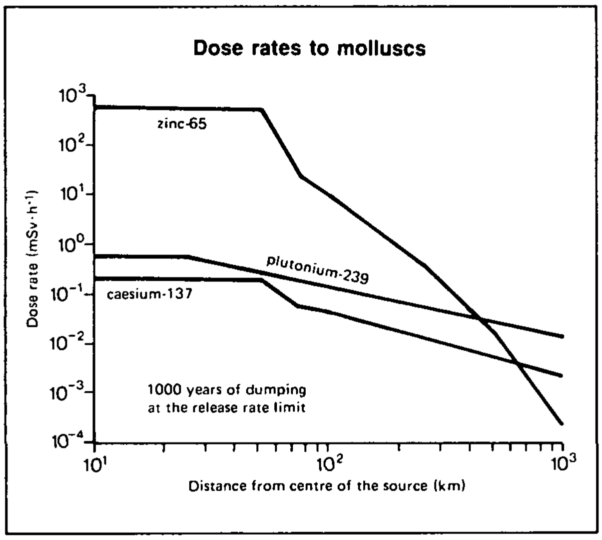
* See IAEA Safety Series No. 78.

** See *Assessing the impact of deep sea disposal of low-level radioactive waste on living marine resources,* Technical Reports Series, No. 228 (1988).

ing is carried out with the assumptions of instantaneous release at the sea floor and dumping over long periods of time. (*See accompanying graph.*) Three zones, demonstrating a gradation of effects that decrease with decreasing dose and therefore distance from the source, are defined. Excessive mortality in the vicinity of a disposal site would be expected only when the dose rates are greater than 10 millisievert per hour ($mSv \cdot h^{-1}$). The possibility that entire populations could be destroyed would be unlikely unless the domain of the species was small and totally within a high dose rate area.

In the report, a hypothetical dose rate to molluscs from three radionuclides is given as a function of distance from the source, based on annual dumping at the release rate limit set in the IAEA definition over a period of 1000 years. Calculations were made for more than 100 radionuclides to examine the potential effect on bottom-dwelling and pelagic (swimming) deep sea fish, large and small crustaceans, and molluscs, and the resulting dose rates presented in a set of tables. A summary table lists a large number of nuclides with the potential of resulting in dose rates to molluscs in excess of set values within a 50 kilometre radius of the source (the dump site) and with fewer such nuclides at radial distances of 100 and 1000 kilometres. The dose rate to molluscs from the three nuclides used as limiting nuclides for the three categories of waste in the IAEA definition were zinc-65 for the short-lived nuclides, caesium-137 for the intermediate and long-lived beta-gammas, and plutonium-239 for the alpha emitters. (*See accompanying table.*) The zinc-65, which poses no significant harm to man, has the potential for giving high doses to bottom-dwelling molluscs.

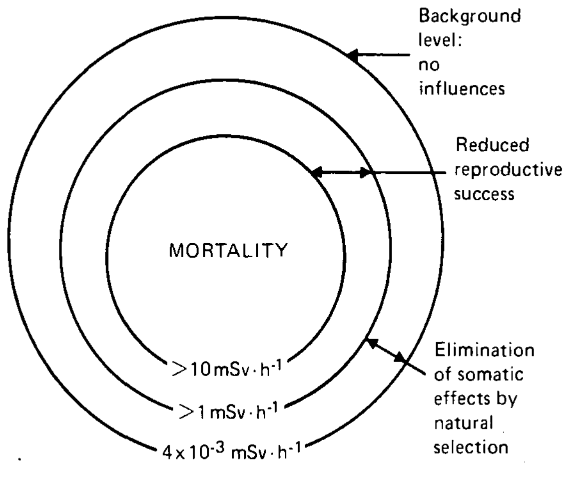


Environmental impact and effects

The report concludes that the potential for some degree of environmental impact from prolonged dumping of certain radionuclides does exist and that future revisions of the dumping definitions and recommendations should take account of potential environmental effects in the calculation of release rate limits. However, this is only one aspect to be considered. The current moratorium on disposal at sea relieves the urgency for such a revision and allows time for other technical advances to take place, such as the development of improved models, and other criteria for human exposure to be agreed upon including the use of global upper bounds to set release rate limits.

Nuclides giving rise to dose rates in excess of set value

	Nuclides		
Dose rates	Within 50 kilometres	100 kilometres	1000 kilometres
Molluscs			
>10 $mSv \cdot h^{-1}$	^{58}Co, ^{88}Y, ^{46}Sc, ^{54}Mn, ^{95}Zr, ^{144}Ce, ^{160}Tb, ^{182}Ta, ^{59}Fe, ^{110}Ag^{m}, ^{65}Zn, ^{192}Ir, ^{143}Pm, ^{227}Ac, ^{115}Cd^{m}, ^{114}In^{m}, ^{175}Hf, ^{60}Co, (^{210}Pb), (^{226}Ra), ^{153}Gd, ^{91}Y, ^{94}Nb, ^{203}Hg, (^{228}Ra), (^{230}Th), ^{159}Dy, ^{152}Eu, ^{154}Eu, ^{124}Sb, (^{232}Th), (^{231}Pa), ^{103}Ru, ^{170}Tm, ^{75}Se, ^{127}Te^{m}, (^{242}Am^{m})	^{110}Am^{m}, ^{115}Cd^{m}, ^{182}Ta, ^{94}Nb, ^{65}Zn, ^{88}Y, ^{203}Hg, ^{58}Co, (^{210}Pb), (^{226}Ra), (^{230}Th), (^{232}Th), (^{242}Am^{m})	(^{226}Ra)
>1 $mSv \cdot h^{-1}$	^{125}Te^{m}, (^{245}Cm), (^{246}Cm), (^{243}Am), (^{247}Bk), ^{113}Cd^{m}, ^{229}Th, ^{155}Eu, (^{249}Cf), (^{241}Am), ^{181}W, ^{133}Ba, (^{231}Pa), (^{241}Pu)	^{46}Sc, ^{95}Zr, ^{160}Tb, ^{124}Sb, ^{114}In^{m}, ^{75}Se, ^{127}Te^{m}, ^{103}Ru, ^{175}Hf, ^{192}Ir, ^{60}Co, ^{228}Ra, ^{59}Fe, ^{144}Ce, (^{245}Cm), (^{246}Cm), (^{249}Cf), ^{143}Pm, (^{231}Pa), (^{241}Pu)	^{94}Nb, (^{242}Am^{m})



Conceptual model of the distribution of dose around a central radiation source

In considering the impact on deep sea biota of the disposal of radioactive waste at a specific site, it can be expected that there would be a gradation of effects that would decrease in severity with decreasing dose, and thus with increased distance from the source. Three zones can be identified (*See accompanying diagram*). The first is closest to the source, and the effects that could be expected would include an increased mortality rate and frequency of histopathological changes. Acute doses required to cause mortality to the individuals in a population have been documented and are both species and life stage specific. Consequently, extensive mortality in the vicinity of a disposal site would be expected only in those areas receiving dose rates in excess of 10 $mSv \cdot h^{-1}$. The possibility that entire populations could be destroyed, which is of primary concern, would be unlikely unless the domain of a species was small and totally within the high-dose rate area of the disposal site. However, the information available indicates that many deep sea species have a wide distribution.

IDAS:

IDAS scientific results

Since the initiation of the IDAS programme, the scientifically significant results achieved as a result of the investigations can be summarized as follows:

Development of new dosimetry systems

- alanine/ESR dosimetry
- lyoluminescence dosimetry
- development of radiochromic dye film

Improvement of dosimetry systems

- methods of calibration in gamma and electron fields
- sample production, data analysis, and precision of the alanine/ESR dosimeter
- glutamine lyoluminescence dosimeters
- electrochemical potentiometry of ceric-cerous sulphate dosimeter
- results on the improvement of the ethanol-chlorobenzene oscillometric dosimeter
- packaging and handling of radiochromic dye film dosimeters

Environmental effects

- temperature during irradiation
- temperature during evaluation
- post-irradiation temperature
- humidity
- light

Dose intercomparison studies

- high- and medium-dose range (1–10 kGy, 5–100 kGy)
- low-dose range (0.01 – 3 kGy – 10 kGy)