3

INTERNATIONAL LAW AND SCIENTIFIC CONSULTATION ON RADIOACTIVE WASTE DISPOSAL IN THE OCEAN

Daniel P. Finn

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ABSTRACT

Currently, radioactive wastes are released into the marine environment from discharges into rivers and coastal waters and from dumping of packaged low-level wastes into the deep ocean. Sea dumping and effluent discharges, especially from commercial-scale reprocessing plants, will probably increase. Deep ocean or other marine repositories may be established for high-level wastes.

Different marine radioactive waste disposal methodologies are subject to distinct legal principles based on their specific location and characteristics. Current activities, primarily sea dumping, are controlled at the international level through technically oriented consultations in organizations of such long standing that these procedures can be considered customary for marine disposal. New developments in technology and in the international legal and political climate will require enhanced international organization of marine waste disposal methodologies.

3.1. INTRODUCTION: NUCLEAR WASTES, THE OCEANS, AND INTERNATIONAL LAW

Radioactive wastes released or otherwise disposed of in connection with nuclear power, weapons production, or other human activities involving radioactive substances enter the marine environment in many ways [International Atomic Energy

Agency (IAEA), 1981a]. Fallout from atmospheric nuclear weapons tests has been by far the greatest contributor to the radioactivity of the marine environment (IAEA, 1978a). The operations of nuclear vessels also result in some but small radioactive releases, but these and nuclear weapons testing will not be discussed here because official government and military activities often involve special legal and political considerations related to the doctrines of sovereign immunity [Inter-Governmental Maritime Consulative Organization (IMCO), 1976b], political question, or act of state. The current popular concern, however, is with radioactive contamination of the oceans arising from nuclear power production. Radionuclides released as a result of uranium mining and milling and other operations in the front end of the nuclear fuel cycle, prior to the fission reaction, may reach the sea by runoff from land. Nuclear power plant operations result in small discharges of liquid and gaseous effluents into rivers or coastal waters (United Nations, 1977; Chapter 1). Of course reactor accidents could lead to potentially catastrophic events, especially locally, but the back end activities, including spent nuclear fuel reprocessing and high-level packaged waste disposal, present the chief causes of environmental, health, and safety concern (Rochlin, 1979). Commercial reprocessing of nuclear fuel would increase considerably the discharge of contaminated chemical wastes into coastal waters or rivers (Hetherington et al., 1976). Spent fuel from reactors or high-level wastes from reprocessing may ultimately be disposed of in oceanic sites, or long-lived radioactive components of high-level wastes could reach the sea by runoff from breached continental repositories [Nuclear Energy Agency (NEA), 1977].

Each stage of nuclear power production and other nuclear activities also creates enormous volumes of low-level radioactive wastes—in the United States alone an estimated 8×10^6 m^3 by the year 2000—in the form of contaminated clothing, chemical agents, and equipment (U.S. Congress, 1978). Large volumes of low-level wastes are currently dumped into the ocean by several European members of the Organization for Economic Cooperation and Development (OECD) (Dyer, 1981; Chapter 2). Such disposal also was permitted in the past by several other countries and is expected to resume under American (U.S. Congress, 1980b) and Japanese authorization. Table 3.1 gives a general summary of these operations. Finally, the decommissioning of nuclear facilities presents the problem of large contaminated structures, which could be disposed of at sea; the U.S. Navy disposed of its submarine, the *Seawolf*, by dumping in 1959, and may repeat such operations (Carter, 1980).

Of the entire range of nuclear releases into the marine environment, this chapter will consider the deliberate use of the oceans as a disposal location for materials with a significant amount of radioactivity arising from civilian nuclear power production and other civilian applications of nuclear technology. Table 3.2 gives a general description of the primary types of these radioactive wastes, their characteristics, and current or anticipated methods of disposal, including marine alternatives. The fate and effects of radionuclides in the marine environment are quite distinct from their behavior on land. When disposed into coastal waters, for example, the releases can be monitored empirically through a range of special pathways (IAEA,

Table 3.1. Summary of Ocean-Dumping Operations and Plans to Date

Responsible Authority and Dates	Location	Details[a]
United States (1946–1970)	Farallon Islands; Massachusetts Bay; off mid-Atlantic states	4.3×10^{15} Bq total in about 107,000 drums; mainly at these four Atlantic and Pacific Ocean sites
Japan (1955–1969)	Shallow, nearshore sites about 40 km from mouth of Tokyo Bay	
United Kingdom (pre-1967)	Deep areas of North Atlantic, southwest of England	1.8×10^{15} Bq (Other western European countries also dumped during this period.)
Republic of Korea (1968–1973)	Territorial sea	
Nuclear Energy Agency and its members (post-1967)	Northeastern Atlantic dumpsite	3.1×10^{15} Bq in 1979; total dumping in excess of 1.9×10^{16} Bq.
Japan (1983), proposed	900 km southeast of Tokyo, 6000-m depth	Initially 5000–10,000 drums, perhaps 10^6 drums during 1980s
United States (1980s), anticipated	Unknown	Unknown

[a]Dash denotes data not available.

1981a). In deep ocean disposal, but only at known sites, the general transmission of radionuclides can be mathematically modelled (Chapters 7 and 17).

The special physical, chemical, and biological characteristics of oceanic radionuclide cycling have international legal and political significance. The rapid physical mixing, complex chemical reactions, and multiple biological transmission pathways in coastal waters raise the legal issue of whether transboundary pollution will result from radioactive discharges into coastal waters or rivers running into the sea. Dumping in the deep ocean, under general principles of quantitative assessment and control, raises the issue of the extent of the prerogative of individual states to pursue such economic activities on the high seas if they potentially interfere with similar or other economic activities of other states. This is the problem of access to and exploitation of "common property" resources. Finally, the utilization of the deep seabed beyond national jurisdiction as a disposal site raises the issue of whether this area is available for national exploitation without some sort of formal approval from the international community—whether the deep seabed is the "common heritage" of mankind and what this term means.

Table 3.2. Radioactive Waste Management

Waste Type	Characteristics	Disposal Methodologies
Effluents	Contaminated gases or liquids: leaks of contaminated primary coolant; corrosion products from contaminated tubing; irradiated water impurities; operational releases of coolant or gases; aqueous wastes from reprocessing chemical stream	Release into rivers, coastal waters, or the atmosphere
Low-level wastes	Contaminated solids or ^3H-containing water, not produced by direct physical or chemical contact with nuclear fuel; generally low in radioactivity but often bulky; above some level of contamination by transuranics. considered transuranic wastes and accorded special treatment.	Shallow burial on land, dumping at sea, some recycling and incineration
High-level wastes	High-level reprocessing wastes, spent fuel if treated as a waste, and possibly some transuranic wastes. High-level wastes are usually considered the product of the first cycle of chemical reprocessing, which results in removal of Pu and U; further cycles to remove other nuclides are possible. Resulting wastes are thermally and radiologically active due to presence of fission products and transuranics; waste nuclides are dissolved in a highly acidic (HNO_3) solution.	After interim storage (about 5 y), probably incorporated into a "waste form" (e.g., glass), packaged, and emplaced in geological formations on continents or in the deep seabed, or in engineered repositories

Resolution of international legal and political issues with respect to ocean disposal of radioactive wastes will depend on procedural and organizational concepts and on the application of substantive legal concepts that are linked with traditional and emerging zones of maritime jurisdiction (Finn, 1981). The international practice and regulation of radioactive waste dumping at sea have been characterized by international technical consultations that have assisted governments in formulating appropriate and legitimate disposal methodologies. No other activity with significant international environmental consequences have been as extensively discussed

and regulated on such a formal basis (Böhme, 1972; Moore, 1976). The willingness of states to accept the results of such technical consultations suggests that marine nuclear activities, and nuclear waste disposal activities in particular, are governed by special international procedural requirements that have broad recognition in the international community (Finn, 1981). In the future, for more complex or hazardous activities, further organizational development may be required in order to satisfy these procedural constraints.

This chapter will summarize the legally and politically significant aspects of past and present international consultations on marine radioactive waste disposal; it will discuss the substantive international legal principles applicable to various sorts of waste disposal activities conducted in different zones of maritime jurisdiction; and it will consider current international procedures and potential organizational requirements for future marine nuclear activities.

3.2. HISTORY OF INTERNATIONAL CONSULTATION ON MARINE RADIOACTIVE WASTE DISPOSAL

A succession of international legal and political actions provides the organizational context for international technical consultation on marine radioactive waste disposal. Relevant consultations occur in various international bodies ranging from nongovernmental to official character. The influence of these bodies depends both on their formal status and on the technical quality and administrative utility or indispensability of their product.

3.2.1. Radiological Protection Standards

Control of radioactive releases by national authorities is widely based on the recommendations of an international nongovernmental scientific body, the International Commission on Radiological Protection (ICRP), which is composed of committees of independent specialists who are responsible to the world radiological community which meets in conferences. The ICRP has established numerical dose limitations based on health considerations for individuals in the general population for exposure to all radioactive sources (ICRP, 1977; Chapters 4 and 20). Under ICRP recommendations no practice leading to radiological exposure should be adopted unless it produces a net benefit (justification); exposures should be "kept as low as reasonably achievable, economic and social factors being taken into account" (optimization); and the level of exposure to individuals at present or in the future should not exceed the limits established for the circumstance in question (ICRP, 1977).

To determine individual exposure from marine releases of radioactivity, a critical pathway analysis is generally undertaken to estimate the transmission of the most significant radionuclides (from which total exposure is calculated) to the most exposed group in the population through the most important pathways (Preston and Mitchell, 1973; Chapters 4 and 20). This group is ordinarily a definite coastal popu-

lation with the highest exposure to radionuclides based on their consumption of seafood or contact with contaminated sediments. In specific coastal environments (such as small islands), however, significant exposures also result from other pathways, such as inhalation of aerosols from sea spray.

3.2.2. Assessment and Control of Dumping and Other Forms of Marine Radioactive Waste Disposal

The first U.N. Conference on the Law of the Sea (UNCLOS I), which met in Geneva in 1958 and was responsible for the codifications of the international law of the sea that are still technically in force today, was unable to agree on the substantive permissibility of marine radioactive waste disposal (McDougal and Burke, 1962). The UNCLOS I was, however, able to include Article 25 in the Geneva Convention on the High Seas (UNCLOS, 1958a), which expressed the concern of states represented at the Conference and their conviction that international action was required on this subject:

> 1. Every State shall take measures to prevent pollution of the seas from the dumping of radioactive wastes, taking into account any standards and regulations which may be formulated by the competent international organizations.
>
> 2. All States shall cooperate with the competent international organizations in taking measures for the prevention of pollution of the seas or air space above, resulting from any activities with radioactive materials or other harmful agents.

In an accompanying resolution UNCLOS I also recognized the need for international regulation of the dumping of radioactive wastes in the ocean, noted the recommendations made by the ICRP on human dose and environmental concentrations of radioactivity, and recommended that the IAEA, along with other organizations (UNCLOS, 1958b):

> . . . 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.

Beginning the long history of involvement by international organizations in this field after UNCLOS I (summarized in Table 3.3), the IAEA immediately convened a group of experts on ocean disposal of radioactive wastes. The conclusions of the resulting Brynielsson report (IAEA, 1961) were essentially that ocean disposal of high-level wastes could not be recommended; that low-level wastes should be dumped only under controlled and specific conditions; and that dumping operations should be conducted on a site-specific basis. The Brynielsson report emphasized that these conclusions were provisional and accompanied them by several supplementary recommendations, including certain operational controls that should

Table 3.3. Major Legal and Political Developments After UNCLOS I

1. Brynielsson report. Published by the IAEA in 1961, this report concluded that high-level waste disposal at sea should be prohibited and low-level waste dumping be conducted under controlled and specified conditions, on a site-specific basis. It also recommended certification and international registration of dumped radioactive wastes and international designation of dumpsites and formulation of operational procedures.
2. Nuclear Energy Agency (NEA) joint disposal operations and technical consultations. Commencing in 1967, joint operations were conducted until 1979; quantities dumped annually grew from 2.9×10^{14} Bq to 3.1×10^{15} Bq and totaled 1.8×10^{16} Bq. The NEA has issued guidelines on packaging and operational procedures and serves as a forum for technical consultations, including assessments of site suitability.
3. London Dumping Convention (signed 1972, effective 1975) and associated regional agreements. This Convention prohibits high-level waste dumping and requires special permits for *all* low-level waste dumping, authorizes the IAEA to define high-level wastes and make recommendations on low-level waste dumping, and requires annual reporting of permits, issued by national authorities, to IMCO.
4. IAEA Definition and Recommendations (1975 and 1978). (a) *High-level waste definition* is on the basis of *concentration* (radioactivity per unit mass), even though the basis of the definition is the limitation of unacceptable exposure to humans estimated by oceanographic and radiological modelling of the effects of *release rates* (dumping rates). (b) Low-level waste dumping recommendations include upper limits on total dumping into an ocean basin, isolation of dumped wastes through site selection and waste containment, and environmental assessment.
5. OECD Multilateral Consultation and Surveillance Mechanism (1977). This established a mechanism of prior notification and consultation procedure, with formation of expert panels in case of objection or other uncertain conditions. The NEA representative oversees operations on board vessel and has power to suspend operations.

be adopted through action in international organizations. Specifically, it was suggested that dumped wastes be certified and internationally registered, dumpsites be designated, and operational procedures for dumping be established. It was proposed that these findings be taken as the basis for an international agreement on this matter.

The IAEA also convened in 1960 a meeting of international legal experts (the Rousseau group) to consider legal and administrative matters related to the Brynielsson report (Reyners, 1975; du Pontavice, 1976). The Rousseau group was, however, unable to reach a consensus since a minority contended that all ocean disposal of radioactive wastes was prohibited (IAEA, 1963). The majority, having concluded that they were mandated to formulate provisions based on the conclusions of the Brynielsson report, called for the establishment of international procedures—preferably through the IAEA—for notification of national disposal plans

and operations on the high seas, in any territorial sea, or in the internal waters of another state. The majority would also have followed the Brynielsson report in excluding high-level waste dumping and proposing that dumpsites be at least 2000 m in depth.

3.2.2a. Universal Legal Requirements

Following a recommendation of the Stockholm Conference that national authority be exercised to control ocean dumping and that a global instrument be concluded on this subject (United Nations, 1972), the London Dumping Convention, which provides an international legal framework to control dumping at sea, was negotiated (IMCO, 1976b). Forty-seven nations are now parties to the Convention. Under the London Dumping Convention the dumping at sea of high-level radioactive wastes is prohibited as listed in Annex I, and special permits must be issued by national authorities for the dumping of other radioactive wastes, which is listed in Annex II (IMCO, 1976b). In issuing permits, national authorities are to give careful consideration to factors specified in Annex III, including prior studies of the dumpsite [IMCO, 1976b, Art. IV(2)]. For radioactive wastes included in Annex II, parties should take full account of the recommendations of the competent international organization—the IAEA (IMCO, 1976b). Parties should notify the IMCO, now called the International Maritime Organization (IMO), which has been designated the secretariat of the Convention, of the permits they have issued, and IMCO reports this information to the parties to the Convention.

1. *Definition of High-Level Wastes.* Under Annex I(6) of the London Dumping Convention, high-level wastes unsuitable for dumping at sea are defined by the IAEA on the basis of public health, biological, or other considerations. Although radiological consultants have advised that only release rate (dumping rate) limitations are significant in establishing the unsuitability of high-level radioactive waste disposal (IAEA, 1978b), the Agency considers itself mandated by the Convention to provide a quantitative definition and has responded by developing a definition of high-level wastes expressed in terms of a concentration of radioactivity per unit mass that, if dumped, would result in an acceptable return of radioactivity to man estimated on the basis of oceanographic and radiological modelling (IAEA, 1978a). Although this definition is not qualitative, it is understood by the IAEA to exclude wastes that would ordinarily be considered high-level, such as first-cycle wastes from nuclear fuel reprocessing, irradiated fuel, and irradiated fuel cladding. However, the absence of a qualitative definition does make it possible for wastes that would otherwise be considered high level to be dumped, provided they are incorporated in a sufficient mass (U.S. Congress, 1980b).

The IAEA's efforts to define high-level wastes and restrict the total disposal of low-level wastes have required the development of mathematical models to estimate the transport of radioactivity from dumpsites to man in relation to the ICRP dose limitations for critically exposed populations (IAEA, 1978a). Within such ceilings the optimization analysis provided for in the ICRP recommendations should be

applied, ideally on an international basis (ICRP, 1977; NEA, 1977). But in no instance should the limitations on exposures from all sources be exceeded (IAEA, 1978a).

The IAEA has twice adopted models to define high-level wastes unsuitable for dumping at sea and to establish limitations on the dumping of low-level wastes. The IAEA's 1975 conclusions were based on an oceanographic model proposed by Webb and Morley (1973) (IAEA, 1975a). The IAEA was asked to reconsider its 1975 oceanographic model by the parties to the London Dumping Convention (IMCO, 1976a). In 1978 the Agency revised its definition of high-level wastes (IAEA, 1978a) and established limits for total radioactivity dumped. The oceanographic basis of this revision was a three-dimensional physical transport model developed by Shepherd (1976) (see Chapter 5). The Shepherd model is more restrictive than that of Webb and Morley for radionuclides with half-lives over 3,000 y (Shepherd, 1976).

The basic mechanisms of physical transport of radionuclides in the ocean are illustrated in Fig. 3.1. The Shepherd model essentially allows for horizontal transport by advection throughout the bottom water of an idealized ocean basin, which is also subject to vertical diffusion. Shepherd considers it probable that the effect of removal of radionuclides from the water column by sedimentation or vertical isolation by a pycnocline would probably offset any direct vertical transport, such as by upwelling. The result of application of the Shepherd model is that the radionuclide concentration in the surface layer would probably be less than the average concentration in the entire ocean basin, if it were well mixed. In adopting this model, the IAEA modified it by adding the assumption of a concentrated plume of released radioactivity for short- or intermediate-lived but very active waste substances (IAEA, 1978a). The IAEA also based its estimates of available radionuclides in the surface waters on their concentrations in the bottom water, as calculated according to Shepherd but assuming a very slow vertical diffusion (Van As and Forster, 1979). The IAEA assumed a very slow vertical diffusion, resulting in greater estimated bottom concentrations, in order to account for possible direct transmission

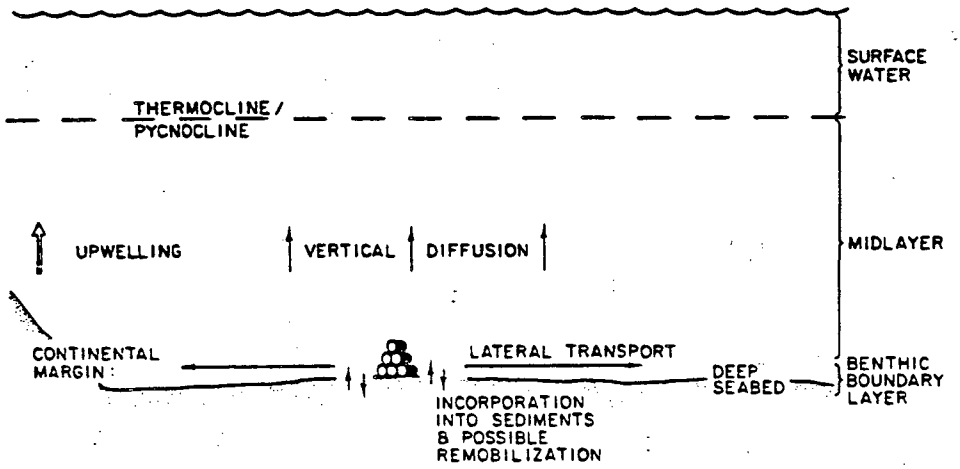

Figure 3.1. Physico-chemical transport of waste nuclides from deep seabed disposal site.

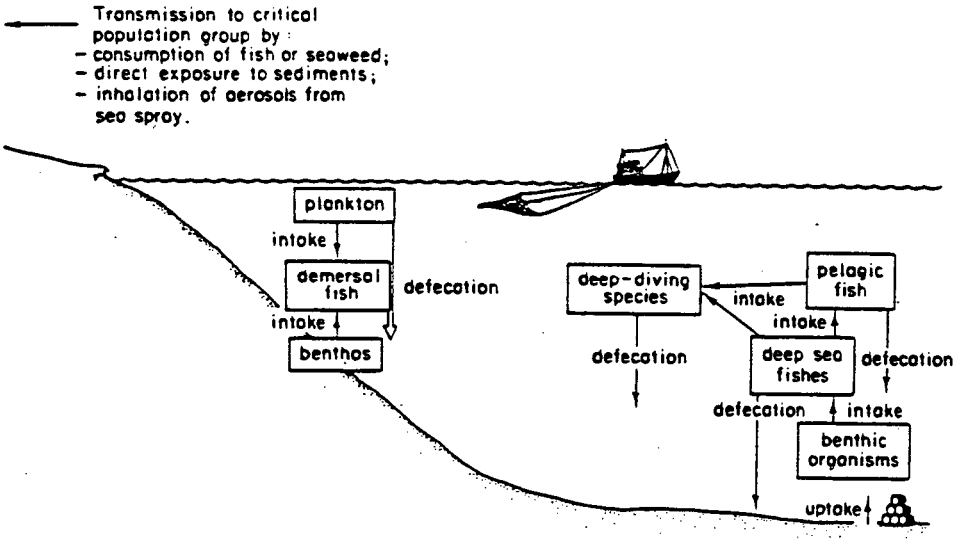

Figure 3.2. Biological transmission of waste nuclides from deep seabed disposal site.

of bottom concentrations to the surface through biological pathways (IAEA, 1978a).

The choice of a physical transport model presents only one of the complicated problems arising from the need to estimate the impact of dumping. Another problem concerns the need to determine the potential impact on human health. Radiological exposure to humans is estimated based on selected pathways, some ultimately involving direct human exposure and others ingestion of marine products (IAEA, 1978a). An illustration of major biological transmission pathways in the ocean is given in Fig. 3.2. Estimations of doses received by man from consuming marine life, as well as the dose commitments of the marine organisms themselves, are determined by looking at concentration factors. The relevant concentration factor for each marine species is a factor derived from the observed relationship of the concentrations of various radionuclides in its tissues to those in the surrounding water (IAEA, 1978b). These factors are not intended to give a completely realistic model of the uptake of radioactivity by marine organisms but rather are deliberate overestimations (Webb, 1980).

It is widely recognized, however, that certain means of biological transport could lead to accumulation of radionuclides in excess of those expected by this method (NEA, 1980), especially as the result of site-specific factors. One example is the existence of long-line fishery for the black scabbard fish near the northeastern Atlantic dumpsite (NEA, 1982). The potential importance of biological transmission at dumpsites was recognized by the IAEA in its oceanographic model (IAEA, 1978a). Biological action is generally thought to remove more radionuclides from the water column through defecation and sedimentation than are concentrated through biological pathways (Webb, 1980). Some scientists, however, are critical of primary reliance on mathematical models based on physical transport, and they stress the potential importance of site-specific biological factors (Rice, 1978). The

IAEA has indicated that it will continue to evaluate the suitability of the oceanographic and radiological models used in establishing limitations on waste dumping in terms of estimates of likely human exposure. It will be assisted in this regard in the future by the U.N. Joint Group of Experts on the Scientific Aspects of Marine Pollution–GESAMP (IMCO, 1980b, 1981a).

2. *Control of Low-Level Waste Dumping.* The IAEA recommendations on low-level waste dumping mandated by Annex II of the London Dumping Convention (IAEA, 1975a, 1978a), the most recent formulated in 1978, contain a basis for issuance of special permits for such activities. The recommendations call for a detailed environmental and ecological assessment on each application (IAEA, 1978a). Proposed operations should conform with the ICRP principles. Upper limits on total releases in a single ocean basin are given (Chapter 1, Table 1.7), and the importance of isolation and containment of waste through suitable packaging are stressed.

According to the IAEA, the required environmental assessments should be communicated to the IMCO along with the notifications of special permits for dumping required under the London Dumping Convention (IAEA, 1978a). They should include, among other things, consideration of the justification for dumping as opposed to land alternatives as well as geological and physical factors at the dumpsite that could affect waste transport. In addition, the assessment should contain information on likely doses to humans and risks to marine ecosystems and the degree to which exposures could be limited by waste conditioning, containment, or selection of a favorable site. As to the sites themselves, they should be located away from areas of fishery trawling, submarine cables in use, areas of navigational difficulties, and areas of biological productivity or potential seabed resources. Sites should be located below 50° latitude and have a depth greater than 4000 m; they should be away from continental margins, islands, and other geologically unsuitable areas. Designated sites should be as small as possible and never more than 10,000 km^2. The number of sites should be strictly limited. After dumping, monitoring should be undertaken in the vicinity of the dumpsite.

Since the adoption of the London Dumping Convention the regulatory efforts of the IAEA with respect to ocean disposal have been primarily directed toward sea dumping. Several other regulatory arrangements also exist, including regional legal agreements [International Legal Materials (ILM), 1974, 1976, 1978] and special administrative procedures adopted by specific groups of states on an exclusive basis.

3.2.2b. Multilateral Arrangements

Prior to adoption of the London Dumping Convention, twelve European countries had already concluded the Oslo Convention to control dumping in the eastern North Atlantic Ocean and the North Sea (ILM, 1972). This convention has served as a model for regional conventions adopted for other areas as well as for the London Dumping Convention itself. As under the London Dumping Convention, the Oslo Convention parties agreed, among other things, not to permit dumping of certain Annex II substances of the London Dumping Convention into North Sea

waters without a special permit issued by the appropriate national authority. Although Annex II does not expressly include low-level radioactive wastes, it is generally assumed that these are covered. The commission established by the Oslo Convention is to be notified by the parties of the permits they issue for such dumping and may provide its opinion on dumping activities. Regional agreements like the Oslo Convention provide a vehicle for more stringent control of dumping and other practices and also a regional focus for efforts against marine pollution. Such regional agreements are accorded global recognition under the London Dumping Convention; parties to regional conventions can provide notifications required under the Convention indirectly through regional organizations established under these conventions (IMCO, 1976b).

In 1967 the Nuclear Energy Agency (NEA) of the OECD assumed organizational responsibility for western European dumping operations (NEA, 1968). Thereafter, dumping operations were organized and conducted by the NEA in nearly each succeeding year (Dyer, 1981). Since 1971, however, only Belgium, the Netherlands, Switzerland, and the United Kingdom have dumped wastes at sea under the NEA auspices. All NEA-supervised dumping has occurred at depths of over 3400 m at the NEA-designated northeastern Atlantic dumpsite, although the site was redelineated in 1977 (Chapter 1, Fig. 1.10). As far as operational matters are concerned, cooperation within the NEA has been most significant for those countries practicing dumping and those others within the OCED that have shown the greatest concern about disposal (Reyners, 1975). Besides designating the dumpsite, the NEA has performed such basic operational functions as arranging and supervising transportation and dumping and arranging for financial security. It has also issued guidelines on the design of packaging for dumped wastes (NEA, 1979a) and on operational procedures (NEA, 1979b).

Since 1977, individual European countries have resumed dumping operations on an individual or joint basis, without direct NEA responsibility, under the multilateral consultation and surveillance mechanism (OECD mechanism) adopted by the OECD Council. The OECD mechanism provides for a system of prior notification and consultation on radioactive waste dumping as well as supervision of actual dumping operations. For routine operations general information concerning a proposed operation is supposed to be communicated six months in advance, and operational details three months in advance. One year notice is required prior to use of a new dumpsite. Expert advisement must be sought upon request of a consulting party or in case of use of new site or unapproved equipment or techniques. An NEA representative is to accompany the ship during operations; the NEA representative can suspend operations in the event of disagreement between him and the national escorting officer.

3.2.3. Current Issues in International Control of Marine Radioactive Waste Disposal

Dumping of low-level radioactive wastes at sea has been subject to several international arrangements since UNCLOS I encouraged international cooperation on dumping and other forms of marine radioactive waste disposal (UNCLOS, 1958a,

1958b). The international cooperation in this field has been progressive. New issues have emerged as agreement has grown on certain aspects of dumping; novel or significantly increased marine nuclear activities will lead to calls for further international controls.

3.2.3a. Environmental Assessment

Under the London Dumping Convention special permits may be issued for low-level waste dumping "after careful consideration of all the factors . . . in Annex III, including prior studies of the characteristics of the dumping site" in relation to the suitability of the site itself or the effects of its use (IMCO, 1976b). Such consideration may not be required by the Convention in each case, since Annex III itself provides only that the factors included in it are to be considered in establishing criteria for permit issuance. On a similar point, a U.S. court has concluded under domestic law that the U.S. Environmental Protection Agency administrators were not required to apply Annex III standards directly but simply to ensure that they were reflected in criteria established under relevant U.S. regulation (U.S. Court of Appeals, 1980).

As noted earlier, the recommendations of the IAEA call for a "detailed environmental . . . assessment" of the consequences of issuing special permits (IAEA, 1978a), including an examination of the alternatives to the proposed operation, factors significantly affecting the transport of waste nuclides such as geological and physical oceanographic characteristics at the dumpsite, dose commitments to humans, and the resulting risk to marine ecosystems. The IAEA interprets this to mean that appropriate studies should be made of dumpsites but that detailed field and experimental studies would not be necessary in each case. The IAEA believes, however, that notifications of special permits issued under the Convention should include this environmental assessment for each permit.

The extent to which environmental assessments should accompany notifications has become an issue in formal consultations of the parties to the London Dumping Convention. The United States has proposed that parties implement the IAEA recommendation; the United Kingdom and the Netherlands have opposed its adoption (IMCO, 1980a). Discussion has centered around the comparative utility of providing environmental assessments on specific operations, and what they would include, versus proceeding to designate and evaluate dumpsites.

3.2.3b. Dumpsite Administration

As the quantity of radioactive wastes dumped at sea increases, proper site selection and monitoring assume greater importance in protecting man and marine resources (NEA, 1980b). Studies of radioactive waste dumpsites are required by the London Dumping Convention and the recommendations of the IAEA (1978a). Due to its organizational role in conducting dumping operations, however, the NEA has been the chief forum for discussion of what studies are required for designation of a dumpsite and its continued use.

Reviews of the current NEA dumpsite and its use have been conducted by the NEA expert groups in 1978 and 1979. Considerable disagreement has occurred at these meetings (U.S. Department of State, 1980). The 1978 meeting concluded that the site could be used only for one additional year, primarily because of the dearth of information about the current site (NEA, 1979c); the 1979 meeting concluded that the site could be used for five additional years but that a site-specific scientific research program should be developed in 1980 and implemented in 1982 (NEA, 1980a, 1980b; U.S. Department of State, 1980). The United States has taken the position that continued use of the site should be conditional upon the timely development and implementation of these site plans (U.S. Department of State, 1980; IMCO, 1980a). The NEA expert consultants have developed a plan, but actual research and analytic responsibilities remain unclear (NEA, 1981).

Although site administration for current dumping activities has been performed by the NEA, it is uncertain whether the NEA can fulfill the role of a regional organization under the London Dumping Convention (IMCO, 1980a). Article VIII of the London Dumping Convention calls for the establishment of regional agreements based on characteristic regional features. The NEA is not organized according to geographically regional lines; it is open only to OECD members and includes members outside the North Atlantic area, such as Japan. Questions have been raised at consultative meetings of the London Dumping Convention parties as to whether the objectives of the NEA are fully consonant with those of the Convention (IMCO, 1980a). Expansion of dumping activities outside the North Atlantic area, for example, by Japan in the Pacific (Chapter 1, Fig. 1.11), subject to NEA procedures, may lead to further international questioning of whether the NEA can legitimately exercise regional functions (Finn, 1982).

3.2.3c. Disposal Strategy

As a result of proceedings under the London Dumping Convention, in both the IAEA and the NEA a general strategy has begun to emerge for future sea dumping and possibly for other marine disposal methodologies. In its provisional definition and recommendations, the IAEA (1975a) defined high-level wastes in terms of the concentrations of various types of radionuclides per unit mass, and it established only general guidelines on low-level waste dumping without numerical limitation of postulated total releases from dumped wastes (IAEA, 1978a). The London Dumping Convention parties then requested reconsideration of the strategy of dilution and dispersion implicit in the provisional definition. In its revised definition and recommendations, the IAEA (1978a) responded by adopting numerical limitations for yearly releases of radionuclides into an ocean basin and stated: "It is essential that a general policy of continued isolation and containment of radioactive wastes after descent to the seabed should be pursued through the use of suitable packaging to minimize to the extent reasonably achievable the radioactivity which might ultimately be released, thereby preventing unnecessary contamination of the marine environment."

Dumping at sea cannot be considered a true isolation strategy since the

containment of wastes is expected to succeed only partially and waste nuclides are presumed to become dispersed in the ocean, which would help dilute their concentrations to safe levels. The IAEA oceanographic and radiological models assume that all the radioactivity contained in dumped wastes is released immediately upon reaching the bottom (IAEA, 1978a). Greater isolation and containment of wastes can be achieved, however, through enhanced administration of dumpsites and improved waste packaging and conditioning.

3.2.3d. Reprocessing Effluents

Although effluents are regularly discharged into internal and coastal waters from the operation of nuclear power plants, the most radiologically significant discharges are from reprocessing facilities (Hetherington et al., 1976). Reprocessing of spent nuclear fuel is a chemical process (Bebbington, 1976) that produces contaminated wastes, some of which have to be discharged for economical operation (Hetherington et al., 1976). Reprocessing wastes contain substantial amounts of transuranic nuclides as well as a wide range of other radionuclides (United Nations, 1977; Hetherington et al., 1976).

Existing commercial reprocessing plants such as Windscale in the United Kingdom, Cap de la Hague and Marcoule in France, and Tokaimura in Japan discharge sufficiently radioactive effluents to justify concern about health consequences for exposed groups in the population (Chapter 1, Table 1.9). British figures based on critical pathway analysis reveal that the exposure of the critical population near Windscale has occasionally reached 10%, and sometimes 40%, of the ICRP annual limits (Hetherington et al., 1976; Webb, 1980). There does not appear to be a general policy in the United Kingdom, or elsewhere, concerning precisely what proportion of the total ICRP limits would be acceptable for exposures from this source. Under the ICRP recommendations all doses to exposed human populations must be summarized (ICRP, 1980), and all such exposures should be justified and optimized, both independently and relatively (ICRP, 1977). The advent of large-scale commercial reprocessing of nuclear fuel could lead to much greater exposures from this source, both to domestic populations and the populations of neighboring states or states that utilize affected marine resources.

3.2.3e. High-Level Waste Emplacement

High-level wastes from nuclear fission—spent nuclear fuel, reprocessing wastes, and associated wastes (Willrich and Lester, 1977)—contain radiologically hazardous substances that must be isolated from the living environment for long periods of time. Depending on the exact criteria selected, effective isolation may be required for a period from 10,000 to 1,000,000 y (Cohen, 1977). In most countries with an announced disposal strategy, mined geological repositories are the favored solution for high-level waste disposal (IAEA, 1980; Chapter 21), although continued techni-

cal and political difficulties are expected. Resorting to the oceans is also ultimately probable for several reasons:

1. Greater scientific understanding of oceanic processes may provide greater security in assessing the effects of disposal on the marine environment.
2. Rapidly developing marine technology may provide reliable means to design, implement, and monitor a waste disposal system and, if necessary, to retrieve disposed wastes.
3. The sediments of the deep seabed, which would tend to trap released radionuclides (Bowen and Hollister, 1980), constitute in certain areas one of the most geologically stable environments in the world (Chapter 13).
4. Partial or complete reliance on the oceans could meet qualitative criteria such as multiplicity of sites and resistance to future human intrusion (Rochlin, 1977).
5. Repository location in the oceans could decrease domestic political pressures associated with choice of a continental repository location (U.S. Congress, 1980b).

Several countries are studying the possibility of locating high-level waste repositories in the oceans, including emplacement of such wastes in the deep ocean. The United States has indicated that it will continue to develop the concept of burial of such wastes in the sediments of the deep seabed (subseabed emplacement) [U.S. Department of Energy (DOE), 1980]; it has obtained the cooperation of several other OECD countries at the technical level through the establishment of a seabed working group (SWG) within the NEA (Sandia National Laboratories, 1980; Chapter 14). The United Kingdom has supported studies of improved isolation and containment that would allow disposal on the deep seafloor (Chapter 1). Several Western European and American authorities have shown an interest in a variety of ocean disposal methods–including on-seabed emplacement (Preston, 1975), disposal on or in the continental shelf (Sullivan, 1982), the mining of geological repositories on islands (DOE, 1980) and construction of artificial islands on the continental shelf (DOE, 1980).

Perhaps the most developed of such concepts at present is subseabed emplacement. The U.S. DOE and other government agencies have sponsored considerable research on this concept (see Part III of this volume). Subseabed emplacement has been selected by the DOE for continued development and possible future use, even though that agency plans to implement its primary strategy–mined continental geological repositories (DOE, 1980). The concept of subseabed emplacement envisions implanting wastes in the clayey sediments of the deep seabed (abyssal plains) in areas remote from the geologically unstable rims of tectonic plates and the great current gyres around the ocean basins that are associated with areas of high biological productivity (Chapters 13 and 14). Implantation would be by mechanical means, most likely through penetration by gravity projectiles (penetrometers) (Silva, 1977; Valent and Lee, 1977; DOE, 1980). Operational monitoring would occur

at least to the extent required to ensure that correct placement was achieved and that the sediments around the waste canisters were returned to a satisfactory state (DOE, 1980; Sandia National Laboratories, 1980). Although no retrieval capacity is currently planned, it would be possible to retrieve implanted waste canisters—at considerable expense—by relocating them remotely and recovering them in a drilled core (overcoring). All of these operations appear to be within the range of existing technology, although some of the operations would be difficult and expensive due to the depth of the disposal site being 4000-6000 m.

The essence of the subseabed emplacement concept is that the deep-sea sediments would provide a waste disposal medium similar to that sought in certain geological formations on the continents (U.S. Congress, 1980b)—that is, a natural medium that would retain its structural integrity despite exposure to intense heat and radioactivity, be stable over the long term, and isolate wastes from the environment (Chapter 1). Isolation would be provided by the low porosity and chemically active nature of the sediments. Wastes released from their primary containment would be unlikely to migrate to the vicinity of the seafloor because of the resistance of the sediments to physical capillary movement and because waste nuclides would tend to become chemically bound to the particles of these clays through adsorption (DOE, 1980). Aside from the effect of penetration on the sediments, the chief technical issues to be resolved about the medium itself involve the response of the sediments near the canister to high heat; the possibility of convection currents in the sediments resulting from the heat; and the ability of the sediments to absorb and retain the radionuclides (Sandia National Laboratories, 1980). Sedimentary adsorption cannot be effective for all waste nuclides or all forms of waste disposal (DOE, 1980).

Other ocean disposal concepts for high-level wastes, like subseabed emplacement, rely to a greater or lesser extent on potential dilution of released wastes by the ocean. Seafloor emplacement would rely on marine dispersion after the failure of containment, probably at best after decay of most fission product activity (NEA, 1977). In this respect it appears to be on a continuum with existing sea dumping practices. Geological repositories constructed on sea islands or in continental shelf geological formations reached by drilling from natural or artificial islands rely primarily on geological isolation (DOE, 1980). Nevertheless, they derive some of their attractiveness by the greater ease of detecting and evaluating releases into the overlying waters and the dispersion of any released wastes in the marine environment (DOE, 1980).

Proposed ocean emplacement of high-level radioactive wastes would undoubtedly lead to political and legal questions by the international community concerning the permissibility of such activities; their technical feasibility and environmental, health, and safety consequences; the relationship between such activities and current international controls on marine radioactive waste disposal; and additional organizational prerequisites for their implementation. These issues will be enhanced by the likely location of such activities outside areas of national jurisdiction, the risks that high-level waste emplacement and associated operations pose to the international marine environment, and the connection of spent fuel and high-level waste manage-

ment with unresolved questions concerning the international organization of the nuclear fuel cycle (Finn, 1981).

3.3. MARINE RADIOACTIVE WASTE DISPOSAL METHODOLOGIES AND SUBSTANTIVE INTERNATIONAL LEGAL PRINCIPLES

Marine radioactive waste disposal must be viewed in the context of received and emerging international law on the environment, natural resources, and the oceans in particular. As a result of the conceptual difficulty of ascribing liability and assessing damages for any injuries allegedly suffered as a result of marine radioactive waste disposal activities, at present regulation of disposal activities rather than compensation for resultant injuries would appear to be of primary legal significance (Ballenegger, 1975; Hardy, 1971). The need for effective regulation also results from the potentially serious and long-lived nature of the environmental harm that could occur as a result of such activities (Hardy, 1971; du Pontavice, 1976). Conceptually, an international legal problem could arise in this context whenever the disposal policies of one state interfere with another state's rights to common property resources (such as high-seas fisheries), jointly controlled resources (such as the resources of international river basins or migratory fish species), its own resources (the environment of its coast and territorial sea or the living resources of its economic zone), or potentially internationally owned resources (such as the mineral resources of the deep seabed) (Bilder, 1980).

There is little question that the physical transport of radioactive substances to the national territory of another state would legally constitute international pollution when it is of sufficient magnitude. In the *Nuclear Tests Cases*, the International Court of Justice (ICJ) based its preliminary measures of protection (which were not accepted by France) on significant anticipated fallout from a series of French tests in the South Pacific onto the national or colonial territories of Australia and New Zealand (ICJ, 1973). Marine radioactive waste disposal would similarly be subject to international law in appropriate circumstances as a source of marine pollution, which is usually defined as follows (United Nations, 1969; UNCLOS, 1980):

> . . . the introduction by man, directly or indirectly, of substances or energy into the marine environment (including estuaries) which results or is likely to result in such deleterious effects as harm to living resources and marine life, hazards to human health, hindrance to marine activities, including fishing and other legitimate uses of the sea, impairment of quality for use of sea water and reduction of amenities.

What is noteworthy about this definition is that it is phrased primarily in terms of human uses of the sea and its resources (Springer, 1977). These protected uses must be seen, in turn, as referring to the interests of states since, if no state interest were violated by an alleged act of marine pollution, no claim could arise under international law (Hardy, 1971; Springer, 1977). The interests of states in the environment and marine resources can arise only in the four instances cited here, which

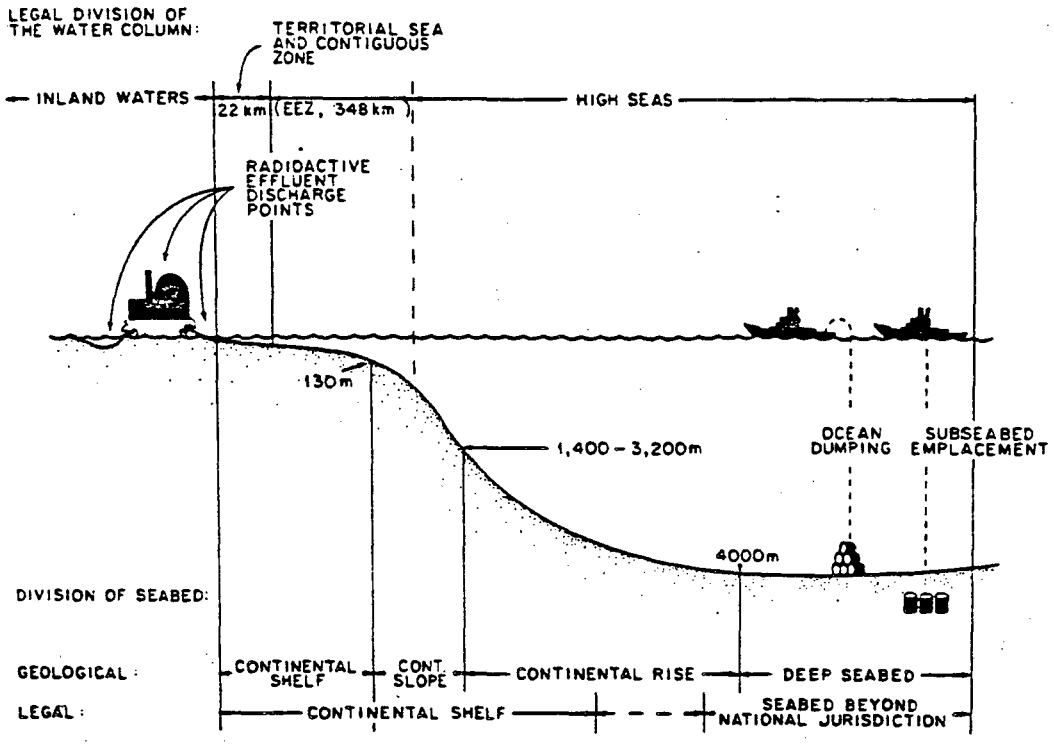

Figure 3.3. Ocean waste disposal methodologies.

correspond roughly with the traditional and emerging zones of national maritime jurisdiction. The substantive legality of marine radioactive waste disposal methodologies must therefore be assessed with respect to their location relevant to zones of maritime jurisdiction, as depicted in Fig. 3.3, and to the legal rules that apply to activities within each zone (Table 3.4).

3.3.1. Effluent Discharges into Coastal and Inland Waters

Discharges from nuclear power plants and reprocessing facilities (Chapter 2) into rivers, estuaries and bays, or coastal waters are primarily subject to national environmental policies, which apply in internal waters and territorial seas that fall within national sovereignty. A number of resolutions of the U.N. General Assembly stress the sovereign right of states to decide their internal natural resources policies (Sohn, 1973; United Nations, 1974). But this generally conceded right (Rajan, 1978) is coupled, among other things, with the obligation to avoid environmental harms outside the nation's borders. According to Principle 21 of the Stockholm Declaration (United Nations, 1972): "States have, in accordance with the Charter of the United Nations and the principles of international law, the sovereign right to exploit their own resources pursuant to their own environmental policies, and the responsibility to ensure that activities within their jurisdiction or control do

Table 3.4. Legal Principles Applicable to Environmentally Significant Activities in the Seas

Inland waters and territorial seas	Coastal state has full sovereignty over natural resources, subject to avoidance of transboundary pollution effects, except when special rules apply (shared water resources, applicable international agreements).
Proposed exclusive economic zone	Coastal state has primary management jurisdiction over living marine resources.
Continental shelf	Coastal state has jurisdiction over all activities connected with the resources of the continental shelf and probably the exclusive right to authorize all construction or placement of facilities.
High seas	"Reasonable use": Exercise of high-seas freedoms with reasonable regard to the similar interests of other states.
Seabed beyond national jurisdiction	"Common heritage of mankind," possibly not subject to national appropriation; states should avoid pollution of the seabed resulting from seabed activities.

not cause damage to the environment of other States or of areas beyond the limits of national jurisdiction."

Discharges from nuclear facilities into coastal or internal waters will inevitably be transported to areas of the high seas and the territorial seas and marine resource zones of other nations (Kautsky, 1980). To date, no evidence is available about harm occurring as a result, nor have any formal diplomatic protests been issued (Pelzer, 1969). International evaluation of proposed activities would be necessary before reprocessing becomes widespread, however.

The ICRP (1977) recommendations require that all sources of radioactive exposure to affected human populations be included in calculating radiological doses subject to limitation, and that the resulting dose commitments be justified and optimized. Effluent discharges authorized by one state could prejudice decisions of other states about similar discharges or other forms of radioactive waste disposal, as well as whether and how to develop coastal fisheries or other marine resources over which they have national jurisdiction. Exposures from this source could even affect national decisions about human exposures from other, nonmarine, sources of radiation such as nuclear medicine. This suggests that at least "harmonization" of national policies on such discharges would become necessary if significant transboundary effects occur (Royal Commission on Environmental Pollution, 1976). In addition,

effluents reaching the high seas or the resource zones of other states could affect the values of subsistence or commercial fishery development or coastal amenities in such a way that economic and social policies of other states could be generally affected. This problem would appear to call for avoidance of pollution of such areas in excess of some internationally agreed standards yet to be formulated. Effluent discharges could also become subject to direct international regulation through embryonic legal agreements controlling land-based sources of pollution (Hickey, 1978), such as the Paris Convention (European Community, 1974) negotiated within the European Community.

3.3.2. Low-Level Waste Dumping on the High Seas

Sea dumping of low-level wastes has usually occurred in deep ocean areas, although some early dumping also occurred on the continental shelf; modern operations are generally conducted in deep ocean areas remote from land. As an activity occurring on the high seas and primarily affecting the living resources of the high seas, dumping is subject to the "reasonableness" test derived from Article 2 of the Geneva Convention on the High Seas (UNCLOS, 1958a, 1980; McDougal and Burke, 1962). Since most dumping takes place in areas relatively distant from land, the seabed used to receive dumped wastes is usually beyond national jurisdiction. As such the claim could be made that this area is arguably subject to common ownership and control under legal developments associated with UNCLOS III. Dumping could constitute an impermissible appropriation of the deep seabed preventing activities such as mineral exploitation (Böhme, 1972) or constituting pollution of the deep seabed and its living resources (United Nations, 1971). These claims could prove politically attractive. It is improbable, however, that dumping would interfere with exploitation of seabed mineral resources. The effect on organisms of the deep seabed would also appear to be marginal, both economically and biologically. Much more important legally, therefore, is whether dumping operations are reasonable uses of the high seas. This treatment of the activity is supported by the history of state practice, international agreement, and scholarly commentary, which have all approached dumping as a high-seas activity. Nevertheless, this history has to date been dominated by a limited number of states. The reasonableness of sea dumping could be approached differently by nations with divergent economic and cultural situations, including patterns of livelihood and dietary preferences, and by those with less stake in nuclear power (Finn, 1983).

Regardless of the reasonableness of dumping as a high-seas activity when properly conducted (McDougal and Burke, 1962), disputes about the reasonableness of specific operations may occur. For example, Portuguese officials have voiced uneasiness with current operations at the northeastern Atlantic dumpsite (IMCO, 1978) and have stressed the need for increased monitoring (de Bettencourt, 1980). But prior to the recent announcement by Japan that it plans to recommence dumping (Science and Technology Agency, n.d.), which triggered widespread reactions in the Pacific (Finn, 1983), there had been only one formal international protest over a radioactive waste dumping operation—by Mexico against an operation in the Gulf

of Mexico which the United States Atomic Energy Commission (AEC) proposed to license (Lowenstein, 1961). A representative of Mexico attended the proceedings on the application, and the AEC ultimately denied permission to dump the wastes.

The reasonableness of high-seas dumping as a legal matter depends in part on the extent to which relevant scientific issues have been identified and resolved (McDougal and Burke, 1962). Due to the presence of long-lived radionuclides in dumped wastes, the consequences of proposed dumping must be viewed cumulatively (IAEA, 1978a). The effects of dumping operations conducted by several nations in an ocean basin must be considered in the aggregate to determine if dumping would constitute impermissible pollution of the high seas, either by interfering with other uses of the high seas such as fishing (either directly through its effect on populations of marine organisms or more likely by resulting restrictions on human intake of fish products) or by causing pollution of coastal waters (de Bettencourt, 1980). Specifically, the contributions of waste dumping to human exposures under the ICRP dose limits must be calculated on an international basis; therefore waste-dumping policies, to be formulated consistently with the ICRP recommendations (IAEA, 1978a), must also be determined subject to international controls. An obligation to cooperate in resolution of the scientific and administrative issues would thus appear to be a consequence of the distinctive features of sea dumping, and the obligation of states would be to ensure that such activities are reasonable in the circumstances. The resulting international procedural obligations will be discussed in the next section.

3.3.3. Deep Ocean Emplacement of High-Level Wastes

Deep ocean disposal of high-level radioactive wastes would most likely occur via seabed or seafloor emplacement beyond national jurisdiction. Deep ocean disposal would necessarily represent a deliberate decision to use the ocean as a medium of disposal or at least as a buffer, or secondary medium, in case of an unanticipated release of wastes from primary containment (DOE, 1980). Current international law is poorly formulated to deal with situations in which national actions create an environmental risk to the global commons or other transfrontier areas. For example, the current definition of marine pollution (UNCLOS, 1980) appears to require an actual release of pollutants and not simply a risk of their release, however likely or potentially damaging. Legal commentators discern, for certain "ultra-hazardous" activities, an emerging norm of customary international law requiring prior international consultation (Jenks, 1966; Kelsen, 1972). The substantive legal rules for such new activities would be those generally accepted in the world community as a result of intergovernmental consultation and cooperation within international organizations. Even if no definite substantive rule were violated in conducting a given activity, a state could still be held responsible for its consequences (Quentin-Baxter, 1980). Since state liability would probably not be an effective remedy if the risked consequences were to occur, other states could be expected to take political action to prevent such activities from being conducted if they were not satisfactorily consulted.

Deep ocean emplacement of high-level radioactive wastes, although it would occur at abyssal locations, would involve strong measures to isolate and contain the wastes from the marine environment. Subseabed emplacement would actually utilize the sedimentary strata of the deep seabed to isolate the wastes, although admittedly these formations are permeated with seawater (Corliss and Hollister, 1979).

The London Dumping Convention now prohibits the dumping at sea of high-level wastes. Nothing in the Convention or the regulations of the IAEA exempts the disposal of otherwise black-listed wastes if they are effectively contained. But seafloor emplacement could be legitimized under the Convention framework in several ways, including amendment of the annexes to the Convention, adoption of a special protocol, or more rule making by the IAEA. For example, special regulations were adopted by the Convention parties for the new technology of incineration of certain Annex I substances on board specially equipped vessels at sea since this method was shown to lead to virtually complete destruction of these substances (U.S. Department of State and Environmental Protection Agency, 1979). The parties amended the annexes of the Convention and adopted a special set of regulations and technical guidelines to control this practice. New containment methods for seafloor emplacement of high-level radioactive wastes could be treated similarly.

Further development of the IAEA definition of high-level wastes might also make deep ocean emplacement permissible. The IAEA is not authorized to determine the scope of "dumping" subject to the London Dumping Convention, however. If the IAEA proceeded to define high-level wastes in terms of anticipated release from containment, parties to the Convention could claim that it had not provided a definition of the prohibited substance, as required, but had in effect decided that otherwise prohibited wastes, if disposed in a certain manner, were not dumped at all. If the parties wished to alter the scope of the term "dumping," or otherwise make special arrangements for deep ocean emplacement, they could do so explicitly. If, however, the parties wished to take this step without initiating the action themselves, they could acquiesce in such a definitional action by the IAEA. In the latter case there would be an action by an international organization that could carry more weight outside the circle of countries currently active in regulating sea dumping of radioactive wastes.

Subseabed emplacement was conceived in order to provide even greater isolation of waste nuclides than could be provided through improved engineered barriers; therefore it creates additional definitional problems. The London Dumping Convention defines dumping as "any deliberate disposal at sea of wastes or other matter from vessels . . . at sea." Ultimate disposal, it appears, must be "at sea"; this interpretation is confirmed by the recurrence of the phrase in describing the location of the disposing agent (Deese, 1978). The background and certain characteristics of subseabed emplacement argue against considering it a method of disposal "at sea." The concept of subseabed emplacement was developed by U.S. federal agencies as a variety of geological emplacement (U.S. Congress, 1977, 1980b). Initial work on this technique was aimed ostensibly at achieving complete or nearly complete isolation of the wastes from the marine environment (U.S. Congress, 1977), but it now

appears that the objective is "satisfactory containment" (U.S. Congress, 1980b) accompanied by a recognition that certain waste nuclides might escape (DOE, 1980). The nature of transportation to the disposal site (by and from ships) does not appear legally significant in this connection, since nothing currently prohibits maritime transportation of high-level wastes to a repository or elsewhere.

There has been little development of this issue at the international level. A draft of the IAEA definition stated that subseabed emplacement should be considered a form of geological disposal and not dumping (IAEA, 1973a). The statement was deleted after the United States objected to its inclusion in a section entitled "sources of radioactivity in the sea" since, it was claimed, it would not be such a source (U.S. Department of State, 1973). The IAEA's radiological consultants have viewed subseabed emplacement as a method of waste containment that should be explored to limit radioactivity releases (IAEA, 1978b).

Aside from the esoteric issue of whether subseabed emplacement would be dumping within the London Dumping Convention, the issues associated with it are generic to deep ocean emplacement. These are the reasonableness of the activity as a use of the high seas, its effect on areas of the seabed beyond national jurisdiction, and the resultant risk of pollution to the entire ocean. Although several experts have claimed that high-level waste disposal in the deep ocean, even without advanced containment, would not significantly pollute the seas (U.S. Congress, 1980b), the current consensus of scientific opinion would appear to be that such disposal would be unacceptable unless effective, long-term containment could be provided (NEA, 1977). Acceptable emplacement would also entail further development of international appreciation and regulation of other aspects of the activity such as system design, environmental assessment—including radionuclide transfer modelling and enhanced understanding of the behavior of long-lived radionuclides (NEA, 1980)—and site selection.

Deep ocean emplacement would also involve use of the deep seabed beyond national jurisdiction for disposal. Use of this area raises questions concerning potential conflict with the developing concept of the "common heritage of mankind." The chief issue in this respect would appear to be the nature and extent of the collective interest in the deep seabed and in activities conducted in it. The Law of the Sea Convention provides that "No State shall claim or exercise sovereignty or sovereign rights over any part of th[is] Area or its resources, nor shall any State appropriate any part thereof" (UNCLOS, 1980). It is not clear whether or not the establishment of a high-level waste repository in the deep ocean would constitute such an exercise of sovereignty or appropriation of part of the deep seabed. Although Part XI of the Convention was formulated primarily to regulate the new technology of deep-sea mining for manganese nodules (Kronmiller, 1980; U.S. Congress, 1980a), the text is not restricted to such resources but speaks generally of the deep seabed and its resources. A broad list of resources is given, which includes non-manganese nodule resources, but is generally confined to minerals or mineral-bearing substances. The "activities in the area," which are subject to regulation under several provisions, are restrictively defined to include only resource-related activities. It does not appear possible at this time to determine whether deep ocean emplacement

would be subject to this regime. Deep ocean repositories could be located away from potential mineral recovery areas. After subseabed emplacement, it is even possible that mineral resources on the seafloor or in shallow sediments could be recovered normally. Concerning the capacity of the deep seabed to serve as a repository for high-level wastes, there would appear to be no realistic limit imposed by the size or characteristics of the area required (DOE, 1980). Limitations on use arise only because of extrinsic determinations concerning the desirable extent of use of a single site (Nielsen, 1978) or of general reliance on the oceans as a disposal location for high-level wastes. That is to say, the capacity of the deep seabed to serve as a repository for high-level wastes is not intrinsically a scarce resource, and thus collective ownership (common heritage) is not required in order to protect the interest of mankind.

A state operating a deep ocean repository might wish to prevent unauthorized parties from interfering with it (Rochlin, 1977; DOE, 1980) and therefore attempt to secure the affected seabed area. There would be little incentive, however, for another state or a nonstate actor to intrude deliberately. High-level wastes in a deep ocean repository would be an unappealing target for the diversion or deliberate dispersal of nuclear materials, both because of the characteristics of the wastes and the location of the repository (DOE, 1980). Exclusionary actions could probably be limited, therefore, to warning other states of the existence of the repository and deterring irrational actions, presumably by nonstate groups.

3.3.4. Waste Disposal Activities on Islands, the Continental Shelf, or Deep Seabed within National Jurisdiction

Increased international pressure on nations practicing or planning marine radioactive waste disposal could lead them to move such activities onto areas like islands, the continental shelf, or deep seabed within 370 km (200 nautical miles) of shore. The fact that the risks of marine disposal of high-level wastes are essentially global, however, could make legal immunities based on such jurisdictional considerations unavailing. Such sites would be selected for disposal operations primarily because of their oceanic location and would involve extensive maritime transport of wastes. The resulting acute or chronic releases of long-lived radionuclides would necessarily become broadly dispersed in the ocean.

3.4. ORGANIZATIONAL REQUIREMENTS FOR MARINE NUCLEAR WASTE MANAGEMENT ACTIVITIES

Extensive international consultation and cooperation have been focused on radioactive wastes, especially packaged low-level wastes, more than any other materials disposed of in the ocean (Böhme, 1972; Moore, 1976). Certain forms of international cooperation are required for marine radioactive waste disposal, based on current international agreements and customs (Finn, 1981). Existing procedural devices will be tested by future waste disposal activities such as effluent discharges

from commercial-scale reprocessing plants, increased low-level waste dumping, and potential high-level waste emplacement. The nature of these activities may make further organizational development necessary, building upon and extending current models (Schachter, 1977). Furthermore other international developments, such as in the principles of the law of the sea and nuclear nonproliferation, appear to require such organizational development before significantly expanded marine nuclear waste management activities can be legitimized within the international community.

3.4.1. Procedural Obligations

As long ago as 1958, UNCLOS I called for international control of marine radioactive waste disposal (UNCLOS, 1958a, 1958b). Various interpretations have been offered as to the legal significance of these results. McDougal and Burke (1962) have interpreted Article 25 of the High Seas Convention (UNCLOS, 1958a) as containing merely "admonishments to states to cooperate; rather than prohibit sea dumping, UNCLOS I contemplated the possibility that under proper conditions disposal can be considered a reasonable use of the sea." Other commentators have suggested that the actions of UNCLOS I resulted in an obligation to engage in cooperative scientific development of substantive norms for dumping and establishment of international controls to ensure that states do not authorize activities that would endanger human health (Reyners, 1975; Courteix, 1975). It has even been claimed that Article 25 constitutes the first international "recognition" of sea dumping that conforms with these conditions, an assertion that has gained credibility as various international arrangements have been made to regulate this activity (McDougal and Burke, 1962; Preston, 1975). Article 25 has been widely cited by commentators to support the existence of a customary law of international cooperation for marine disposal of radioactive wastes, especially by dumping (McDougal and Burke, 1962; Reyners, 1975).

There is no doubt that the actions of UNCLOS I triggered the development of international procedures and organization to control marine radioactive waste disposal. Important functions were exercised by the IAEA in consequence, including the publication of the Brynielsson report, IAEA's (1961) general document on marine radioactive waste disposal which will be revised (IMCO, 1981b). The IAEA's role has been supplemented and refined by other international developments, including negotiation of the London Dumping Convention (IMCO, 1976b) and associated regional conventions (International Legal Materials, 1974, 1976, 1978) and the development of special standards and procedures within the NEA (OECD, 1977; NEA, 1979a, 1979c). It would appear on the basis of all these developments that there is a customary international norm requiring special technical cooperation within international organizations on marine radioactive waste disposal. Developments at UNCLOS III also support the claim that there is an obligation for states to cooperate, especially through international organizations, to protect the marine environment against polluting activities, which like dumping are subject to their national jurisdiction (UNCLOS III, 1980). The exact characteristics of the required cooperation cannot be stated in the abstract, however, but must be related to the scientific issues associated with various waste disposal methodologies.

3.4.2. Organizational Issues

The current international organization of marine radioactive waste disposal is neither synoptic nor uniform. Certain apparently universal legal obligations have been created by treaty (for example, High Seas Convention) and attendant custom, and special legally binding agreements have been concluded on a global (London Dumping Convention) and regional basis. Standards and procedures have been established by international organizations on both an inclusive (for example, IAEA) and exclusive (for example, NEA) basis. The potential functions of international organization with respect to control of nuclear waste management activities could be characterized as informational, managerial, and operational (Rochlin, 1979). Within these functions several types or levels of organization would be possible, including efforts to implement a common framework for policy making, adopt a common policy, promulgate a single policy, or conduct joint operations. Current international controls on marine radioactive waste disposal incorporate several of these organizational functions and types in various combinations. For example, the present organization of sea dumping of low-level wastes is primarily informational in function and intended to provide a common framework for national decision making. Elements of international management with common policy or even joint operations can be discerned, however, for example, in the recent dispute settlement protocol to the London Dumping Convention, the powers of regional commissions (International Legal Materials, 1972, 1974), bilateral arrangements (U.S./Canada), past NEA operations, and the OECD mechanism. Future marine radioactive waste disposal activities may require further organizational development in order to acquire legitimacy in the international community (Finn, 1981).

3.4.2a. Low-Level Waste Dumping

To date, the masses of low-level wastes dumped annually have never exceeded 10% of the mass rate per site assumed by the IAEA. Total amounts of radionuclides have never exceeded 1% of the upper limits on releases into an ocean basin, and for some nuclides it has been much lower (IAEA, 1978a). These rates, however, are expected to increase; additional countries may recommence dumping, and others may commence dumping at new dumpsites. Continued pursuit of an isolation strategy for dumped wastes will require more attention to selection, operation, and monitoring of specific dumpsites. Other improvements to the current system of control should also be initiated—for example, a complete register of dumped wastes maintained by international organizations (IMCO, 1980a). It is important to realize that for some nations, sea disposal is an extremely attractive method of low-level waste disposal due to inadequate disposal areas on land (du Pontavice, 1976; Chapter 21). If such countries have to accept further substantive or procedural requirements for high-seas operations—such as improved containment, environmental assessment, or waste certification and registration—they may respond by increasing dumping activities on the basis of these controls or moving operations to deep ocean areas within their extended maritime resources (370 km, or "200 nautical mile") zones. The

status of nuclear activities within these zones, where national jurisdiction over natural resources is paramount, is by no means clear (von Welck, 1975).

3.4.2b. Discharges from Commercial Reprocessing

Effluent discharges which are directly connected to the central operations of the back end of the nuclear fuel cycle raise issues in addition to possible pollution of the international marine environment. Any nuclear pollution from routine operations is of necessity primarily related to activities in the advanced industrial countries, since nuclear power facilities are concentrated in these countries. But pollution of the high seas or resource zones of other states resulting from discharged reprocessing effluents would result from specially restricted nuclear operations. Nuclear reprocessing technology is closely held by the technologically advanced states and, when transferred, is usually provided subject to safeguards pursuant to the Nuclear Nonproliferation Treaty (United Nations, 1968). If commercial reprocessing operations remain generally confined to the advanced states, and if reprocessing services are furthermore provided by them only on a commercial basis, then the resulting pollution to the international marine environment would be from an activity not only confined to these states but also from the sales of reprocessing services that provide them further economic benefit. It is unlikely that the underdeveloped countries would accept this situation, either under the law of the sea or the current international regime to prevent proliferation of nuclear weapons. The international inequity could be reduced, though probably not completely eliminated, by unilateral measures by the technologically advanced states, such as equipment export, technical information transfer, or favorable financing for access to civilian nuclear technology or services. Multilateral solutions could also be found, such as the establishment of an international authority to develop and manage fuel cycle technology, or an international corporation to provide fuel cycle services (Rochlin, 1979). Many of the activities of such organizations could place special reliance on the oceans.

3.4.2c. High-Level Waste Emplacement

High-level waste disposal involves even more serious environmental concerns, and new legal procedures will undoubtedly be required to ensure that any such activities are subject to adequate international control (Strohl, 1978). Because of the current prohibition by the London Dumping Convention on disposal of high-level wastes at sea, some action would probably be necessary within the Convention framework before deep ocean emplacement could be undertaken. In addition some global negotiation probably will be necessary before deep ocean emplacement of high-level wastes could be conducted (Rochlin, 1979). A variety of measures short of straightforward international management, such as monitoring and exchange of information through the IAEA and NEA, advance notification and consultation (OECD mechanism and Euratom Treaty), and dispute settlement, already apply to

current ocean disposal practices, although sometimes on a limited basis (European Community, 1958).

In view of the history of cooperation in this field, the opinions of scientific experts, and the growing tendency to use managerial methods to control nuclear development and regulate sources of marine pollution, it would be politically difficult for any state or group of states to proceed with deep ocean emplacement of high-level wastes in the absence of an effective international regulatory regime. Experience at UNCLOS III and at other international conferences that consider basic issues of international equity, including access to nuclear technology (Lewis, 1980a, 1980b), also suggests that most ocean disposal options would not be politically viable unless steps were taken within the world community to achieve a consensus on the organizational prerequisites of such activities.

Assuming that satisfactory international institutions can be created for controlling spent-fuel reprocessing and resupply activities, accompanying waste management arrangements should be designed with several goals in mind (Rochlin, 1979). These include economic efficiency, the reduction of environmental hazards (including those associated with maritime transportation of high-level wastes), and the equitable provision of disposal services to underdeveloped countries. Various institutional forms and functional combinations have been proposed (Rochlin, 1979) to provide back end services on an international basis. "Fuel cycle centers" could provide such services (IAEA, 1980a), most likely on a regional basis (IAEA, 1976a), and would probably involve co-location of various facilities in order to reduce the safety and security risks associated with transportation and widely scattered independent activities (Rochlin, 1979). The fuel cycle centers could be operated on a national or international basis, and sensitive operations could be conducted within a facility or enclave inside national home territory or in remote areas. Designing an international organization to administer back end operations would involve resolving many delicate questions about the powers and structure of the organization (Williams and Deese, 1979).

Remote locations, including such marine areas as sea islands and distant coastlines, have been suggested for various back end operations, including spent-fuel storage (Washington Post, 1979a, 1979b; U.S. Congress, 1980b), reprocessing and associated activities, and high-level waste disposal (Rochlin, 1979). Such locations have appeared attractive in order to defuse domestic opposition to back end operations, to avoid national resistance to accept spent fuel or wastes from abroad, and to encourage international solutions to the organization of the back end of the nuclear fuel cycle (Rochlin, 1979; IAEA, 1980). Location of fuel cycle services in remote areas could lessen the reluctance of nuclear suppliers to permit international control of such operations (Rochlin, 1979). A number of operations could be concentrated at a single remote site to minimize the hazards of transportation losses and the dangers of diversion or theft, while realizing the economic advantages of co-location and a large-scale operation. Remote sites could be chosen for convenience of regional transportation and proximity to disposal locations. Although the detailed analysis necessary to project the characteristics of such sites is not now available, it appears that any such strategy would place substantial reliance on the oceans for transportation, physical security, and possibly waste disposal.

Exposing the oceans to the risks of maritime accidents that involve highly radioactive cargoes, high-level waste disposal in ocean locations, or greatly increased levels of reprocessing discharges will require a generally acceptable international organization of the fuel cycle and consequent waste disposal. The relationship of waste disposal to other controversial issues concerning the back end of the nuclear fuel cycle means that nations proposing systematic ocean disposal of fuel cycle wastes first will likely have to resolve the outstanding equity issues concerning the sharing of the benefits of associated nuclear technology for peaceful purposes.

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REFERENCES

Ballenegger, J. 1975. La Pollution en droit international. Travaux de droit, d'économie, de sociologie et de sciences politiques, no. 105, Librairie Droz, Geneva, 268 pp.

Bebbington, W. 1976. The reprocessing of nuclear fuels. *Scientific American*, 235 (6), 30–41.

Bilder, R. B. 1980. International law and natural resources policies. *Natural Resources Journal*, 20, 451–486.

Böhme, E. 1972. The use of the seabed as a dumping site. *In*: From the Law of the Sea towards an Ocean Space Regime, E. Böhme and M. I. Kehden (Eds.). A. Metzner Verlag, Hamburg, pp. 93–121.

Bowen, V. T., and C. D. Hollister. 1981. Pre- and post-dumping investigations for inauguration of low-level radioactive waste dumpsites. *Radioactive Waste Management*, 1, 235–269.

Carter, L. 1980. Navy considers scuttling old nuclear subs. *Science*, 209, 1495–1497.

Cohen, B. 1977. The disposal of radioactive wastes from fission reactions. *Scientific American*, 236 (6), 21–31.

Corliss, B., and C. D. Hollister. 1979. Cenozoic sedimentation in the central North Pacific. *Nature*, 282 (5470), 707–709.

Courteix, S. 1975. Droit nucléaire et droit océanique: une synthèse. *In*: Nuclear Inter Jura 75, Proceedings of a Conference in Aix-en-Provence, 29 September–3 October 1975. International Nuclear Law Association, Paris, pp 71–82.

de Bettencourt, O. 1980. Contribution au contrôle radiologique du milieu marin. *In*: Proceedings of The Third NEA Seminar on Marine Radioecology (Tokyo),

1 October 1979, Nuclear Energy Agency, Organisation for Economic Co-operation and Development, Paris, pp. 47–54.

Deese, D. A. 1978. Nuclear Power and Radioactive Waste: A Sub-Seabed Disposal Option? Lexington Books, Lexington, Massachusetts. 206 pp.

du Pontavice, E. 1976. Réflexions sur la pollution maritime d'origine radioactive. *Le Droit maritime français* (November–December), 643–676 and 708–731.

Dyer, R. S. 1981. Sea disposal of nuclear waste: a brief history. *In*: Nuclear Waste Management: The Ocean Alternative, T. C. Jackson (Ed.). Pergamon Press, New York, pp. 9–16.

European Community (EC). 1958. Treaty establishing the European Atomic Energy Community, *done* 25 March 1957, 298 U.N.T.S. 167 (1958), *entered into force* 1 January 1958. European Community, Rome, 1958.

European Community. 1974. Convention for the prevention of marine pollution from land-based sources, *not in force, reprinted in International Legal Materials*, 13, 352–376. European Community, Paris, 29 Articles, Annexes A–B, 5 Resolutions.

Finn, D. P. 1981. Ocean disposal of radioactive wastes: the obligation of international cooperation to protect the marine environment. *Virginia Journal of International Law*, 21, 621–690.

Finn, D. P. 1983. Nuclear waste management activities in the Pacific Basin and regional cooperation on the nuclear fuel cycle. *Ocean Development and International Law*, in press.

Handl, G. 1978. An international legal perspective on the conduct of abnormally dangerous activities in frontier areas: the case of nuclear power plant siting. *Ecology Law Quarterly*, 7, 1–50.

Hardy, M. 1971. International control of marine pollution. *Natural Resources Journal*, 11, 296–348.

Heath, G. R. 1977. Barriers to radioactive waste migration. *Oceanus*, 20 (1), 26–30.

Hetherington, J. A., D. F. Jefferies, N. T. Mitchell, R. J. Pentreath, and D. S. Woodhead. 1976. Environmental consequences of the controlled disposal of transuranic elements to the marine environment. *In*: Transuranium Nuclides in the Environment. International Atomic Energy Agency, Vienna, pp. 139–154.

Hickey, J. E. 1978. Custom and land-based pollution of the high seas. *San Diego Law Review*, 15, 409–475.

Hollister, C. D. 1977. The seabed option. *Oceanus*, 20 (1), 18–25.

Hollister, C. D., D. R. Anderson, and G. R. Heath. 1981. Subseabed disposal of nuclear wastes. *Science*, 213, 1321–1326.

Inter-Governmental Maritime Consultative Organization (IMCO). 1976a. Report of the First Consultative Meeting of Contracting Parties to the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter (20–24 September 1976). IMCO Doc. LDC 1/16, Inter-Governmental Maritime Consultative Organization, London, 25 pp.

Inter-Governmental Maritime Consultative Organization. 1976b. Inter-Governmental Conference on the Convention of Wastes at Sea. (London, 30 October–13 November 1971). Final Act of the Conference with Technical Memorandum and Resolution adopted by the Conference and Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter. Inter-Govern-

mental Maritime Consultative Organization, London, 36 pp. plus Amendments (Publication No. 76.14 E), 6 pp. *Done* 29 December 1972; *entered into force* 1976. Legal citation: 26 U.S.T. 2403, TIAS No. 8165.

Inter-Governmental Maritime Consultative Organization. 1978. Report of the Third Consultative Meeting of the Contracting Parties to the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter, 9–13 October 1978. IMCO Doc. LDC III/12 (24 October), *reprinted in International Legal Materials*, 18, 817–826 (1979). Inter-Governmental Maritime Consultative Organization, London.

Inter-Governmental Maritime Consultative Organization. 1980a. Report of the Fifth Consultative Meeting of Contracting Parties to the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter, 22–25 September 1980. IMCO Doc. LDC V/12, Inter-Governmental Maritime Consultative Organization, London, 19 pp. and 9 Annexes.

Inter-Governmental Maritime Consultative Organization. 1980b. Fifth Consultative Meeting, Relations with Other Organizations, Note by the Secretariat. IMCO Doc. LDC V/9 (8 July 1980), Inter-Governmental Maritime Consultative Organization, London, 3 pp.

Inter-Governmental Maritime Consultative Organization. 1981a. Report of the Sixth Consultative Meeting of Contracting Parties to the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter, 5–9 October 1981. Agenda item 7, Matters Related to the Dumping of Radioactive Waste at Sea, Environmental Assessment Studies, Note by the Secretariat. IMCO Doc. LDC VI/7/1 (14 September 1981), Inter-Governmental Maritime Consultative Organization, London, 3 pp.

Inter-Governmental Maritime Consultative Organization. 1981b. Matters Related to the Dumping of Radioactive Wastes at Sea: IAEA Activities Related to Its Responsibilities for Radioactive Matters under the London Dumping Convention. IMCO Doc. LDC VI/7/2 (14 September 1981), Inter-Governmental Maritime Consultative Organization, London, 9 pp.

International Atomic Energy Agency (IAEA). 1961. Radioactive Waste Disposal into the Sea. Safety Series No. 5, International Atomic Energy Agency, Vienna, 174 pp.

International Atomic Energy Agency. 1963. Report of the Ad Hoc International Legal Group to Consider Legal and Administrative Matters Related to the Brynielsson Report (IAEA, 1961). IAEA Doc. DG/WDS/L.19 (19 June 1963) (restricted), International Atomic Energy Agency, Vienna.

International Atomic Energy Agency. 1973a. IAEA Doc. GOV/1622 (3 September 1973) (restricted), International Atomic Energy Agency, Vienna.

International Atomic Energy Agency. 1973b. Radioactive Contamination of the Marine Environment. Proceedings of a Symposium, Seattle, 1972. IAEA Doc. IAEA-SM-158-36, International Atomic Energy Agency, Vienna, 786 pp.

International Atomic Energy Agency. 1975a. Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter. The Definition Required by Annex I, Paragraph 6 to the Convention and the Recommendations Required by Annex II, Section D. Information Circular INFCIRC/205/Add.1, International Atomic Energy Agency, Vienna, 22 pp.

International Atomic Energy Agency. 1975b. Impacts of Nuclear Releases into the

Aquatic Environment. Proceedings of a Conference, Otaniemi, Finland, 30 June–4 July 1975. IAEA. Doc. IAEA-SM-198/58, International Atomic Energy Agency, Vienna, 524 pp.

International Atomic Energy Agency. 1976a. Regional Nuclear Fuel Cycle Centres. IAEA Doc. RFCC/1-2; Volume 1, 127 pp.; Volume 2, 306 pp. International Atomic Energy Agency, Vienna.

International Atomic Energy Agency. 1976b. Transuranium Nuclides in the Environment. Proceedings of a Symposium, San Francisco, 1976. IAEA Doc. IAEA-SM-199/11, International Atomic Energy Agency, Vienna, 724 pp.

International Atomic Energy Agency. 1977. The Agency's Role in Connection with the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter, IAEA Doc. GOV/1820 (restricted), Annex, International Atomic Energy Agency, Board of Governors, Vienna, 11 pp.

International Atomic Energy Agency. 1978a. Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter. The IAEA Revised Definition and Recommendations of 1978 Concerning Radioactive Wastes and Other Radioactive Matter, Referred to Annex I and II to the Convention. Information Circular INFCIRC/205/Add.1/Rev.1, International Atomic Energy Agency, Vienna, 26 pp.

International Atomic Energy Agency. 1978b. The Radiological Basis of the IAEA Revised Definition and Recommendations Concerning High-Level Radioactive Waste Unsuitable for Dumping at Sea. Report of a Consultants Meeting, London, June 1977. Technical Document IAEA-211, International Atomic Energy Agency, Vienna, 58 pp.

International Atomic Energy Agency. 1980a. International Nuclear Fuel Cycle Evaluation. International Atomic Energy Agency, Vienna, 9 vols.

International Atomic Energy Agency. 1980b. Draft Report on Packaging of Radioactive Wastes for Sea Disposal. International Atomic Energy Agency, Vienna, unpaginated.

International Atomic Energy Agency. 1980c. Regulatory Aspects of Underground Radioactive Waste. Technical Document IAEA-TECDOC-230, International Atomic Energy Agency, Vienna, 132 pp.

International Atomic Energy Agency. 1981a. Considerations Concerning "De Minimis" Quantities of Radioactive Waste Suitable for Dumping at Sea under a General Permit. Technical Document IAEA-TECDOC-244, International Atomic Energy Agency, Vienna, 28 pp.

International Atomic Energy Agency. 1981b. Packaging of Radioactive Wastes for Sea Disposal. Report of a Technical Committee, Vienna, December 1979. Technical Document IAEA-TECDOC-244, International Atomic Energy Agency, Vienna, 43 pp.

International Atomic Energy Agency. 1982. Impact of Nuclear Releases into the Marine Environment. Proceedings of a Symposium, Vienna, 6–10 October 1980. International Atomic Energy Agency, Vienna, 748 pp.

International Commission on Radiological Protection (ICRP). 1977. Recommendations of the International Commission on Radiological Protection. ICRP Pub. No. 26, International Commission on Radiological Protection, Pergamon Press, Oxford, 53 pp.

International Commission on Radiological Protection. 1980. Implications of Commission Recommendations that Doses be Kept as Low as Readily Achievable. ICRP Pub. No. 22 (orig. 1973), International Commission on Radiological Protection, Pergamon Press, Oxford, 17 pp.

International Court of Justice (ICJ). 1973. Nuclear Tests Cases, Australia v. France, [1973] I.C.J. Rep. 99; New Zealand v. France, [1973] I.C.J. Rep. 135 (interim measures of protection). International Court of Justice, The Hague.

International Court of Justice. 1974. Nuclear Tests Cases, [1974] I.C.J. Rep. 253 (judgment). International Court of Justice, The Hague.

International Legal Materials (ILM). 1972. Convention for the Prevention of Marine Pollution by Dumping from Ships and Aircraft ("Oslo Convention"). *Entered into force* 1974. *International Legal Materials*, 11, 262–266.

International Legal Materials. 1974. Convention on the Protection of the Marine Environment of the Baltic Sea Area ("Helsinki Convention"). *Done* 22 March 1974, *not in force*. *International Legal Materials*, 13, 546–590.

International Legal Materials. 1976. Convention for the Protection of the Mediterranean Sea Against Pollution and Protocol for the Prevention of Pollution of the Mediterranean Sea by Dumping from Ships and Aircraft ("Barcelona Convention and Protocol"). *Done* 16 February 1976, *entered into force*. *International Legal Materials*, 15, 290–318.

International Legal Materials. 1978. Kuwait Regional Convention for Cooperation on the Protection of the Marine Environment from Pollution. *Done* 23 April 1978, *not in force*. *International Legal Materials*, 17, 511–526.

Jenks, W. 1966. Liability for ultra-hazardous activities in international law. I *Receuil des cours de droit international*, Academie de droit international, pp. 105–200. A. W. Sijthoff, Leyden, the Netherlands.

Kautsky, H. 1980. The North Sea region taken as an example for the behavior of artificial radioisotopes in nearshore sea areas. *In:* Proceedings of The Third NEA Seminar on Marine Radioecology (Tokyo), 1 October 1979, Nuclear Energy Agency, Organization for Economic Cooperation and Development, Paris, pp. 283–289.

Kelsen, J. M. 1972. State responsibility and the abnormally dangerous activity. *Harvard International Law Journal*, 13, 197–244.

Kronmiller, T. G. 1980. The Lawfulness of Deep Seabed Mining, U.S. National Technical Information Service, Bethesda, Maryland, 2 vols., 560 pp.

Lewis, A. 1980a. Talks end in failure on atomic weapons. *International Herald Tribune*, 8 September 1980, p. 1, col. 1.

Lewis, A. 1980b. Short fuses at the nuclear treaty review. *New York Times*, 18 August 1980, p. 4E, col. 4.

Lowenstein, R. L. 1961. Some legal considerations in the ocean disposal of radioactive wastes. *Health Physics*, 6, 110–113.

McDougal, M. P., and W. T. Burke. 1962. The Public Order of the Oceans. Macmillan Publishing Company, New York, 1226 pp.

Moore, G. 1976. Legal aspects of marine pollution control. *In*: Marine Pollution, R. Johnston (Ed.). Academic Press, New York, pp. 587–697.

National Radiological Protection Board. 1973. A Model for the Evaluation of the

Deep Ocean Disposal of Radioactive Waste. No. NRPB-R14, National Radiological Protection Board, London, 29 pp.

Nielsen, S. O. 1974. Nuclear waste disposal in the oceans. *Science*, 185, 1183.

Nielsen, S. O. 1979. Comparison of some geologic and ocean disposal concepts regarding realistic modelling that allows objective risk assessment to be made. *In*: Scientific Basis for Nuclear Waste Management, Vol. 1, G. McCarthy (Ed.). Plenum Press, New York, pp. 549–554.

Nuclear Energy Agency (NEA). 1968. Radioactive Waste Disposal Operation into the Atlantic (1967). Nuclear Energy Agency, OECD, Paris, 74 pp.

Nuclear Energy Agency. 1977. Objectives, Concepts and Strategies for the Management of Radioactive Waste Arising from Nuclear Power Programs. Nuclear Energy Agency, OECD, Paris, 71 pp.

Nuclear Energy Agency. 1979a. Guidelines for Sea Dumping Packages of Radioactive Waste (orig. 1977, rev. April 1979). Nuclear Energy Agency, OECD, Paris, 32 pp.

Nuclear Energy Agency. 1979b. Recommended Operational Procedures for Sea Dumping of Radioactive Waste. Nuclear Energy Agency, OECD, Paris, 15 pp.

Nuclear Energy Agency. 1979c. Seventh Activity Report (1978). Nuclear Energy Agency, OECD, Paris, 106 pp.

Nuclear Energy Agency. 1980a. Proceedings of the Third NEA Seminar on Marine Radioecology (Tokyo), 1 October 1979. Nuclear Energy Agency, OECD, Paris, 409 pp.

Nuclear Energy Agency. 1980b. Review of the Continued Suitability of the Dumping Site for Radioactive Waste in the North-East Atlantic. Nuclear Energy Agency, OECD, Paris, 100 pp.

Nuclear Energy Agency. 1980c. Eighth Activity Report (1979). Nuclear Energy Agency, OECD, Paris, 114 pp.

Nuclear Energy Agency. 1981. Research and Environmental Surveillance Program Related to Sea Disposal of Radioactive Waste. Nuclear Energy Agency, OECD, Paris, 38 pp.

Nuclear Law Bulletin. 1974a. International conventions relating to radioactive marine pollution. *Nuclear Law Bulletin*, 13, 39–55.

Nuclear Law Bulletin. 1974b. International cooperation in the field of radioactive transfrontier pollution. *Nuclear Law Bulletin*, 14, 55–72.

Organisation for Economic Co-operation and Development (OECD). 1977. Multilateral Consultation and Surveillance Mechanism. OECD Doc. C (77) 115 (final), July 22, 1977, OECD, Paris, 7 pp.

Pelzer, N. 1969. Le caractère admissible au regard du droit international du deversément en mer des dechêts radioactifs. *Cahiers du droit de l'énergie atomique* (Centre d'études du droit de l'énergie atomique, Institute de droit comparé de Paris, Paris), 2, 106–129.

Preston, A. 1975. The radiological consequences of releases from nuclear facilities to the aquatic environment. *In*: Impacts of Nuclear Releases into the Aquatic Environment. IAEA Doc. IAEA-SM-198/58, International Atomic Energy Agency, Vienna, pp. 3–23.

Preston A., and N. T. Mitchell. 1973. Evaluation of public radiation exposure from the controlled marine disposal of radioactive waste (with special reference to the United Kingdom). *In*: Radioactive Contamination of the Marine Environment. IAEA Doc. IAEA-SM-158-36, International Atomic Energy Agency, Vienna, pp. 575–593.

Quentin-Baxter, R. Q. 1980. Preliminary Reports to the International Law Commission on the Subject of International Liability for Injurious Consequences Arising Out of Acts not Prohibited by International Law. U.N. Docs. A/CN./4/334 and Adds. 1-2, U.N. International Law Commission, Geneva, 48 pp.

Rajan, M. S. 1978. Sovereignty over National Resources. Humanities Press, Atlantic Highlands, New Jersey, 176 pp.

Reyners, P. 1975. La Pratique des evacuations en mer des dechêts radioactifs et necessité d'une reglémentation internationale. *In*: Université de Paris I. Droit nucléaire et droit océanique: une colloque, 12–15 juin 1975, pp. 95–115. Recherches Panthéon-Sorbonne, Economica, Paris, 170 pp. and discussion.

Rice, A. L. 1978. Radioactive waste disposal and deep-sea biology. *Oceanlogica Acta*, 1(4), 483–491.

Rochlin, G. 1977. Nuclear waste disposal: two social criteria. *Science*, 195, 23–31.

Rochlin, G. 1979. Plutonium, Power, and Politics. University of California Press, Berkeley, California, 397 pp.

Royal Commission on Environmental Pollution (Flowers Commission). 1976. Sixth Report, Nuclear Power and the Environment. Her Majesty's Stationery Office, London, 205 pp.

Sandia National Laboratories. 1980. Subseabed Disposal Program Plan, 2 vols. Sandia National Laboratories, Seabed Programs Division, U.S. Department of Energy, Albuquerque, New Mexico, 134 pp.

Schachter, O. 1977. Sharing the World's Resources. Columbia University Press, New York, 172 pp.

Schneider, J. 1977. Something old, something new: some thoughts on Grotius and the marine environment. *Virginia Journal of International Law*, 18, 147–164.

Science and Technology Agency (S & T Agency). n.d. Safety on [sic] Sea-Dumping of Low-Level Radioactive Wastes. Science and Technology Agency of Japan, Nuclear Safety Bureau, Tokyo, 10 pp.

Shepherd, J. G. 1976. A Simple Model for the Dispersion of Radioactive Wastes Dumped on the Deep-Sea Bed. MAFF Fisheries Research Technical Report No. 29, U.K. Ministry of Agriculture, Fisheries and Food, Lowestoft, 19 pp.

Silva, S. J. 1977. Physical processes in deep-sea clays. *Oceanus*, 20 (1), 31–40.

Sohn, L. B. 1973. The Stockholm declaration on the human environment. *Harvard International Law Journal*, 14, 423–515.

Springer, L. 1977. Towards a meaningful concept of pollution in international law. *International and Comparative Law Quarterly*, 26, 531–557.

Strohl, P. 1978. Legal, administrative and financial aspects of long term management of radioactive wastes. *Nuclear Law Bulletin*, 21, 77–88.

Sullivan, W. 1982. Nuclear waste disposal: bold innovations abroad instructive for U.S. *New York Times*, 31 August 1982, p. D4, col. 4.

United Nations. 1968. Treaty on the Non-Proliferation of Nuclear Weapons. *Done* 1 July 1968, 21 U.S.T. 483, TIAS No. 6839, 729 U.N.T.S. 161. U.N. General Assembly, New York.

United Nations. 1969a. General Assembly Resolution No. 2574D, 24 U.N. GAOR, Supp. (No. 30) 11, U.N. Doc. A/7630 ("Seabed Moratorium Resolution"). U.N. General Assembly, New York.

United Nations. 1969b. Comprehensive Outline of the Scope of the Long-Term and Expanded Program of Oceanic Exploration and Research, U.N. Doc. A/7750, see Part I, p. 3. United Nations Joint Group of Experts on the Scientific Aspects of Marine Pollution (GESAMP).

United Nations. 1970. General Assembly Resolution No. 2759, 25 U.N. GAOR, Supp. (No. 28), 24, U.N. Doc. A/8028 ("Seabed Principles Resolution"). U.N. General Assembly, New York.

United Nations. 1972. Report of the U.N. Conference on the Human Environment, U.N. Doc. A/CONF. 48/14/Corr.1. U.N. Conference on the Human Environment, Stockholm, 5–16 June 1972.

United Nations. 1974. General Assembly Resolution No. 3281, 29 U.N. GAOR, Supp. (No. 31) 50, U.N. Doc. A/9631, Arts. 2 (principle of permanent national sovereignty over natural resources), 30 (state responsibility to ensure that internal environmental policies do not damage the environment in transfrontier areas). U.N. General Assembly, New York.

United Nations. 1977. Sources and Effects of Ionizing Radiation. U.N. Scientific Committee on the Effects of Atomic Radiation, New York, 725 pp.

United Nations Environment Program. 1978. Draft Principles of Conduct in the Field of Environment for the Guidance of States in the Conservation and Harmonious Utilization of Natural Resources Shared by Two or More States, U.N. GAOR, Supp. (No. 25), 154, U.N. Doc. A/33/25. U.N. Environment Program, Nairobi.

United Nations Conference on the Law of the Sea (UNCLOS). 1958a. Convention on the High Seas, 13 U.S.T. 2312, TIAS No. 5200, 450 U.N.T.S. 82, *entered into force* 30 September 1962. U.N. Conference on the Law of the Sea, Geneva.

United Nations Conference on the Law of the Sea. 1958b. Resolutions Adopted by the U.N. Conference on the Law of the Sea, Pollution of the High Seas by Radioactive Materials, 450 U.N.T.S. 58 (27 April 1958). U.N. Conference on the Law of the Sea, Geneva.

United Nations Conference on the Law of the Sea. 1958c. Convention on the Continental Shelf, *Done* 29 April 1958, 15 U.S.T. 471, TIAS No. 5578, 499 U.N.T.S. 311, *entered into force* 10 June 1964. U.N. Conference on the Law of the Sea, Geneva.

United Nations Third Conference on the Law of the Sea. 1980. Draft Convention on the Law of the Sea (Informal Text). U.N. Doc. A/CONF.62/WP.10/Rev.3/Add.1, United Nations, New York.

U.S. Congress. 1977. Oversight Hearings on Radiological Contamination of the Oceans before the House Committee on Energy and the Environment, 94th Congress, 1st and 2nd Sessions (1976 and 1977), Ser. No. 94–69, Washington, 1030 pp.

U.S. Congress. 1978. Ocean Dumping and Pollution: Hearings before the Subcommittee on Oceanography and the Subcommittee on Fisheries and Wildlife Conservation and the Environment of the House Committee on Merchant Marine and Fisheries, Ser. No. 95–42, 95th Congress, 1st and 2nd Sessions, Washington, 493 pp.

U.S. Congress. 1980a. Deep Seabed Hard Mineral Resources Act, Public Law No. 96–283, *Statutes-at-Large*, 94, 553–586. U.S. Congress, Washington.

U.S. Congress. 1980b. Oceanography Miscellaneous-Part 2: Hearings before the Subcommittee on Oceanography of the House Committee on Merchant Marine and Fisheries, Ser. No. 96–53, 96th Congress, 1st and 2nd Sessions, Washington, 583 pp.

U.S. Court of Appeals. 1980. National Wildlife Federation v. Costle, 629 F.2d 118. U.S. Court of Appeals for the District of Columbia Circuit, Washington.

U.S. Department of Energy (DOE). 1980. Final Environmental Impact Statement, Management of Commercially Generated Radioactive Waste. U.S. Department of Energy, Washington, D.C., 3 vols., 1518 pp.

U.S. Department of State. 1973. Airgram No. A9894 from U.S. Department of State, Washington, D.C., to IAEA, Vienna, 30 November 1973.

U.S. Department of State. 1980. Summary, Committee on Ocean Dumping. U.S. Environmental Protection Agency, Washington, D.C., 8 pp.

U.S. Department of State and Environmental Protection Agency. 1979. Final Environmental Impact Statement on the Incineration of Wastes at Sea under the 1972 Ocean Dumping Convention. U.S. Environmental Protection Agency, Washington, D.C., unpaginated.

U.S. Environmental Protection Agency (EPA). 1978. London Ocean Dumping Convention Third Consultative Meeting, Agenda Item 6 (9–13 October 1978) (briefing paper). U.S. Environmental Protection Agency, Washington, D.C., 4 pp.

U.S. EPA. 1980. Fact Sheet on Ocean Dumping of Radioactive Waste Materials. U.S. Environmental Protection Agency, Washington, D.C., 10 pp.

U.S./Canada. 1972. Agreement between the United States and Canada on Great Lakes Water Quality, Art. III, Annex I(1)(h), 23 U.S.T. 301, TIAS No. 7312, 837 U.N.T.S. 213 (*entered into force* 15 April 1972) (radiation levels to be kept at lowest practicable levels and in any event controlled to the extent necessary to protect human health), Annex I(7)(b) (continued consultation to develop "refined objectives" for radioactivity in light of the recommendations of the ICRP).

Valent, P. J., and H. J. Lee. 1977. Feasibility of subseafloor emplacement of nuclear waste. *Marine Geotechnology*, 1, 267–293.

Van As, D., and W. O. Forster. 1979. Disposal of radionuclides in the sea. *IAEA Bulletin* (August 1979), 24–31.

von Welck, Baron S. 1975. Third United Nations Conference on the Law of the Sea and the use of nuclear energy. *Nuclear Law Bulletin*, 15, 63–72.

Washington Post. 1979a. Tiny Pacific island of Palmyra targeted as nuclear dump. *Washington Post*, 18 August 1979, sec. A, p. 1, col. 1.

Washington Post. 1979b. Plan for storing nuclear wastes on Pacific atoll strongly protested. *Washington Post*, 23 August 1979, sec. A, p. 4, col. 1.

Webb, G. A. M. 1980. The interaction between radiological assessments and research requirements related to waste disposal in the deep sea. *In*: Proceedings of the Third NEA Seminar on Marine Radioecology (Tokyo), 1 October 1979. Nuclear Energy Agency, Organization for Economic Cooperation and Development, Paris, pp. 13–19.

Webb, G. A. M., and P. D. Grimwood. 1976. A Revised Oceanographic Model to Calculate the Limiting Capacity of the Ocean to Accept Radioactive Waste. Report NRPB–R58, National Radiological Protection Board, London, 19 pp.

Williams, J., and D. A. Deese (Eds.). 1979. Nuclear Proliferation: The Spent Fuel Problem. Pergamon Press, New York, 221 pp.

Willrich, M., and R. Lester. 1977. Radioactive Waste: Management and Regulation. Free Press, Macmillan Publishing Co., New York, 138 pp.