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Managing Nuclear Wastes: The International Connection

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MANAGING NUCLEAR WASTES: THE INTERNATIONAL CONNECTION

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I. INTRODUCTION

Any discussion of radioactive waste management without consideration of its transnational aspects would be substantially incomplete. Decisive transnational restraints influence both formulation and implementation of national waste management policies. National management efforts are fundamentally interdependent, and safe management of radioactive wastes is achievable only through considerable international cooperation and coordination. Specific policies which reflect this fact are urgently needed. In this respect nuclear waste management is another example of the growing spectrum of human activities which render notions of national boundaries and domestic jurisdiction obsolete.[1]

National radioactive waste management policy also has a distinct foreign policy component,[2] since it is intimately related to nuclear

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1. *See* McDougal, *International Law and the Future,* 50 MISS. L.J. 259 (1979), in which the observation is made that "from any anthropological perspective it is easy to observe that humankind is today confronted with not merely some important transnational problems, but that practically all of humankind's important problems are transnational and interconnected in origin and impact. Because of this transnational origin and interdetermination in impact any effective and continuing solutions for these problems must be equally transnational and comprehensive." *Id.* at 269. A recently publicized case in point is the industrial use of chlorofluorocarbons, which has been identified as a major cause of stratospheric ozone depletion. Unless the use of chlorofluorocarbons is curtailed on a worldwide basis, significant increases in skin cancer and crop damage may occur. *See* NAT'L RESEARCH COUNCIL, NAT'L ACADEMY OF SCIENCES, PROTECTION AGAINST DEPLETION OF STRATOSPHERIC OZONE BY CHLOROFLUOROCARBONS 138-40 (1979). For further discussion on transnational ramifications of toxic substances which render internationally consistent management approaches beneficial, if not essential, see REPORT TO THE PRESIDENT BY THE TOXIC SUBSTANCES STRATEGY COMMITTEE (PUBLIC REVIEW DRAFT) at 2 (CEQ-EHTS-03: 1979).

2. National waste management parameters are clearly affected by the decision to reprocess spent nuclear reactor fuel. Reprocessing, on the other hand, has been considered a crucial danger point in the proliferation connection of nuclear power generation. On the perceived existence of the latter connection, *see* President Carter's 1977 statement on the indefinite deferment of domestic reprocessing and corresponding international diplomatic

nonproliferation objectives and criteria.[3] Other transnational social ramifications stem in part from the long term effect of radiological waste hazards on human beings and the biosphere, since national waste management practices invariably affect the global environment. A 1977 report on nuclear waste management by a group of experts from the Nuclear Energy Agency of the Organization for Economic Co-Operation and Development (OECD) notes:

> The international aspects of radioactive waste management have also to be recognized, notably in view of possible accidental releases of long-lived radio-nuclides and of improper storage or disposal conditions in one country which might affect neighbouring regions through rivers and groundwater movements. In this respect present national borders have no real significance given the long-term hazard of some radioactive waste. Even if the actual risks of disposal can be reduced to extremely low levels, possible implications of a global nature might be envisaged and this aspect of radioactive waste management deserves careful consideration by the international community.[4]

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initiatives by the United States, White House press release, April 7, 1977, *reprinted in* 76 DEP'T. STATE BULL. 429-30 (1977) and transcript of the President's press conference, 13 WEEKLY PRESIDENTIAL DOCUMENTS 502-05 (1977).

3. A link between specific domestic management strategies and foreign policy objectives emerges from the report of the Interagency Review Group on Nuclear Waste Management, which acknowledges that "high level waste strategies might conceivably differ in their implications for (1) the nuclear power programs of other countries and (2) the credibility of the U.S. international posture with respect to nuclear power and reprocessing." INTERAGENCY REVIEW GROUP ON NUCLEAR WASTE MANAGEMENT, SUBGROUP REPORT ON ALTERNATIVE TECHNOLOGY STRATEGIES FOR THE ISOLATION OF NUCLEAR WASTE 78 (TID-28818 (DRAFT): 1978). In line with this link has been the U.S. government's offer to accept (on a limited basis) foreign spent fuel in exchange for a one-time fee to cover the costs of temporary storage and eventual geologic disposal. This is only one plank in the U.S. non-proliferation platform and might accordingly be extended sparingly as a disincentive to a would-be reprocessing nation. With respect to the underlying non-proliferation objective, *see* State Dep't News Release, Oct. 18, 1977, *reprinted in* 76 DEP'T STATE BULL. 665-77 (1977). In any event, any such agreement between the United States and a foreign country is subject to Congressional review. *See* Nuclear Non-Proliferation Act of 1978, Pub. L. No. 95-242 § 304, 92 Stat. 120 (1978) (to be codified in scattered sections of 42 U.S.C.). *See also* DEP'T OF ENERGY, DRAFT ENVIRONMENTAL IMPACT STATEMENT: STORAGE OF FOREIGN SPENT POWER REACTOR FUEL (DOE/EIS-0040-D: 1978).

4. NUCLEAR ENERGY AGENCY, ORGANIZATION FOR ECONOMIC COOPERATION & DEVELOPMENT, OBJECTIVES, CONCEPTS AND STRATEGIES FOR THE MANAGEMENT OF RADIOACTIVE WASTE ARISING FROM NUCLEAR POWER PROGRAMMES 61 (1977) [hereinafter cited as POLVANI REPORT]. In 1979, the Nuclear Energy Agency launched a study of the legal, administrative, and financial aspects of long-term management of radioactive waste, the purpose of which is to assist national authorities in forming regulatory policies and specific management procedures. *See* NUCLEAR ENERGY AGENCY, ORGANIZATION FOR ECONOMIC COOPERATION & DEVELOPMENT, EIGHTH ACTIVITY REPORT 1979 at 20 (1980) [hereinafter cited as NEA ACTIVITY REPORT]. This endeavor is obviously inspired by the perceived need to arrive at internationally standardized waste management operations.

In a similar vein, the International Nuclear Fuel Cycle Evaluation (INFCE)[5] program's working group on radioactive waste management and disposal dwelled on the transnational implications of certain national waste management operations. Foremost among the factors it deemed necessary to consider were "the relative stability of national frontiers and also of national and international institutions as compared to the half-lives of some of the radioisotopes under consideration."[6] In short, the peculiar time and space dimensions of nuclear waste management[7] make any national program a matter of intrinsic international concern, subject to at least international review, if not regulation.

The purpose of this paper is to put national management activities into this global context with particular emphasis on associated health and environmental effects. At a time when key national policy decisions regarding nuclear waste control are being finalized,[8] it is important for decisionmakers to recognize that certain radioactive waste management problems will not be solved by national legislation alone, but will require coordinated action among nuclear power countries.

This discussion assumes that the present trend towards reprocessing of spent fuel will continue.[9] With reprocessing services offered by

5. The principal purpose of INFCE has been to examine on an international scale fuel cycle arrangements which would reduce the risks of weapons proliferation and nuclear terrorism while assuring adequate and reliable fuel supplies, particularly to those countries which are in a state of special dependence on nuclear power. For the terms of reference of the organizing conference, *see* Text of Final Communique of October 21, *reprinted in* 77 DEP'T STATE BULL. 661, at 662-63 (1977). Another major issue for review by the conference has been the management, especially the disposal, of radioactive wastes. *Id.*

6. INTERNATIONAL NUCLEAR FUEL CYCLE EVALUATION, WASTE MANAGEMENT AND DISPOSAL, REPORT OF INFCE WORKING GROUP 7, at 108 (INFCE/PC/2/7: 1980) [hereinafter cited as INFCE REPORT].

7. In paraphrasing Rodière, one must indeed agree that "atomic energy . . . take[s] us into a world in which space is immeasurably expanded and time excessively stretched." Rodière, *Responsabilité civile et risque atomique,* 11 REV. INTERN. DROIT COMP. 505 (1959).

8. The Nuclear Regulatory Commission recently proposed rules on licensing procedures for the disposal of high-level radioactive wastes in geologic repositories. *See* 44 Fed. Reg. 70408 (1979). EPA is expected to soon finalize its proposed radioactive waste criteria intended to provide basic guidance in the formulation of policies, plans, programs, and decisions involving U.S. management of radioactive waste. *See* 43 Fed Reg. 53262 (1978). Note further President Carter's message to Congress on the administration's "Radioactive Waste Management Program," *reprinted in* 16 WEEKLY PRESIDENTIAL DOCUMENTS 296 (1980). Although the President takes note of some transnational ramifications of nuclear waste management alternatives, he unfortunately fails to clearly endorse the principle of internationally agreed upon management standards and practices, the logical corollary of the interdependence of national waste management objectives and the multipolarity of the transnational decision-making environment.

9. Long-standing European and Japanese commitments to reprocessing are well known. As to the European commitment, *see, e.g.,* EC Council Res. of Feb. 18, 1980 on the repro-

only a limited number of countries, or at multinational or international fuel cycle centers, a significant increase in ocean transport of highly radioactive materials can be expected. The problems which arise as a result of such shipping are not specifically dealt with here, nor are the institutional implications of a system in which nuclear wastes are managed at multinational or international storage or disposal centers.[10] Questions concerning the international liability of states for transnational radioactive pollution are also excluded. This paper focuses on the need for international preventive standards and measures to eliminate the risk of transnational radioactive contamination, rather than on the necessity for ex post facto international remedial action.

II. INTERNATIONAL CONCERN AS A FUNCTION OF THE LONG TERM HAZARD OF NUCLEAR WASTES

A. *A Proper View of the Relevance of the Time Factor*

High level wastes (HLW)[11] and concentrations of transuranic

cessing of irradiated nuclear fuels (EC, O.J. No. C51, Feb. 29, 1980). Note also the conclusions by the International Nuclear Fuel Cycle Evaluation which though phrased very cautiously, must be read to amount to a relatively "clean bill of health" for reprocessing. *See* INTERNATIONAL NUCLEAR FUEL CYCLE EVALUATION, REPROCESSING, PLUTONIUM HANDLING, RECYCLE, REPORT OF WORKING GROUP 4 (INFCE/PC/2/4:1980). In the United States, the Carter administration's opposition to domestic and foreign reprocessing may well undergo a drastic change corresponding to the new government's expected shift with regard to national energy policy and the political makeup of the new Congress. As to allegations that towards the end the Carter administration's stand on foreign reprocessing had softened; *see* N.Y. Times, Oct. 25, 1979, A9, col. 1 and 23 NUCLEAR NEWS 68 (No. 8-1980). In any event, Australia, which had been in step with Canada and the U.S. in insisting on prior approval of each shipment for reprocessing of Australian origin spent fuel, is now apparently breaking rank in offering blanket approvals to individual countries. *See* THE ECONOMIST, Dec. 6, 1980, at 72-73.

10. Regarding INFCE recommendations of multinational and international repositories, *see* INFCE REPORT, *supra* note 6, at 112-14. Similar recommendations have been made in other fora. *See, e.g.*, INTERNATIONAL ATOMIC ENERGY AGENCY, 1 REGIONAL NUCLEAR FUEL CYCLE CENTRES 21-30 (1977); R. FOX & M. WILLRICH, INTERNATIONAL CUSTODY OF PLUTONIUM STOCKS: A FIRST STEP TOWARD AN INTERNATIONAL REGIME FOR SENSITIVE NUCLEAR ENERGY ACTIVITIES (1978). One suggestion has been to set up energy centers on uninhabited atolls, where spent fuel could be reprocessed, conditioned, and disposed of. *See* INTERNATIONAL INSTITUTE FOR APPLIED SYSTEMS ANALYSIS, NUCLEAR WASTE STORAGE AND THE ENERGY ISLAND–A NEW POSSIBILITY FOR ACTION (1977). The U.S. government itself has been the principal party behind plans for a spent fuel storage center in the Pacific area. *See* *Pacific Spent Fuel Storage: Hearings Before the Senate Committee on Energy and Natural Resources*, 96th Cong., 1st Sess. 2-3 (1979) and International Herald Tribune, July 25, 1980, at 2, col. 6. At one point, the Japanese response was described as "lukewarm." *See* 2 INT'L ENVT'L RPTR. 899 (1979).

11. Generally speaking, HLW are materials with a high specific activity (i.e., radioactivity per unit weight or volume of the waste materials concerned) often expressed in curies per gram, cubic meter or liter. In other words, they constitute intensely radioactive substances.

(TRU)[12] elements have traditionally been recognized as long term hazardous wastes requiring isolation from the biosphere for thousands of years.[13] Presently, experts agree that the most practicable method of achieving this goal is irretrievable disposal in deep geologic formations. Successful disposal, however, is a function of a number of variables, principally the conditioning of wastes prior to disposal (solidification and encapsulation in the case of HLW) and suitability of the final repository, particularly its hydrogeologic and seismic features. Irretrievable storage implies reliable projections of long term seismic stability, good heat conductivity, and the absence of groundwater movement as prerequisites to a reasonable assurance that no

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The classification of materials as HLW is essentially a function of the waste management requirements involved. Thus while national specific qualification criteria may perhaps vary, the functional approach to the classification is based on a recognized need to rule out disposal in shallow land burial sites and instead to aim at elimination from the biosphere preferably by final disposal in suitable geological formation.

At least until recently, U.S. waste management philosophy seemed to draw a basic distinction between "HLW" and "other than HLW," with HLW being identified as "[t]he fission product waste resulting from the reprocessing to separate uranium and plutonium from the fission products," and ultimate disposal in stable geological formations as the proper final management step. *See* U.S. Energy Research and Development Administration, Press Release 75-235 (Nov. 17, 1975) and 10 C.F.R. Part 50, App. F (1980).

This definition of HLW is, to be sure, too narrow in that cladding hulls from reprocessing and certain wastes from decommissioning of nuclear facilities clearly qualify for classification as HLW. The NRC recently proposed rules on licensing procedures for the disposal of high-level radioactive wastes in geological repositories which contain a more comprehensive definition. In those rules, HLW means "(1) irradiated reactor fuel, (2) liquid wastes resulting from the operation of the first cycle solvent extraction system, or equivalent, and the concentrated wastes from subsequent extraction cycles, or equivalent, in a facility for reprocessing irradiated reactor fuel, and (3) solids into which such liquid wastes have been converted." 44 Fed. Reg. 7408, 7415-16 (1979).

12. Transuranic wastes are any wastes measured or assumed to contain more than a specified concentration of transuranic elements. The presently applicable U.S. classification value is 10 nanocuries of transuranic nuclides per gram of waste (10 nCi/g, i.e., 10^{-8} curies/gram). *See* 39 Fed. Reg. 32921 (1974). No further regulatory action has yet been taken. *See also* U.S. ENVT'L PROTECTION AGENCY, TECHNICAL SUPPORT OF STANDARDS FOR HIGH LEVEL RADIOACTIVE WASTE MANAGEMENT, VOLUME A: SOURCE TERM CHARACTERIZATION (EPA 520/4-79-007A:1979), which states "whether deep geologic burial would . . . be used is not clear; it certainly seems to be one possible result of the proposed regulation, since changes to 10 C.F.R. § 20.304, proposed at the same time, forbid burial of transuranic waste in soil by a licensee. . . . For planning purposes, ERDA has assumed that permanent geologic disposal is the intent of the cited proposed rules." *Id.* at V-1. This is the most reasonable assumption in view of the high radiotoxicity and extremely long half-lives of TRU waste elements which thus may constitute a virtually permanent hazard to man. For a sharply critical view of the relevance of the interim value, *see* Rodger, *Critical Evaluation of the Limit of Transuranic Contamination of Low Level Waste*, in *ERDA Authorizing Legislation Fiscal Year 1977, Hearings Before the Subcom. on Legislation of the JOAE*, 94th Cong., 2d Sess., Part 2, 2285 (1976).

13. Note that mill tailings constitute another category of long-term hazardous wastes which would qualify for discussion in the present context. However, as these wastes entail also a potentially significant near-term transnational environmental problem they are more appropriately reviewed in the section analyzing the factor "space."

significant migration of the disposed radioactive substances will occur over the extremely long time spans involved.

Consequently, specific operational criteria rather than general objectives of national waste management programs[14] should be matters of tangible concern to the international community. Given the long term hazards associated with nuclear wastes, there is always a possibility that in the long run significant amounts of waste material will reach the transnational environment.[15] National management concepts for long-lived hazardous wastes also may be visualized from a slightly different angle. Irrespective of the correlation between inadequate national waste management practices and the long term risk of significant transboundary radioactive pollution, management operations, particularly if they fall short of safety standards commonly applied by other nations, are a matter of international concern. In other words, the relative increase in the long term risk of exposure, even when assumed to be limited to the population within the national boundaries, holds transnational implications of a special kind.

Simply stated, the issue is whether nations are free to adopt a waste management philosophy which may impose a burdensome intergenerational legacy, by invoking the principle of territorial sovereignty and claiming that state action is not subject to international review as long as its effects are felt only within national boundaries. This fundamental issue also emerges in the context of management operations featuring final surface or near-surface waste storage/disposal repositories, mothballed fuel cycle facilities,[16] or surface-stabilized mill tailing piles,[17] all of which require long term monitoring[18] and surveillance.[19]

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14. Reference is made here to the fundamental principles of radiation protection promulgated by the International Commission on Radiological Protection (ICRP) which sets merely broad objectives and minimum protection standards while leaving to the various national authorities the responsibility of formulating codes of practice or regulations that are best suited to the needs of their individual countries.

15. *See* note 6, *supra*, and accompanying text.

16. Mothballing constitutes the minimal step in the decommissioning of fuel cycle facilities. Minimal demolition is followed by isolation and control of radioactive residues. *See* U.S. ENERGY RESEARCH & DEVELOPMENT ADMIN., ALTERNATIVES FOR MANAGING WASTE FROM REACTORS AND POST-FISSION OPERATIONS IN THE LWR FUEL CYCLE 15.1-15.6 (ERDA 76-43 (VOL. 2): 1976) [hereinafter cited as ERDA ALTERNATIVES].

17. *See* notes 78-89, *infra*, and accompanying text.

18. All the surface or near-surface storage alternatives analyzed by ERDA (storage of unpackaged fuel in water basins and air cooled vaults, concrete surface silos, or near-surface heat sinks) require at least periodic inspection and/or maintenance. ERDA ALTERNATIVES, *supra* note 16, at 17.1-17.44.

19. Terminal storage in surface or near-surface engineered facilities might be difficult to reverse because of a strong economic disincentive to relocation of wastes. Note in this context the neutralized high-level liquid wastes presently based at the now shut-down West

The question arises, then, whether such a long term burden or intergenerational risk transference transcends the narrow confines of the territorially defined social organization and ideology that are responsible for the initial national commitment. At the time of the original decision, the allocation of resources and risk was presumably based on a consensus within the territorially defined society. The decision's effects may have been deemed to be truly national, giving rise only to the question of intergenerational legacies as a moral issue to be decided within that society.[20]

Careful reflection, however, leads to the conclusion that such a decision holds additional transnational implications. During the time at issue here societies may undergo extensive changes. Their organizational structures and the territorial parameters by which they may be defined will experience considerable evolution. Yet a commitment of the above kind represents an implicit projection of present-day conditions into a very distant future. It implies a social organization which pursues similar values as a fundamental characteristic of that social entity.

While there may be disagreement over the degree of unreasonableness of such projections, there appears little room for doubt that future patterns of global social interaction and organization will undergo drastic changes.[21] The authority by which a territorially

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Valley, N.Y. fuel reprocessing plant, which require recovery from the storage tanks and solidification. Both the technical difficulties and the costs of the necessary clean-up operation are expected to be gigantic. For a review of the problem, *see, e.g., Decommissioning and Decontamination, Hearings Before the Subcom. on the Env. & the Atmosphere of the Comm. on Science & Technology,* H.R., 95th Cong., 1st Sess. (1977). The possibility that an interim-storage system may become permanent solely due to economic costs has been warned against by various experts. *See* testimony of Roger Strelow, in *Oversight Hearings on Nuclear Energy–Overview of the Major Issues, Hearings Before the Subcomm. on Energy and the Env. of the Comm. on Interior & Insular Affairs,* H.R., 94th Cong., 1st Sess. (Part I) 35, 36-37 (1975); and Rowe & Holcomb, *The Hidden Commitment of Nuclear Wastes, id.* at 37, who state that "interim facility may become permanent, solely due to the economic costs involved in reprocessing and repackaging the interim stored wastes . . . , their transportation to the ultimate disposal site, and the decommissioning of the interim storage facilities."

20. *See generally* Gardner, *Discrimination against Future Generations: The Possibility of Constitutional Limitation,* 9 ENVT'L L. 29 (1978).

21. Thus to summarize only briefly, it would appear that future social organizational structures will be characterized by greater functionalism that will de-emphasize considerably the present-day status of the sovereign nation state. Institutionalized authoritative decisionmaking will increasingly take place on regional and global levels. Given the growing global interdependence in particular in energy, food, and environmental quality, which all constitute essential prerequisites for human survival and which are likely to be regulated by supranational decisionmaking institutions, principal identification and loyalty patterns of the individual might shape in accordance with the perceived relevance of, and the benefits derived from these transnational functional organizations. This process, in turn, could result in a complete revision of presently accepted definitions of social organization.

For some pertinent thoughts on such an evolution, *see* R. FALK, THE STATUS OF INTERNATIONAL SOCIETY 559 n.3 (1970); S. HOFFMAN, PRIMACY AND WORLD organized society makes decisions regarding nuclear waste systems within that territory may ultimately belong to what is known as the international community as a whole. It follows, then, that nuclear waste management decisions in a given society may not merely be seen as serious moral issues for the society on whose national territory the system is to be implemented, but rather must be recognized as a matter of international concern. Effects of such decisions might be felt long after concepts such as territorial sovereignty have become anachronistic. Since decisions could significantly affect groups of people whose organizational context cannot be anticipated, the decision directly concerns mankind as a whole.

Of course, the history of civilization is the history of human beings living with, enlarging upon, refining, and at times, successfully reversing intergenerational legacies which are often burdensome and quasi-irreversible. A new dimension is now present, however, in that some of these legacies may pose potential long term threats to human lives, health, and well-being. Nuclear wastes are an example. Similar legacies of present-day human conduct include spoilation of the natural environment by certain toxic chemicals, extinction of entire species of flora and fauna, and the exhaustion of nonrenewable minerals.

Not surprisingly, such activities have been established as a matter of international concern. Principles two through six of the Stockholm Declaration on the Human Environment all express the idea that wise management of natural resources, particularly safeguarding against serious or irreversible damage or exhaustion, constitutes a matter of intrinsic interest to mankind as a whole—an obligation towards future generations.[22] So does the national management of long-lived wastes,

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ORDER: AMERICAN FOREIGN POLICY SINCE THE COLD WAR 105-95 (1978); McDougal, Lasswell & Reisman, *Theories about International Law: Prologue to a Configurative Jurisprudence,* 8 VA. J. INT'L L. 188, 189-95 (1968); McDougal, Lasswell & Chen, *Human Rights and World Public Order: A Framework for Policy-Oriented Inquiry,* 63 AM. J. INT'L L. 237, 258-64 (1969); Singer, *The Global System and its Sub-Systems: A Developmental View* (paper delivered at the 1966 meeting of the American Political Science Association in New York, *quoted in* Knorr, *Transnational Phenomena and the Future of the Nation-State,* in SEARCH FOR WORLD ORDER 401, n.2 (Lepawsky, Buehring & Lasswell eds. 1971).

22. Stockholm Declaration on the Human Environment, U.N. Doc. A/CONF. 48/14 and Corr. 1, *reprinted in* 11 INT'L LEG. MAT'LS 1416, 1418 (1972); and Blix, *Oral Intervention,* in THE PROTECTION OF THE ENVIRONMENT AND INTERNATIONAL LAW, 1973 COLLOQUIUM AT THE HAGUE ACADEMY OF INTERNATIONAL LAW 451-52 (A-C. Kiss ed. 1975). As to the underlying public trust doctrine, *see generally* Nanda and Ris, *The Public Trust Doctrine: A Viable Approach to International Environmental Protection,* 5 ECOLOGY L. Q. 291 (1976).

In an analogous context, the very same notion of intergenerational obligation as a matter of international concern emerges also from a 1972 UNESCO Recommendation entitled Protection, at a National Level, of the Cultural and Natural Heritage, *reprinted in* 11 INT'L LEG. MAT'LS 1367 (1972); *see also* the follow-up Convention entitled Protection of the even though management activities are limited within national boundaries, and for the foreseeable future may not pose a recognizable risk of transnational radioactive contamination.

B. Towards an International Response to the Transnational Ramifications of National Management of Long-Lived Hazardous Wastes

Given this clarification of the relevance of the time factor, any national program for the terminal management of HLW and TRU elements would seem to demand international review of the standards and criteria specifically bearing on long term safety aspects of the program.

Efforts to justify exposing future generations to risks from present-day radioactive waste management or disposal operations have given rise to spirited debates on the ethical implications of such intergenerational risk transference. Positions range from adoption of a waste management policy which is neutral to future generations by confining benefits as well as hazards to the present population,[23] to the straightforward discounting of risks to future generations.[24] Neither extremist position appears to satisfy present-day notions of fairness. On the one hand, a policy of strict intergenerational nondegradation of the environment is an impossibility.[25] It would also offend our sense of fairness since future risks of harm would be viewed in isola-

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World Cultural and Natural Heritage, *id.* at 1358; and the European Convention on the Protection of the Archeological Heritage, *reprinted in* 8 INT'L LEG. MAT'LS 736 (1969). For an interesting extension of the principle of legitimate international concern, *see* Prott & O'Keefe, *International Legal Protection of the Underwater Cultural Heritage*, 14 REV. BELGE D.I. 85 (1978-79). Note further Recommendation 38 of the Final Documents of the United Nations Conference on the Human Environment, *reprinted in* 11 INT'L LEG. MAT'LS 1416, 1435 (1972).

23. *See* Cochran, Rotow & Tamplin, Radioactive Waste Management (Part I), in *Nuclear Waste Management, Hearings Before the Subcom. on Energy Res. & Production of the Comm. on Science & Techn.*, H.R., 96th Cong., 1st Sess. 561, 572 (1979) [hereinafter cited as NUCLEAR WASTE HEARINGS].

24. For a strong advocacy of discounting, *see, e.g.*, statement by Kenneth Arrow, in NATIONAL ACADEMY OF SCIENCES, NUCLEAR WASTE: WHAT TO DO WITH IT? 19-20 (1979).

25. One way or the other, every human activity entails costs as well as benefits. The history of civilization, it is a truism, is one of positive as well as negative intergenerational legacies. Progress in the sense of accommodating the very basic needs of an ever increasing human population has necessarily resulted in detrimental impacts on the natural environment. A strict non-degradation policy in breaking with this historical pattern of trade-offs would almost certainly imply an unacceptable policy of social and economic standstill. Only a modified non-degradation policy in the sense of precluding legacies which might pose significant threats to the very survival of *homo sapiens* as well as those which might involve risks to future generations which would be deemed unacceptable to the present, would appear to make sense. As to the paramount importance of the latter standard, see notes 28-29, *infra*, and accompanying text.

tion from future benefits associated with one and the same activity. On the other hand, discounting potential future health effects relative to those that might occur at present is an ethically untenable proposition.[26] Unless discounting is inspired by a doomsday philosophy, expectations that in the short or long run cataclysmic events would reduce passed-on risks from nuclear wastes to a negligible size in comparison to other problems confronting humankind, it presupposes that relatively detailed long term projections of social, economic, and scientific evolution are entirely feasible. While this pessimistic philosophy may be morally irresponsible, particularly since it serves as a subterfuge for inaction on a long term management solution, long term projections are notoriously unreliable when social change occurs at exponential speed. The ability to extrapolate future developments with a degree of certainty from present trends, which alone could render long term discounting a reasonable policy option, must be deemed severely limited for periods exceeding 100 years.[27] Consequently, long term discounting does not appear a morally responsible approach to the issue of intergenerational risk transfer.

Confronted with this problem, the Environmental Protection Agency (EPA) has proposed a commendable standard which could be adopted on the international level: nuclear waste management schemes must not entail risks to future generations that are greater

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26. The present "worth" or "value" of a future good or event can be estimated by using a time-related weighting factor or discount rate—a technique which is the inverse of compounding interest. With regard to the value of money at a given date, a proper future discount rate may be relatively easily set. However, the choice of such a rate for the value of future risks is more complex and decidedly controversial primarily because the predictability of socio-economic developments on which discounting depends is inherently lacking in long-term social trend projections. *See* note 27, *infra.* It has been noted in the literature that "there is more to intertemporal decision-making, than estimating future costs and benefits, choosing a discount rate and forming irreversibilities with present benefits and future long-term risks." Ferejohn & Page, *On the Foundations of Intertemporal Choice,* in CONTEMPORARY ISSUES IN NATURAL RESOURCES ECONOMICS 20 (E. Castle ed. 1978).

27. *See, e.g.,* U.S. ENVT'L PROTECTION AGENCY, BACKGROUND REPORT: CONSIDERATIONS OF ENVIRONMENTAL PROTECTION CRITERIA FOR RADIOACTIVE WASTE 25 (1978); M. BADIBANGA & R. GAGNON, LONGEVITÉ D'UN SYSTÈME DE CONTRÔLE INSTITUTIONELLE: UNE PROJECTION TEMPORELLE DANS LE DOMAINE DE LA GESTION DES DÉCHETS NUCLÉAIRES (1978). Note furthermore the rejection by the NRC as an "unrealistic and not responsible" speculation, of projections of an eventual cure for cancer on the basis of which the long-term risk from uranium mill tailings was claimed to be of short term significance only. *See* Final Rules on Uranium Mill Licensing Requirements, 45 Fed. Reg. 65521, 65525 (1980). The concept of discounting of future radiation-induced detriment was also rejected by an OECD panel. *See* NUCLEAR ENERGY AGENCY, ORGANIZATION FOR ECONOMIC COOPERATION AND DEVELOPMENT, RADIOLOGICAL SIGNIFICANCE AND MANAGEMENT OF TRITIUM, CARBON-14, KRYPTON-85, IODINE-129 ARISING FROM THE NUCLEAR FUEL CYCLE: REPORT BY AN NEA GROUP OF EXPERTS 14 (1980) [hereinafter cited as RADIOLOGICAL SIGNIFICANCE REPORT].

than those acceptable to the current generation.[28] To act differently would mean to allocate an unfair burden on future societies. For "injustice . . . is simply inequalities that are not for the benefit of all."[29]

This standard allows a critical inference: unless a proposed management policy offers long term protection equivalent to presently demanded margins of safety without the need for future human intervention (reliance on institutional controls), the potential risk transferred into the future is implicitly greater than would be acceptable at present. Since the long term effectiveness of such controls cannot be guaranteed, long term reliability of the waste management system is potentially compromised, along with the principle of intergenerational justice. It follows, then, that national management programs ought to rely on natural and engineered barriers and not on institutional controls as the essential element of the system to secure long term protection against a significant contamination of the environment.

As for specific operational or disposal parameters, it is clear that binding international criteria for the performance of waste forms and waste sites, for example, would help assure that individual nations would refrain from taking short cuts, which predjuce the required long term containment of wastes by compromising safety standards. Such guiding criteria would help reduce the long term risk of transnational radioactive pollution by accident, and create that measure of confidence among potential victim nations, without which coexistence among national societies has become unthinkable in this era of technology-intensive industrial activities. Moreover, the "internationalization" of basic safety standards, quality assurance programs, and proof of compliance with strict internationally devised standards, might, in individual cases, enhance the credibility of national management efforts and mitigate domestic opposition to given features of a national waste management program. A strong case can thus be made for international agreements adopting criteria for the performance of waste forms and sites, utilizing a common methodology for the safety assessment of disposal options,[30] and establishing an international

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28. *See* Criteria for Radioactive Waste, Proposed Criterion No. 4, 43 Fed. Reg. 53262 (1978), and POLVANI REPORT, *supra* note 4, at 23.

29. J. RAWLS, A THEORY OF JUSTICE 62 (1973).

30. *See* POLVANI REPORT, *supra* note 4, at 69. *See also Report to the American Physical Society by the Study Group on Nuclear Fuel Cycles and Waste Management* 50 REVIEWS OF MODERN PHYSICS S128 (No. 1, Part II-1978) [hereinafter cited as APS REPORT]. In view of the many uncertainties characteristic of HLW management operations, it is well understood that modeling ought not to be the "primary decision tool to determine the capability of the geologic repository to contain and isolate waste from the biosphere." *See* 10 C.F.R. Part 60 (Proposed), Technical Criteria for Regulating Geologic Disposal High-Level Radioactive Waste, 45 Fed. Reg. 32393, 32398 (1980).

data bank with files identifying the specific characteristics of all nationally (or internationally) operated waste sites.[31] These policies presuppose close cooperation among nations, pooling research data, and easing technology transfers. The advantages of such internationalization are quite clear: long term nuclear waste disposal safety would be enhanced, duplication of national research and development avoided, and the cost of individual national programs reduced.

Until recently the management of HLW and TRU elements had "been dealt with by competent authorities exclusively in national terms."[32] However, the need for internationally coordinated management policies is rapidly gaining recognition. The call for adoption of international standards on 1) approval procedures for geological disposal; 2) site selection criteria for geological disposal; 3) site confirmation procedures; and 4) design and operation procedures for the disposal facilities[33] by a panel of the International Atomic Energy Agency (IAEA) has been reiterated at INFCE. Working Group Seven has suggested similar comprehensive international guidelines on the handling, conditioning, storage, and disposal of various wastes from nuclear fuel cycle operations.[34] Preliminary work on such regulatory parameters is presently being carried out within the European Economic Community (EEC),[35] the Nuclear Energy Agency of the OECD, and the IAEA.[36]

International cooperation related to safety research is not only ex-

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31. For a more detailed discussion, see POLVANI REPORT, *supra* note 4, at 62. As to the fundamental importance of a documentation of disposal activities, note the experience of a U.S. construction company encountering explosive eruptions in the soil at a site at which non-documented burials of low-level thorium wastes had taken place. *See generally* N.Y. Times, July 16, 1978, at 21, col. 1; *U.S. Officials Suggest Presence of More [Unknown] Sites of Radioactive Wastes,* N.Y. Times, Feb. 25, 1979, at 22, col. 1; and *Atom Wastes of War Haunt Niagara Area from "Grave,"* N.Y. Times, June 23, 1980, at B1, col. 5.

32. COMMUNICATION FROM THE COMMISSION TO THE COUNCIL ON A COMMUNITY PLAN OF ACTION IN THE FIELD OF RADIOACTIVE WASTE 11 (EEC Doc. COMM (77) 397:1977) [hereinafter cited as EEC PLAN OF ACTION].

33. *See* Mason, *Regulatory Requirements for Radiation Protection,* in INT'L ATOM. ENERGY AGENCY, 4 NUCLEAR POWER AND ITS FUEL CYCLE, PROCEEDINGS OF AN INTERNATIONAL CONFERENCE, SALZBURG 63, 74 (1977) [hereinafter cited as IAEA CONF.] and Richter, *National and International Activities in the Field of Underground Disposal of Radioactive Wastes,* 2 INT'L ATOM. ENERGY AGENCY BULL. 30 (No. 4-1978).

34. *See* INFCE REPORT, *supra* note 6, at 108-09.

35. *See* EEC Council Decision of 18 March 1980 adopting a programme on the management and storage of radioactive waste (1980 to 1984), O.J. EC, No. L.78, March 25, 1980; and Council Res. of 18 Feb. 1980 on the implementation of a Community plan of action in the field of radioactive waste, O.J. EC, No. C 51, Feb. 29, 1980, 1-3.

36. As to NEA work, *see* NEA ACTIVITY REPORT, *supra* note 4, at 30; as to work within the IAEA, *see* INT'L ATOM. ENERGY AGENCY, ANNUAL REPORT FOR 1979 at 24 (IAEA Doc. GC (XXIV)/627:1980).

panding on a bilateral basis.[37] In addition to INFCE, intensive joint international research is taking place under the auspices of the Nuclear Energy Agency of the OECD and within the framework of the EEC[38] and the Council of Mutual Economic Assistance.[39] Unfortunately, the sensitive issue of protection of industrial and scientific know-how still remains a key obstacle to the international transfer of waste management technology.[40] In the future greater flexibility in national licensing criteria may be required by recipient countries to allow a maximum utilization of already available waste management technology.

Although strong momentum towards the internationalization of

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37. *See, e.g.,* Technical Exchange and Co-operation Agreement in the Field of Management of Radioactive Wastes, Dec. 20, 1974, United States-West Germany, 29 U.S.T. 4544, T.I.A.S. 9067. *See also* 15 NUCLEAR L. BULL. 31 (1975). Note further the joint U.S.-Swedish experiments related to the emplacement of HLW into granite masses, mentioned in NUCLEAR ENERGY AGENCY, ORGANIZATION FOR ECONOMIC COOPERATION AND DEVELOPMENT, SIXTH ACTIVITY REPORT (1977) at 36 (1978) [hereinafter cited as NEA SIXTH REPORT]. Note also the recent agreement between Euratom and Canada on joint environmental assessments and research into the handling of radioactive waste, described in International Herald Tribune, Nov. 4, 1980, at 2, col. 7.

38. Thus, the Radioactive Waste Management Committee of the OECD/NEA recently set up a Co-ordinating Group on Geological Disposal for the purpose of exchanging information and promoting cooperation among member countries. *See* NEA SIXTH REPORT, *supra* note 37, at 35. *See also* EEC PLAN OF ACTION, *supra* note 32, at 14; res. of the European Parliament, paras. 19-22, O.J. No. C85, 4.10. 1978, p. 47; references in U.S. DEP'T OF ENERGY, REPORT OF TASK FORCE FOR REVIEW OF WASTE MANAGEMENT (DRAFT) 94 (1978); and, *e.g., infra* notes 181 and 213 and accompanying text; *cf. also* Art. 42, para. 1(c) of the 1974 Agreement setting up the International Energy Agency which lists as a matter of priority, international cooperative programs on radioactive waste management, *reprinted in* 14 INT'L LEG. MAT'LS 1, 20 (1975). For details of the European Communities' collaborative program of research and development into waste management, see review of the first EC Conference on Radioactive Waste Management and Disposal, 23 NUCLEAR NEWS 65 (No. 9-1980).

39. Richter, *supra* note 33, at 39. *See also* Specter & Shields, *Nuclear Waste Disposal: An International Legal Perspective,* 1 NORTHWESTERN J. INT'L L. & BUSINESS 569, 606-16 (1979).

40. One case in point is the transfer of French waste solidification technology to the U.S. Despite a keen U.S. interest in the French technology, no transfer deal was possible because of the public nature of the NRC licensing process which provides public access to all pertinent information and data. The French feared a "pirating" of their technology developed at great cost and, as recent reprocessing contracts prove, of a potentially considerable market value. *See* APS REPORT, *supra* note 30, at S162-63. Pursuant to 10 C.F.R. § 2.790, only a compelling reason for nondisclosure to be ascertained by balancing the interests of the parties urging non-disclosure and the public interest in disclosure, will persuade the NRC to preserve the confidentiality of proprietary information submitted to it in the course of Commission proceedings. For confirmation of the validity of the Commission's rule of practice setting forth this test of disclosure, *see* Westinghouse Electric Corp. v. NRC, 555 F.2d 82 (3d Cir. 1977).

Note, however, that a recent amendment to the 1974 U.S.-German Agreement on Technical Exchange and Cooperation seeks to maximize exchange of confidential information while protecting proprietary interests. *See* Technical Exchange and Co-operation Agreement in the Field of Management of Radioactive Wastes, *supra* note 37, at Appendix B.

long-lived radioactive waste management operations exists much of the regulatory framework must yet be devised. In other words, forging a consensus on the international acceptability of a great many very specific management criteria remains a major political challenge.

III. INTERNATIONAL CONCERN AS A FUNCTION OF SPACE UTILIZATION IN NUCLEAR WASTE MANAGEMENT

A. Introduction

Reference has already been made to the siting of nuclear waste repositories in boundary areas as a concern to neighboring states. The risk of a transfrontier migration of radionuclides released from the site by accident or natural failure of containment barriers over time not only makes the siting decision reviewable by the potentially affected states but may also raise serious questions about its propriety under international law.[41] Diplomatic activity over a final waste repository proposed for Swiss territory close to the Italian border[42] illustrates this point.[43]

Since this use of national territory has been extensively analyzed elsewhere,[44] the following paragraphs will deal with the general issue of waste management practices within national territory, involving the buildup of global radioactivity. Oceans as repositories of nuclear wastes will also be considered. Other areas beyond national jurisdic-

41. For further details, *see* Handl, *An International Legal Perspective on the Conduct of Abnormally Dangerous Activities in Frontier Areas: The Case of Nuclear Power Plant Siting*, 7 ECOLOGY L.Q. 1 (1978).

42. *See* Roussau, *Chronique des Faits Internationaux*, 81 RGDIP 967-68 (1977) and 1 INT'L ENVT'L RPTR. 209-10 (1978).

43. Another potential source of international concern is the temporarily stored HLW at the shut-down fuel reprocessing plant at West Valley, N.Y. U.S. scientists have established a link between leaks at the storage facility and measurable traces of radioactivity of the waters of Lake Erie. *See* Austin American-Statesman, Nov. 4, 1979, at C1 and Democrat and Chronicle (New York), Nov. 5, 1978, at 15.

Note, moreover, the recently expressed concern by the government of Lower Saxony (West Germany) that leakage from a low to medium-level radioactive waste repository in East Germany, in proximity to the border, could endanger fresh water supplies in West Germany. *See* Sdt. Zeitung, Sept. 23, 1980, at 7, col. 5 and Written Question No. 785/79 to the Commission of the EC on the risk of transfrontier radioactive pollution of water resources in Italy due to uranium mining on the French side of the Maritime Alps (O.J. EC, No. C315/3, Dec. 15, 1979).

44. *See* Handl, *supra* note 41. *See also* Randelzhofer & Simma, *Das Kernkraftwerk an der Grenze*, in FESTSCHRIFT F. FRIEDRICH BERBER 389 (D. Blumenwitz & A. Randelzhofer eds. 1973) and Pelzer, *Errichtung und Betrieb von Kernkraftanlagen im Lichte des Völkerrechts*, in INTERNATIONAL NUCLEAR LAW ASSOCIATION, NUCLEAR INTER JURA 75: PROCEEDINGS 49 (1975). Note in this context Art. 37 of the Euratom Treaty which commits member states to submit to the Commission for its opinion data on any national waste management plans which are likely to involve radioactive contamination of the water, soil or airspace of another member state.

tion and control are not discussed even though extraterrestrial disposal might become a technically feasible option when space shuttle systems become available.[45]

B. *Global Environmental Impact Potential of Front End Nuclear Fuel Cycle Wastes*

1. The Issue in Perspective

Low level nuclear wastes from the front end of the nuclear fuel cycle have gained attention only recently as a potentially significant long term source of radiological contamination. Most concern centers on mill tailings, a sand-like byproduct of the uranium extraction process which retains most of the radioactivity of the original, premilled ore. Mill tailings are important to this discussion because radionuclides possess extremely long half-lives, the bulkiness of the tailings exceeds that of the ore itself,[46] and more than one billion tons of tailings will exist in the United States alone by the end of the century.[47] Surface or near-surface disposal of tailings enhances the likelihood of biospheric contact over the enormous time span during which tailings remain an environmentally hazardous source of radiation.

The key radionuclides are decay products of natural uranium, namely thorium-230 and its progeny radium-226 with half-lives of 80,000 and 1600 years, respectively. Thus, radiation from these elements and their daughter products continues "essentially for as long as we care to consider."[48]

Tailings are initially pumped as slurry into natural retainment ponds. The gradual evaporation of water leaves behind dry tailings piles. Traditionally these piles have been accorded minimal or no stabilization treatment such as earth covering. Besides creating a risk of exposure to external gamma radiation to persons in the immediate vicinity of the pile, this practice allows an environmental dispersion of radionuclides due to the escape of gaseous radon-222, a progeny of radium-226, and the erosion by wind and water of radioactive particulates. Stabilization and maintenance of piles to prevent distribution of radionuclides may have to continue for tens of thousands of

45. Note in this context that NASA is presently studying such a space transport system which might allow the placing into a solar orbit of radioactive wastes. *See* U.S. DEP'T OF ENERGY, *supra* note 38, at 165.

46. This is due to the space between the grains, given an average 0.5 percent uranium content of the ore. *See* IAEA CONF., *supra* note 33, at 545, 548.

47. *Id.* at 550.

48. *Id.*

years[49] since such release of radioactivity entails nonnegligible health risks to the exposed population.

The general population close to the tailings piles can be exposed to significant radiation doses by inhalation of radon and its daughter products or ingestion of resuspended particulates.[50] Moreover, a significant number of health effects among distant U.S. and world populations could result from the long term environmental buildup and persistence of low level radioactivity of radon gas. This "environmental dose commitment"[51] is explained by the fact that upon release from mill tailings piles in the western United States, for example, radon will disperse over the eastern part of the country and into the northern hemisphere.[52] Although the dose to any individual is small, the actual number of people exposed is large. Assuming a linear, nonthreshold relationship between biological effects and exposure to low level radiation, EPA computations suggest a not insignificant number of potential health effects.[53] Thus by the year 2000, U.S. commercial mill tailings piles[54] alone might generate over 20,000 adverse health effects unless adequate stabilization measures are taken.[55]

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49. *See* APS REPORT, *supra* note 30, at S79.

50. For details *see, e.g.*, SWIFT, POTENTIAL RADIOLOGICAL IMPACT OF AIRBORNE RELEASES AND DIRECT GAMMA RADIATION TO INDIVIDUALS LIVING NEAR INACTIVE URANIUM MILL TAILINGS PILES (EPA-520/1-76-991: 1976). These findings have found strong endorsement recently. "40 C.F.R. § 190 limits are not met at locations near the mill. Doses received by the nearby individual greatly exceed 25 rem per year; 40 C.F.R. § 190 bone and lung doses are 120 and 36 rem, respectively. Analysis indicates the limit could not be met within about four km downwind from the mill." U.S. NUCLEAR REGULATORY COMMISSION, DRAFT GENERIC ENVIRONMENTAL IMPACT STATEMENT ON URANIUM MILLING 4 (NUREG-0511: 1979) [hereinafter cited as DRAFT GEIS].

51. "A . . . perspective of the environmental impact of radioactive effluents includes the additional impact in subsequent years due to the buildup and persistence of long-lived radionuclides. This perspective is termed 'the environmental dose commitment' and, simply defined, is the sum of all doses to individuals over the entire period the material persists in the environment in a state available for interaction with humans." U.S. ENVT'L PROTECTION AGENCY, ENVIRONMENTAL RADIATION DOSE COMMITMENT: AN APPLICATION TO THE NUCLEAR POWER INDUSTRY 5 (EPA-520/4-73-002: 1974). *See also* IAEA CONF., *supra* note 33, at 23.

52. *See* U.S. ENVT'L PROTECTION AGENCY, ENVIRONMENTAL ANALYSIS OF THE URANIUM FUEL CYCLE, PART I–FUEL SUPPLY 71 (EPA-520/9-73-003-B: 1973).

53. EPA has thus calculated a total of 200 potential health effects due to the environmental radiation dose delivered over a period of 100 years by radon-222 emanations from a model tailings pile. *Id.* at 73.

54. In other words, this excludes the weapons-program related tailings piles.

55. This is based on EPA data of 200 health effects per model pile, which covers an area of 250 acres. ENVT'L PROTECTION AGENCY, *supra* note 52, at 73. The 109 tons of tailings which will be produced by the year 2000 might cover 26,250 acres. The total health effects likely to occur would therefore increase by two orders of magnitude. As of May, 1978, there were approximately 140 million tons of tailings at various uranium milling sites

These findings, however, are subject to caveats, particularly as a result of recent scientific studies on the dose-response relationship, characteristic of exposure to low level radiation.[56] Nevertheless, the tentative nature of the above EPA data does not diminish the validity of the conclusion that mill tailings may constitute a potentially serious environmental health problem. Danger from such small doses has been dismissed as indistinguishable from natural background radiation and hence insignificant.[57] However, such a view is incompatible with the nonthreshold hypothesis for radiation effects which ought to be the cornerstone of any prudent radiation protection policy. In light of prevailing uncertainty[58] it is being assumed "that there is some potential ill health attributable to any exposure to ionizing radiation. . . ."[59] This hypothesis for radiation standard setting was strongly supported by the International Commission on Radiological Protection.[60] It serves as the basis of EPA's regulatory activity in re-

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in the West. Address by Commissioner Victor Gilinsky, U.S. Nuclear Regulatory Commission, presented at the Pacific Southwest Minerals & Energy Conference, Anaheim, CA (May 2, 1978), *reprinted in* Nuclear Regulatory Commission, Office of Public Aff. Publ. No. J-78-3 at 2 (1978).

56. The linear relationship model for estimating biological effects from low doses of low-level radiation has been under attack for some time. In 1979, the National Academy of Science (amidst much controversy) declined to publish an updated version of its 1972 report on the biological effects of ionizing radiation (BEIR I) in which a majority of the scientists involved had endorsed continued reliance on the linear model. The 1980 revised version (BEIR III) now substitutes a linear-quadratic for the original linear relationship model to describe the dose-response curve at low levels of dose. Cancer deaths per million per rem under the new model are calculated to range from 67 to 226 while the linear approach would give a result of 158 to 201. *See* COMMITTEE ON THE BIOLOGICAL EFFECTS OF IONIZING RADIATION, DIV. OF MEDICAL SCIENCES, ASSEMBLY OF LIFE SCIENCES, NATIONAL RESEARCH COUNCIL, THE EFFECTS ON POPULATIONS OF EXPOSURE TO LOW LEVEL OF IONIZING RADIATIONS 147 (1980) [hereinafter cited as BEIR III]. TheEPA-computed potential health effects might thus represent substantial overestimates. However, dissenting reports to BEIR III underline the fact that postulated effects from exposure to low-level radiation are conjectural in nature. *See* Land, *Estimating Cancer Risks from Low Doses of Ionizing Radiation,* 209 SCI. 1197 (1980).

On the need to improve the dosimetry of radon and daughters and the modeling of airborne and liquid pathways of radionuclides from tailings piles, see DRAFT REPORT OF THE SUBGROUP ON FEDERAL INVOLVEMENT OF THE INTERAGENCY REVIEW GROUP ON NUCLEAR WASTE MANAGEMENT (APPENDIX II) 17 (1978).

57. *See, e.g.,* IAEA CONF., *supra* note 33, at 303, 315.

58. *See, e.g.,* UNITED NATIONS SCIENTIFIC COMMITTEE ON THE EFFECTS OF ATOMIC RADIATION, SOURCES AND EFFECTS OF IONIZING RADIATION 414-46 (1977). The Committee itself based, however, its calculations on the linear relationship model. *Id.* at 28.

59. EPA Policy Statement on Relationship between Radiation Dose and Effect, 41 Fed. Reg. 28402 (1974).

60. *See* RECOMMENDATIONS OF THE INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION 6-7 (ICRP Publ. No. 27: 1977) [hereinafter cited as ICRP RECOMMENDATIONS] and IAEA CONF., *supra* note 33, at 3.

spect to environmental radioactivity,[61] as a basic premise in the Nuclear Regulatory Commission's (NRC) updating of its "Environmental Survey of the Nuclear Fuel Cycle"[62] and has again been endorsed in the 1980 National Academy of Sciences Report on the Biological Effects of Ionizing Radiation (BEIR III)[63] and by a group of experts on the Nuclear Energy Agency of the OECD.[64] Accordingly, even if long term exposure to low level radiation could be dismissed by itself for generating only insignificant health risks, such irradiation must be considered as a factor contributing to the overall risk of cancer.

A fundamental tenet of prudent radiation policy would therefore be violated if low radiation doses are dismissed and any risk of harm justified by surrounding circumstances.[65] Since the doses involved are avoidable manmade doses which increase the risk of cancer, their justification should be subject to review automatically.

Management of mill tailings must be considered a potential issue, and one that falls squarely into the ambit of transnational inquiry. Given the extremely long half-lives of key radionuclides involved, the potential problem remains significant for an indefinite period of time. Authors of the American Physical Society's study group on nuclear fuel cycles and waste management, for example, provide an interesting perspective on this time factor. In assessing the long term hazard from the residual radioactivity of the tailings they compared the 63 Ci/GWe-yr of Ra-226 from front end wastes to the 10^7 Ci/GWe-yr of fission products in high level wastes from nuclear reprocessing:

> The mill tailings are comparable to the high-level wastes as a potential health hazard after a few hundreds of years. When we consider the relative likelihood of biospheric contact with geologically buried plutonium as opposed to surface piled 226 Ra, the mill tailings may well be more important for the long term.[66]

The relative importance of mill tailings has been corroborated by the INFCE Working Group, which surveyed the waste management and

61. *See* Fed. Reg. 2858, 2859 (1977), 41 Fed. Reg. 28402 (1974), and 46 Fed. Reg. 2556 (1981).
62. *See* 43 Fed. Reg. 39801 (1978).
63. *See* note 56, *supra.*
64. RADIOLOGICAL SIGNIFICANCE REPORT, *supra* note 27, at 13.
65. *See* ICRP RECOMMENDATIONS, *supra* note 60, at 3 and 43 Fed. Reg. 53262 (1978).
66. APS REPORT, *supra* note 30, at S79-80. *See also* Address by Victor Gilinsky, *supra* note 55, at 3.

disposal segments of selected nuclear fuel cycles.[67] Consistent with the initial exposition of the time parameter of "international concern," the management of mill tailings therefore represents an issue that transcends national decisionmaking.

The other factor which establishes mill tailings management operations as a matter of international concern is the transnational health impact potential of environmentally distributed radon. Of the 20,000 potential health effects associated with long term exposure to atmospheric radon and daughters from unstabilized U.S. commercial mill tailings piles, 8,000 are estimated to occur outside U.S. boundaries.[68] In other words, U.S. waste management decisions have an obvious potential for a significant transboundary health impact. Likewise, foreign tailings management operations are likely to have a corresponding impact on the U.S.[69]

There can be little doubt that tailings management is an issue which highlights the interdependence of national waste programs aimed at protecting the environment and preventing undue health risks to human beings. Successful action at home depends on complementary measures abroad. In conclusion, mill tailings raise inherently global environmental and health issues which require an internationally coordinated approach.

2. Towards a Proper Response to the Mill Tailings Issue

From national and international viewpoints the essence of the radiological problem posed by mill tailings lies in its very long term source of enhanced environmental radioactivity. Regulatory regimes for uranium milling operations ought to reflect the overriding importance of the tailings disposal issue. This tenet has a number of important implications, most notably for siting new mills, since site selection and tailings disposal options are interrelated.[70] Before reviewing specific ramifications, fundamental policy objectives which inspire long term management should be delineated.

Two principles might be posited as basic guidelines. First, tailings

67. *See* Table XXII on Collective Dose Commitments from Waste Arisings of Reference Fuel Cycles in INFCE REPORT, *supra* note 6, at 81. Note the NRC's view that regulations for the management of uranium mill tailings were urgently needed. *See* 45 Fed. Reg. 65521, 65523 (1980).

68. *See* note 55, *supra.*

69. Of course, all these computations depend on a number of variables such as age distribution, life expectancy, etc. Accordingly, the present figures give only an approximate picture of the transnational impact potential.

70. *See* 45 Fed. Reg. 65521, 65523 (1980).

should be disposed of in such a manner that radon emissions approximate natural background radiation in the disposal area. Secondly, the design of the repository should facilitate a constant emission rate over the long term without requiring active human care of the stabilized piles.

Since surface or subsurface uranium ore deposits contribute to natural background radiation even in the absence of front end fuel cycle activities,[71] the former criterion emphasizes minimization of the manmade contribution to the environmental dose commitment, thereby taking account of ICRP recommendations.[72] Moreover, incentives to site final repositories near elevated background radiation would avoid additional "hot spots" in areas where background radiation is relatively low. The latter criterion stems from the conclusion that long term reliance on institutional controls, which are essential to secure a desired level of future radiation protection, reflects unjustified expectations of their long term effectiveness. Consequently, the risk transferred is actually greater than would presently be considered acceptable.

Implementation of these two basic policy objectives is admittedly a difficult endeavor. Although a "pile can be constructed and managed for minimal erosion over a conventional engineering time span, it certainly must be considered no more secure than any other surface feature over [the period of time involved]."[73] Erosion or disturbance due to weathering, seismic activity, or human intrusion must constantly be guarded against. Therefore, unless tailings stabilization programs provide for underground burial, long term stability of piles may well imply permanent use restrictions, long term site monitoring, and fencing and warning markers as permanent monuments of the nuclear age.[74] All of this reflects a dubious sense of moral responsibility towards future generations.

Several technical strategies featuring underground burial are theo-

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71. The relevance of this sometimes overlooked fact with regard to cost-benefit calculations for management options has been specifically emphasized at INFCE. *See* INFCE REPORT, *supra* note 6, at 9.

72. In particular it recommends that any practice or operation carrying a risk of harm be justified and that the provision of protection be pursued as far as is reasonably achievable. *See* note 60 *supra*.

73. APS REPORT, *supra* note 30, at S79.

74. *See* DRAFT GEIS, *supra* note 50, at 9-38 to 9-39. Only deep burial of the tailings would obviate the need for long-term site monitoring and thus allow virtually unrestricted productive use of the site. *See id.* at 10-15. *See also* U.S. NUCLEAR REG. COMM., FINAL ENVIRONMENTAL STATEMENT RELATED TO THE OPERATION OF LUCKY MCGAS HILL URANIUM MILL 3-15 to 3-16 (NUREG-0357: 1977) and ENVT'L PROTECTION AGENCY, ENVIRONMENTAL ANALYSIS OF THE URANIUM FUEL CYCLE, PART IV–SUPPL. ANALYSIS–1976 at 33 (EPA 520/4-76-017: 1976).

retically available. The options range from singling out for special treatment a significant fraction of the radium in the waste materials[75] and stabilizing the tailings with asphalt or concrete[76] to simple backfilling of underground mines with supplementary surface waste retention systems, soil coverage, and revegetation.[77] Most of these approaches are quite costly to implement, and few are without drawbacks. For example, the benefits of extracting radium from the tailings right after the milling process is based on the fact that radon emanation is directly proportional to radium concentration in the tailings. Therefore, it is claimed, "[e]xtraction of the radium would provide an advantage in reducing the hazard from the bulk of the waste material and concentrating the hazard into a small volume that might be disposed of in a manner comparable to that envisioned for high level wastes."[78] It is readily conceded, however, that the benefits of this approach would be partially offset by radiation to which the workers would be exposed.[79]

The cost-risk analyses to be performed for each option thus involve difficult value judgments. Because national decisions on this issue hold intrinsically transnational implications, the matter of long term tailings pile management calls for an international approach.

Issuance by the IAEA, in 1976, of a Code of Practice concerning the mining and milling of uranium and thorium ores[80] presents evidence of a consensus among nations that at least minimal stabilization measures at national sites are a matter of international concern. The Code does not offer specific guidance on the more intricate cost-benefit issues. It suggests, however, a number of steps towards an

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75. Process alternatives include nitric acid leaching, separation of the slimes (in which most of the radium and its daughter products are concentrated) from the sands fraction of the tailings, precipitation of radium through neutralizing the acidic slurry with lime, removal by ion-exchange and through treatment with barium chloride (the latter used to precipitate radium ions from sulfuric acid). DRAFT GEIS, *supra* note 50, at 8-8 to 8-9.

76. APS REPORT, *supra* note 30, at S80.

77. For detailed reviews of alternative tailings preparation, disposal site options and alternatives for site preparation and tailings stabilization, *see* DRAFT GEIS, *supra* note 50, at 8-8 to 8-26; and LANDA, ISOLATION OF URANIUM MILL TAILINGS AND THEIR COMPONENT RADIONUCLIDES FROM THE BIOSPHERE–SOME EARTH SCIENCE PERSPECTIVES 19-26 (U.S. Geological Survey Circular 814: 1980).

78. Schiager, *Radwaste Radium–Radon Risk,* in U.S. EPA, PROCEEDINGS: A WORKSHOP ON POLICY AND TECHNICAL ISSUES PERTINENT TO THE DEVELOPMENT OF ENVIRONMENTAL PROTECTION CRITERIA FOR RADIOACTIVE WASTES 2-45, 2-56 (ORP/CSD-77-2: 1977).

79. *Id.* For additional drawbacks such as technological uncertainties, expected high costs, etc., *see* DRAFT GEIS, *supra* note 50, at 12-8. As to the distributional justice problem of present benefits vs. future hazards, *see* notes 23-29, *supra* and accompanying text.

80. Safety standards and codes of practice are approved and recommended by the IAEA Board of Governors to member states to be taken into account in the formulation of national regulations and rules of practice.

adequate long term management solution, such as a provision by the owner/operator of the mill of financial guarantees (bonding, escrow accounts) to ensure maintenance and monitoring programs, and the transfer of ownership of the tailings sites to the state on the grounds that direct government responsibility would in the long run provide better assurance that tailings piles are accorded the requisite care.[81]

In the absence of any more detailed, internationally agreed upon recommendations on final tailings disposal, the U.S. management program which has now largely taken shape[82] might, in many respects, provide a model regime for other countries with tailings disposal problems.

Pursuant to Title I of the Uranium Mill Tailings Radiation Control Act of 1978[83] the Department of Energy has initiated a remedial stabilization program for inactive mill tailings sites.[84] The NRC[85] has recently promulgated strict effluent control measures for the licensing and regulation of current and future sources of tailings.[86] To the extent that they bear on avoidance of transnational radiation effects, the salient features of the NRC technical criteria are certainly worth pointing out in greater detail.

As a fundamental tenet the new regulations stipulate that "[i]n general, the conditions of tailings disposal sites should be virtually the same as those in surrounding environs and should remain so without

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81. INT'L ATOMIC ENERGY AGENCY, MANAGEMENT OF WASTES FROM THE MINING AND MILLING OF URANIUM AND THORIUM ORES: A CODE OF PRACTICE AND GUIDE TO THE CODE (Safety Series No. 44-1976). As to the latter steps, *see, e.g.*, Strohl, *Legal, Administrative, and Financial Aspects of Long Term Management of Radioactive Waste,* 21 NUCLEAR L. BULL. 77, 80 (1978) and INFCE REPORT, *supra* note 6, at 8-7.

82. As to the jurisdictional problems which for a long time thwarted any comprehensive "cradle to grave" regulatory approach to the tailings issue, *see* Address by Victor Gilinsky, *supra* note 55, at 3-7; for a comprehensive review, *see Uranium Mill Tailings Control, Hearings Before the Subcom. on Energy and the Env. of the Comm. on Interior and Insular Aff.,* H.R., 95th Cong., 2d Sess. (1978). *See also* Friedman, *Environmental Problems Relating to Uranium Mining and Milling,* 11 NAT. RES. L. 277 (1978).

83. 42 U.S.C. §§ 7901-7942 (Supp. II 1978).

84. For a list identifying "priority remedial action sites," *see* 44 Fed. Reg. 51894 (1979).

85. In so-called "agreement states" it is the state authorities which have exclusive jurisdiction over mill tailings sites as long as the state continues to exercise licensing authority. As a result of the recent amendment to the 1978 act, the NRC's role has thus been limited to rendering assistance to the states in upgrading their regulatory programs to meet the new statutory requirements. *See* Pub. L. No. 96-106, 93 Stat. 799 (1979).

86. *See* 45 Fed. Reg. 65521 (1980). EPA has just proposed disposal standards for tailings which qualify for remedial action under Title I of Pub. L. No. 95-604 (40 C.F.R. Part 192). *See* 46 Fed. Reg. 2556 (1981). In crucial respects, such as long term avoidance of institutional controls and values for emission limitation, EPA standards mirror NRC requirements.

active care and maintenance."[87] The prime option for disposal of tailings is considered to be "placement below grade, either in mines or specifically excavated pits."[88] As to minimization of long term radon emissions, the regulations do not prescribe fixation of the tailings to improve isolation, but instead require reduction of the radon flux to a maximum of two picocurie per square meter and second above the natural background level.[89] This is to be achieved by a sufficient earth cover placed over the buried tailings. It must also feature either a self-sustaining vegetative cover or, in arid areas, a sufficient rock cover to assure the long term integrity of the repository against wind and water erosion.[90] The regulations' financial surety arrangements and site ownership provisions,[91] which largely correspond to those recommended in the IAEA Code, as well as the general emphasis on subordination of short term conveniences or benefits (as in the context of transportation or land acquisition costs) to the long term management objectives[92] are also important.

To be sure, some of the regulations, such as the numerical limitation of radon emissions from the repository, may reflect value judgments which are not shared in other nations. Although this is a reminder that international minimum standard setting will be unavoidable, the transnational importance of the U.S. regulatory effort is a major one. It sets a precedent by creating a solid basis for discussion of the much needed long term safety standards of global applicability.

C. *The Transnational Impact of Long-Lived Waste Radionuclides in Effluent Streams from Nuclear Power and Reprocessing Facilities*

1. The Nature of the Problem

Environmentally diluted routine effluents of international concern are not only characteristic of reprocessing plant operations but occur also at nuclear power stations.[93] While only reprocessing effluents

87. 45 Fed. Reg. 65525 (1980). The technical criteria for tailings disposal sites, twelve in all, can be found at 45 Fed. Reg. 65,533-36 (1980) (to be codified at 10 C.F.R. Part 40, App. A).

88. *Id.* at 65,533 (Criterion 3).

89. *Id.* at 65,534 (Criterion 6). *See also* 40 C.F.R. § 192.03 (Proposed).

90. 45 Fed. Reg. 65,533-34 (1980) (Criterion 4(d)).

91. *Id.* at 65,535-36 (Criteria 9-10).

92. *Id.* at 65,533 (Criterion 1).

93. Routine gaseous effluents from power stations include krypton-85, tritium and carbon-14. ERDA ALTERNATIVES, *supra* note 16, at 2.15-2.17. Another effluent is nitrogen-16, a relatively short-lived, high-energy, gamma emitter in the steam of BWRs. U.S. ENVT'L PROTECTION AGENCY, *supra* note 74, at 59. Because of its localized effects, N-16 is, however, of no consequence to the present discussion.

cover the whole spectrum of environmental radioactivity, power plants are a significant source of routine, transnational, long-lived radioactive effluents.[94] These discharges occur as both airborne and liquid effluents. Different reactor systems, fuel properties, and location of the worldwide source terms (coastal or inland) account for variations in the ratio of production and environmental release and the ratio between airborne and liquid release forms for the radionuclides of interest.[95] These variations evidently render estimates of the potential overall global health and environmental impact from routine discharges exceedingly difficult. For purposes of this discussion, somewhat more reliable estimates, based on more uniform assumptions, of potential health effects created nationally and transnationally by the U.S. nuclear power industry alone are considered, to provide perspective on the scope of the transnational problem. Iodine 129 (I-129), a fission product with a physical half-life of 17 million years, is a routine effluent; its release is almost exclusively restricted to fuel reprocessing facilities.[96] At least in one instance, possibly indicative of general practices, 45-90 percent of this isotope appears to have been routinely discharged into the environment.[97] In addition, practically all krypton 85 (Kr-85), a gaseous fission product with a physical half-life of 10.7 years, has traditionally been released from reprocessing facilities, the only significant source term. Tritium (H-3), a fission product, and to a smaller extent an activation product, is routinely discharged from power plants and reprocessing facilities. The release rate for H-3 at reactors is a function of a number of variables. For most reactors it is considerably less than the 75-100 percent release at reprocessing plants.[98] Finally, carbon-14 (C-14) is predominantly an activation product with a physical half-life of 5,370 years. It is assumed that all of it is released in the form of carbon dioxide at

94. For details, *see* RADIOLOGICAL SIGNIFICANCE REPORT, *supra* note 27, at 33-42. As to projected health effects for the individual radionuclide concerned, *see* note 109, *infra*, and accompanying text.

95. *See* POLVANI REPORT, *supra* note 4, at 75-88 and RADIOLOGICAL SIGNIFICANCE REPORT, *supra* note 27, at 33-42.

96. U.S. ENVT'L PROTECTION AGENCY, *supra* note 51, at 18.

97. The 90 percent figure is from Hatfield, *Nuclear Fuel Reprocessing: Radiological Impact of West Valley Plant*, in UNION OF CONCERNED SCIENTISTS, THE NUCLEAR FUEL CYCLE: A SURVEY OF THE PUBLIC HEALTH, ENVIRONMENTAL AND NATIONAL SECURITY EFFECTS OF NUCLEAR POWER 162, 169 (rev. ed. 1975). The 45 percent figure constitutes a minimum based on calculations by MAGNO, IODINE-129 IN THE ENVIRONMENT AROUND A NUCLEAR FUEL REPROCESSING PLANT 13 (EPA ORP/FOD 72-5: 1972). According to ERDA, "[u]p to 90% of the iodine would be released without the use of iodine cleanup systems." ERDA ALTERNATIVES, *supra* note 16, at 13.12.

98. The figures are quoted from POLVANI REPORT, *supra* note 4, at 80-81 and RADIOLOGICAL SIGNIFICANCE REPORT, *supra* note 27, at 37.

reprocessing plants. However, releases from power stations make up a significant portion of the total environmental C-14 released from nuclear fuel cycle activities.[99]

Effects of these low level routine releases[100] must be considered from two perspectives. First, their immediate impact would be largely restricted to the vicinity of the plant sites. The associated short term exposures are of no transnational consequence unless the discharging facilities are situated near international borders.

From a long term perspective, however, routine effluents from reprocessing plants and power stations produce transnational as well as local effects. Indeed, the discharges of any one of these radionuclides can be considered "contributions of a permanent contaminant to the worldwide environment"[101] because of their long radioactive half-lives and their great dispersibility. While a release of I-129 into the atmosphere will result in an initial ground deposition of the isotope within 20 miles of the plant,[102] it is estimated the isotope will spread eventually over large geographical areas.[103] Similarly, the quantities of Kr-85, H-3, and C-14 discharged from plants in one country are expected to disperse globally.[104]

The global distribution of these very long-lived radionuclides translates into cumulative and irreversible levels of environmental radioactivity,[105] which in turn has been estimated to cause adverse world-

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99. *See* FOWLER, PUBLIC HEALTH CONSIDERATIONS OF CARBON-14 DISCHARGES FROM THE LIGHT-WATER-COOLED NUCLEAR POWER REACTOR INDUSTRY 17 (EPA Technical Note ORP/TAD-76-3: 1976). By contrast, Kelly assumes a discharge of only 10 percent of the carbon-14 produced in metal-clad fuels, but this difference accounts only for a minor decrease of the dose rate. *See* KELLY, THE PREDICTED RADIATION EXPOSURE OF THE POPULATION OF THE EUROPEAN COMMUNITY RESULTING FROM DISCHARGE OF KRYPTON-85, TRITIUM, CARBON-14, AND IODINE-129 FROM THE NUCLEAR POWER INDUSTRY TO THE YEAR 2000 at 30 (EEC Doc. V/2676/75: 1975). As to discharges from reprocessing plants, *see* U.S. NUCLEAR REGULATORY COMMISSION, DRAFT SUPPLEMENT NO. 1 TO THE FINAL ENVIRONMENTAL STATEMENT RELATED TO CONSTRUCTION AND OPERATION OF BARNWELL NUCLEAR FUEL PLANT, ALLIED-GENERAL NUCLEAR SERVICES IX-10 (Docket No. 50-332, NUREG-0082 Supp. 1 (Draft)–1976) [hereinafter cited as BARNWELL FES SUPP.].

100. These include also some actinides. *See* U.S. ENVT'L PROTECTION AGENCY, *supra* note 51, at 16.

101. FOWLER, *supra* note 99, at 1.

102. Hatfield, *supra* note 97, at 198.

103. The EPA study refers to the "entire eastern land area of the United States" as a result, presumably, of the operation of the U.S. commercial reprocessing facilities which are all located in that part of the country. U.S. ENVT'L PROTECTION AGENCY, *supra* note 51, at 19.

104. *Id. See also* KELLY, *supra* note 99, at 21-33.

105. *See* U.S. ENVT'L PROTECTION AGENCY, ENVIRONMENTAL ANALYSIS OF THE URANIUM FUEL CYCLE, PART III–NUCLEAR FUEL REPROCESSING 27 (EPA-520/9-73-003-D: 1973).

wide health effects. Indeed, the threatened global or regional effects render these routine effluents a significant health issue.[106] Relying on EPA and other data, Ellett and Richardson[107] have computed the number of potential fatal cancer cases per gigawatt electricity produced over one year for three waste radionuclides (based on a 100-year environmental dose commitment).[108] Assuming average facilities operating under then current U.S. control requirements,[109] they arrive at 4.6×10^{-2} potential fatal cancer cases for Kr-85 releases, 1.8×10^{-2} cases for H-3, and 3.2×10^{-1} cases for C-14.[110]

A correlation of these data with the growth estimates for the U.S. nuclear power industry would suggest the following globally distributed potential health effects: with a maximum of 200 GW(e) installed nuclear capacity by the year 2000,[111] releases from U.S. facilities can be estimated to result in 69 fatal environmental cancer cases each year due to C-14, 0.6 fatalities from tritium, and 9.2 fatal cases from Kr-85. At INFCE the globally installed nuclear capacity by the year 2000, not including, however, countries with a centrally planned economy,[112] was projected at a maximum of 1200 GW(e).[113] The worldwide impact potential of these environmentally diluted long-lived radionuclides thus readily emerges as a significant one, latent computational uncertainties notwithstanding.[114]

2. Towards an Adequate Management Strategy

The inherently transnational nature of the management challenge posed by long-lived radioactive routine effluents makes an interna-

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106. *See, e.g.*, U.S. ENVT'L PROTECTION AGENCY, *supra* note 105, at 12 and RADIOLOGICAL SIGNIFICANCE REPORT, *supra* note 27, at 78-79.

107. ELLETT & RICHARDSON, ESTIMATE OF THE CANCER RISK DUE TO NUCLEAR-ELECTRIC POWER GENERATION (EPA Technical Note ORP/CSD-76-2: 1976).

108. As to the notion of environmental dose commitment, *see* note 51, *supra*.

109. ELLETT & RICHARDSON, *supra* note 107, at 5. As to control requirements that will take effect by 1983, *see* notes 152 and 158, *infra*, and accompanying text.

110. ELLETT & RICHARDSON, *supra* note 107, at 9-10.

111. This figure is used in U.S. NUCLEAR REGULATORY COMMISSION, FINAL GENERIC ENVIRONMENTAL IMPACT STATEMENT ON URANIUM MILLING 3-2 (NUREG-0706, vol. I: 1980). In early 1980, the official DOE median forecast was of 240 GW(e) installed capacity by 2000. Frank v. Hippel, Uranium Security Without the Breeder (paper delivered at the meeting of the American Assoc. for the Advancement of Science, San Francisco, January 1980).

112. In 1978, countries with centrally planned economies (in Europe and Asia) accounted for 15% of the world's installed nuclear capacity. *See* INTERNATIONAL NUCLEAR FUEL CYCLE EVALUATION, INFCE SUMMARY VOLUME 5 (INFCE/PC/2/9: 1980).

113. *Id.* at 4.

114. Potential health effects due to routine effluents from the global nuclear power industry are, as already noted, very difficult to estimate. For some of the uncertainties involved in any such calculation, *see* KELLY, *supra* note 99, at 30, 56; APS REPORT, *supra* note 30, at S81; and RADIOLOGICAL SIGNIFICANCE REPORT, *supra* note 27, at 111-14.

tionally coordinated approach paramount. "Owing to the many sources of release and the dispersion of these nuclides certainly transcending national boundaries, such controls will need to be established on an international basis if they are to be effective."[115]

The contours of a responsible international management policy are determined by the availability of effective control technology and the risk-benefit ratio for installing such technology at nuclear facilities. In the final analysis, however, such a policy will depend on its overall risk-benefit ratio after a comprehensive evaluation of environmental release versus effluent control. Nonnegligible factors in assessing the latter are economic costs and potential risks associated with management of radionuclides once they have been recovered.

Alternatives to environmental discharge of the nuclides is separation from effluent streams, special treatment such as conditioning, and eventual terminal storage or disposal. From a technical viewpoint, the most challenging step in this sequence appears to be the initial radionuclide capture. Much of the technology and expertise in conditioning and terminal storage has evolved as a spin-off of research and development in HLW management. Effective control technology for all radionuclides of interest here is either available on a commercial basis or will soon be ready for industrial use.

Efficient retention technology of Kr-85 is available through the cryogenic process.[116] An equally efficient control system, operating on the basis of "selective absorption," might be available for commercial use by the early 1980s.[117] Follow-up steps in the utilization of these recovery technologies are likely to include encapsulation of the radioactive gas in pressurized steel cylinders[118] or chemical fixation in metal such as copper or titanium,[119] and final storage for as long as 150 years in above or underground bunkers or disposal into the sea.[120]

The "Iodox" scrubbing process appears to be the most promising

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115. POLVANI REPORT, *supra* note 4, at 75. *See also* KELLY, *supra* note 99, at 57-58.

116. For a detailed description, *see* ERDA ALTERNATIVES, *supra* note 16, at 13.4 to 13.6.

117. U.S. ENVT'L PROTECTION AGENCY, *supra* note 52, at 116.

118. For a discussion of options, *see* RADIOLOGICAL SIGNIFICANCE REPORT, *supra* note 27, at 151-53 and Laser, *Off-Gas Treatment and Krypton Disposal in the HTGR-Fuel Element Reprocessing,* in MANAGEMENT OF RADIOACTIVE WASTES FROM THE FUEL REPROCESSING, PROCEEDINGS OF A SYMPOSIUM JOINTLY ORGANIZED BY THE OECD/NEA AND IAEA, 27TH NOV.-1ST DEC. 1972 at 77 (1973).

119. This process of fixing krypton bubbles in metal reportedly results in greater safety with regard to final storage than encapsulation in pressurized containers. *See* Frankfurter Allgemeine Zeitung, Aug. 20, 1980, at 25, col. 2.

120. *See* Laser, *supra* note 118, at 90 and U.S. ENVT'L PROTECTION AGENCY, *supra* note 52, at 116.

approach to I-129 control because of its high efficiency ratio.[121] While this process may not yet be available, other present state of the art systems, either in isolation or together, provide removal efficiencies of no less than 90 percent.[122] After conditioning of the wastes, quasi-permanent isolation from the biosphere must be effected by disposal either in on-land geologic formations or into deep oceans.[123] If risk of transportation accidents were acceptable, extraterrestrial disposal might be a preferable option.[124]

Recovery of tritium is somewhat more complex because of the large volume of H-3 wastes and their comparatively low level of contamination.[125] Several efficient recovery technologies are being developed or investigated.[126] Of these, the so-called "volodixation" process may be the most effective way of dealing with H-3 wastes at reprocessing facilities.[127] Captured tritium could be disposed of either in liquid form by injection under high pressure into deep wells, or in solidified form in deep geologic formations.[128]

Finally retention of C-14 at fuel reprocessing plants might be achievable on a basis incidental to removal of Kr-85.[129] However, corresponding control efforts must also be directed to power reactors in order to achieve a significant reduction in overall release of C-14. In either case, capture could be effected by absorption on molecular sieves or by caustic scrubbing.[130] Follow-up steps to C-14 removal are not expected to present any undue technological difficulties: C-14 would be incorporated into stable carbonate and thus readied for long term isolation.[131]

In the end, availability of highly efficient control devices is proportional to the time and money involved. As with any allocation of societal resources, the desirability of such a commitment depends on

121. According to the ERDA waste management study, a decontamination factor (DF) of 10^6 is feasible. ERDA ALTERNATIVES, *supra* note 16, at 13.18. The DF denotes the reduction in release in terms of a fraction of the otherwise totally discharged radioactivity. A DF of 10^6 therefore implies a release reduction to one millionth of the original release potential.

122. *See* U.S. ENVT'L PROTECTION AGENCY, *supra* note 52, at 90-92.

123. *See* RADIOLOGICAL SIGNIFICANCE REPORT, *supra* note 27, at 92.

124. P. ALTOMARE, ASSESSMENT OF WASTE MANAGEMENT OF VOLATILE RADIONUCLIDES 13 (EPA Doc. ORP/CSD 79-2: 1979).

125. *Id.*

126. For an overview, *see* ERDA ALTERNATIVES, *supra* note 16, at 13.21 to 13.40.

127. I.e., the separation of H-3 from the off-gas stream subsequent to its volatilization brought about by the heating of the chopped fuel. *Id.* at 13.21 to 13.25.

128. *See, e.g.*, RADIOLOGICAL SIGNIFICANCE REPORT, *supra* note 27, at 84-89.

129. By utilization of either the cryogenic distillation or the selective absorption process. *See, e.g.*, BARNWELL FES SUPP., *supra* note 99, at IX-6.

130. For details, *see* RADIOLOGICAL SIGNIFICANCE REPORT, *supra* note 27, at 89.

131. *See id.*

the ratio of unit resources allocated to unit results obtained, and on the value of each unit to society. As recent debates show, the cost-benefit of environmental controls is an increasingly controversial issue.[132] The transnational scope of the problem makes the assessment even more difficult. This is certainly true for the management of routine radioactive effluents. On one hand, no control technology (with the exception of the cryogenic process) has yet been tested in commercial operations. Cost scenarios for these technologies are based on theoretical calculations, or on extrapolations from laboratory or pilot plant experiments. Moreover, relatively few exact data are available on the financial and radiological safety aspects associated with steps subsequent to nuclide capture.

On the other hand, estimated environmental and health effects from routine effluents are subject to caveats, as noted earlier. Their monetary valuation, a prerequisite for any cost-benefit analysis, is particularly difficult since health detriments are ascertainable statistically only from increments of the collective dose, but ought to be evaluated in monetary terms which reflect the individual's preference for risk avoidance or incurrence.[133] In other words, the regulator's dilemma lies in the allocation of a monetary value to avoidance of the health effects projected to occur within an entire population. When the individual's dose is exceedingly small and based on the individual's perception of the risk involved, this value might well be zero. From a regulatory viewpoint, allocation of a zero value appears inappropriate in light of real though hidden health effects among the general population.[134]

In these circumstances the individual preference function obviously fails as a basic guideline for regulatory action. Still, some affirmative conclusions concerning the cost-effectiveness of at least a partial control of these routine effluents appear justified. Before reviewing them in detail, a consideration of fundamental policy principles regarding

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132. For an excellent overview of the issues, *see, e.g.*, Rodgers, *Benefits, Costs, and Risks: Oversight of Health and Environmental Decisionmaking*, 4 HARV. ENVT'L L.J. 191 (1980).

133. The individual preference function is of fundamental significance in any cost-benefit analysis the objective of which is the efficient allocation of economic resources. In terms of the Pareto criterion an economic (or social) arrangement can be said to be efficient when it is not possible to change the allocation so as to make at least someone better off without at the same time making another worse off. In other words, it represents an equilibrium situation in which individual members of society retain their voluntary chosen positions as contemplated changes are not expected to bring about any improvement in their respective positions.

134. Though there appears to be a general consensus as to the inapplicability of a zero value, the valuation, by the decisionmaker, may vary considerably. *See* note 146, *infra*, for details.

transnationally relevant cost-benefit determinations is in order. First, the formulation of national regulatory policy on health risks must reflect the state of the art domestically and internationally and should force advances in control techniques and their timely application.[135] Successful foreign testing of effluent control technology is likely to set a valid standard for national policy purposes when domestic technical know-how or actual experience is lacking.[136] In any event, national standard setting must be future oriented to anticipate technology which is economically and technically feasible but not yet available.[137] Secondly, in justifying national remedial action, any transnationally caused health or environmental effects must be taken into account. The transnational impact is an integral part of any national cost-benefit analysis which underlies the decision on control device installation. Third, if elimination of the global problem requires action by the international community, nations are obliged to work in good faith toward such a solution. They also may be committed to act independently provided such action is cost-effective by national standards. Failure of unilateral measures to produce significant remedial impact on global problems, however, cannot justify a nation's refusal to initiate independent action.

Fourth, the limit on national expenditures to reduce per unit radiation exposure or estimated health effects also must be subject to international review, since value judgments differ between national societies. Unilateral cost-benefit decisions on national activities with transnational impact invariably risk imposing national environmental, economic, and public health priorities on countries exposed to the transfrontier pollutants. Obviously, this may open the way to serious international conflict centered on the "decisional sovereignty" of the

135. U.S. ENVT'L PROTECTION AGENCY, CONSIDERATIONS OF HEALTH BENEFIT-COST ANALYSIS FOR ACTIVITIES INVOLVING IONIZING RADIATION EXPOSURE AND ALTERNATIVES: A REPORT OF THE NRS-NAS & ASSEMBLY OF LIFE SCIENCES ADV. COMM. ON BEIR 110-11 (EPA/520/4-77-003: 1977).

136. An example in point is the highly effective use by Japanese utilities of lime/limestone scrubbers for removing sulfur dioxide from fossil-fired power plants. The Japanese success had gained major significance in the U.S. debate about "full scrubbing" with th EPA claiming that "the scrubber technology used in Japan . . . could be transferred to the U.S. 'with a reasonable degree of confidence'." *See* 9 ENVT'L REPTR. 916-17 (1978). For further details, *see* MAXWELL, SULFUR OXIDES CONTROL TECHNOLOGY IN JAPAN (Interagency Task Force Report: 1978). However, concern over the protection of proprietary information may prove to be a major obstacle to transnational technology transfer. A case in point is the refusal by the Japanese iron and steel industry to allow U.S. EPA officials to observe its innovative pollution control technologies. *See* 1 INT'L ENVT'L REPTR. 328 (1978) and note 40, *supra.*

137. For an analysis of the success and shortcomings of technology-forcing standard-setting with regard to air pollution, *see, e.g.*, Note, *Forcing Technology: The Clean Air Act Experience*, 88 YALE L.J. 1713 (1979).

affected nations–their right to decide for themselves benefit and radiation exposure levels within their territory.[138] Eventually the solution to the problem of routine effluents from nuclear power facilities will require internationally agreed upon discharge limits.

These basic transnational policy objectives are rooted in existing principles of international environmental law which (a) commit states to refrain from activities within their jurisdiction or control that cause damage to the environment of other states or to the area beyond the limits of national jurisdiction;[139] (b) insure greater internationalization of transnational pollution damage, namely that it is borne by the polluting rather than the victim nation;[140] (c) in any situation of interdependent natural resource utilization,[141] impose on the acting nation a duty to take into account the affected state's interest and to reconcile such interest with its own;[142] and (d) in its cost-benefit analysis commit the acting state not to discriminate between pollution affecting its own territory and population and pollution affecting the environment of a neighboring area.[143]

Although international standard setting for routine effluents has not progressed much beyond informal discussions and preliminary studies,[144] several countries have unilaterally adopted policies which are clearly consistent with the basic objectives just outlined. Thus, in the United States, the Environmental Protection Agency promulgated

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138. This is one basis upon which Australia attacked the legality of French atmospheric nuclear testing before the International Court of Justice. *See* 1 Nuclear Tests Case (Australia-France) ICJ Pleadings, Nuclear Tests 188 (1973).

139. *See, e.g.,* Principle 21 of the Stockholm Declaration on the Human Environment, *supra* note 22, *reprinted in* 11 INT'L LEG. MAT'LS 1416, 1420 (1972).

140. *See* the Polluter-Pays-Principle, adopted by the OECD, *reprinted in* 14 INT'L LEG. MAT'LS. 234 (1975); and by the European Economic Community, *id.* at 238. As to the applicability of this principle not only within each member country but also between them, see Smets, *Alternative Economic Policies of Unidirectional Transfrontier Pollution* in ORGANIZATION FOR ECONOMIC COOPERATION AND DEVELOPMENT, PROBLEMS ON TRANSFRONTIER POLLUTION 75, 85 (1974). For details on the general applicability of this principle, see Handl, *supra* note 44, at 43-44.

141. Such a situation exists here as the transfrontier radioactive pollution transfer media–air and water–constitute internationally shared natural resources.

142. *See generally* Lake Lanoux Case, 24 I.L.R. 101, 139 and Handl, *The Principle of "Equitable Use" as Applied to Internationally Shared Natural Resources: Its Role in Resolving Potential International Disputes over Transfrontier Pollution,* 14 REV. BELGE D.I. 40 (1978-79).

143. *See, e.g.,* Title C, Principle of Non-Discrimination of OECD Council Recommendation on Guiding Principles of Transfrontier Pollution (OECD Doc. C(74) 224, *reprinted in* 14 INT'L LEG. MAT'LS 242, 244 (1975); and OECD Council Recommendation for the Implementation of a Regime of Equal Right of Access and Non-Discrimination in Relation to Transfrontier Pollution (OECD Doc. C(77) 28 (Final), *reprinted in* 16 INT'L LEG. MAT'LS 977 (1977).

144. The most notable among the latter is RADIOLOGICAL SIGNIFICANCE REPORT, *supra* note 27.

environmental radiation standards which provide for a significant reduction of krypton-85 and iodine-129 discharges from reprocessing facilities.[145] EPA's conclusion that the cryogenic distillation process was cost-effective even by a standard of questionable applicability (the interim value of $1000 per reduced man/rem exposure used in the licensing of power plants)[146] was strongly attacked.[147] The criticism's persuasiveness, however, depended on an untenable premise: failure to take into account the potential health impact from environmental radioactivity in an area beyond the 50-mile radius of the reprocessing facility including the large number of effects estimated to occur abroad.[148] Similarly, many comments on the then proposed EPA regulations questioned the wisdom of unilateral action since international coordination was obviously required to get the problem firmly under control,[149] since by the end of the century the United States' contribution of Kr-85 to the world's atmosphere would be overshadowed by that of other nations.[150] In what amounts to a remarkable formulation, the agency rejected this challenge by concluding:

145. Environmental Radiation Protection Standards for Nuclear Power Operations, 40 C.F.R. Part 190 (1980).

146. Appendix I to 10 C.F.R. Part 50 (1980) provides for numerical guides for plant design objectives and limiting conditions for operations to help assure that radioactive material in effluents released be kept as low as is practicably achievable. *Id.* at paragraph D stipulates a limit of $1000 per man-rem reduction in the dose to the population within 50 miles of the reactor, as an interim value for the installation of radwaste systems.

EPA concluded that the cost, in 1977 dollars, per unit radiation dose reduction at future reprocessing facilities would be $50.-75 per man-rem and, thus, substantially below the $1000 interim value used in NRC licensing. *See* 42 Fed. Reg. 2859 (1977).

For an admission by the NRC staff that the $1000 value used in the 50 mile radius evaluation process for power reactors may be inapplicable to reprocessing plants with a worldwide impact potential, *see* BARNWELL FES SUPP., *supra* note 99, at IX-10. Note that, by contrast, the British National Radiological Protection Board recently suggested the guidance value of £10 per man-rem avoided as the most reasonable choice among alternative valuations ranging from zero to £50-100. *See* BRITISH NATIONAL RADIOLOGICAL PROTECTION BOARD, THE APPLICATION OF COST-BENEFIT ANALYSIS TO THE RADIOLOGICAL PROTECTION OF THE PUBLIC: A CONSULTATIVE DOCUMENT 10 (1980). By this yardstick, EPA's cost estimates of $50-75/man-rem avoided might not be justifiable.

147. For a summary of the various arguments and EPA responses, *see* U.S. ENVT'L PROTECTION AGENCY, FINAL ENVIRONMENTAL STATEMENT FOR 40 C.F.R. PART 190 (Vol. 2) at 10-17 [hereinafter cited as EPA FES].

148. For the strongest criticism in this respect, see letter from Shaw, Pittman, Potts, and Trowbridge, *id.* at A-122. "The product obtained by EPA, when they use the population of the entire world and calculate the dose over 130 years . . . is completely meaningless." *Id.* at A-162. In this context, see also the implicitly negative conclusions by the NRC staff concerning the cost-benefit of a krypton recovery system for the Barnwell plant. By applying the standard $1000 test and thus limiting the inquiry to the 50 mile radius, the staff managed to arrive at a cost estimate of $27,000 per man-rem reduction. *See* BARNWELL FES SUPP., *supra* note 99, at IX-10.

149. *See, e.g.,* comments by the NRC in EPA FES, *supra* note 147, at A-209, A-220.

150. *Id.*

> It is the view of the Agency that Krypton-85 from nuclear electrical power generation should be controlled by all major countries, and that as the acknowledged world leader in the development of nuclear power it has a responsibility to provide leadership, as it has in development of nuclear energy itself, for controlling adverse impacts on the environment and the public. This responsibility exists for localized effects as well as those which distribute and persist so as to affect large populations. Setting an appropriate example is basic to providing such leadership.[151]

EPA regulations to take effect by 1983 will consequently limit the Kr-85 release per unit energy generated to 50 percent of the current level or about 50 MCi/GW(e)yr.[152] In Germany a significantly more stringent discharge limitation of less than 1 MCi/yr has been recommended.[153] In Japan a Kr-85 retention system is being installed at the Tokai Mura plant.[154] The British Parliament accepted recommendations in the so-called Parker Report to install a krypton hold-out system at the expanded Windscale reprocessing facility "if reasonably practical."[155] Such a system would have been required for the originally proposed German reprocessing center at Gorleben.[156] Thus, there are clear indications that despite different social value considerations a growing number of nations consider the benefits of Kr-85 control to outweigh its costs. The advantageous cost-benefit relationship should be more pronounced when the potentially harmful, non-radiological effects of krypton are taken into account.[157]

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151. EPA FES (Vol. 1), *supra* note 147, at 176.

152. 40 C.F.R. § § 190.10 and 190.20 (1980).

153. Empfehlungen der Strahlenschutzkommission, *Bundesanzeiger* No. 132, July 23, 1975, 2.

154. *See* 21 NUCLEAR NEWS 64 (No. 10-1978).

155. *See* 21 NUCLEAR NEWS 26 (No. 8-1978).

156. *See* 23 NUCLEAR NEWS 70 (No. 9-1980).

157. For possible additional environmental effects of a buildup of Kr-85 see testimony by Dr. Knox, Division of the Atmospheric and Geophysics Division, Livermore Laboratory, California, in *The Costs and Effects of Chronic Exposure to Low-Level Pollutants in the Environment, Hearings Before the Subcommittee on the Environment and the Atmosphere on the Comm. on Science and Technology*, H.R., 94th Cong., 1st Sess. 679 (1975). "It has been estimated in very preliminary work that by the year 2000, when the krypton concentration of the atmosphere would be approximately 1 percent at MPC (maximum permissible concentration) we would have about a 10 percent change in conductivity of the atmosphere at sea level. It has been speculated that this may influence precipitation patterns." *Id.* at 686. *See also* Boeck, *Meteorological Consequences of Atmospheric Krypton-85*, 193 SCI. 195 (1976). "Nonradiobiological phenomena affected by Kr-85 include environmental radioactivity, atmospheric electricity, and inadvertent weather modification. If release of Kr-85 into the atmosphere continues unabated, global changes in the atmospheric electric circuit will occur within 50 years. Our present understanding of atmospheric processes is insufficient to determine the extent of consequent weather changes and whether they would be beneficial or harmful. Because of the 10-year half-life of Kr-85, global changes may last decades." *Id.* at 198.

EPA's iodine removal standards call for a limitation of the release to 5 mC (0.005 Ci) per GW(e)/yr.[158] Again, the standard is based on cost-effectiveness calculations for presently available control technologies, with the incremental cost of storage and disposal of the additional I-129 waste expected to be insignificant.[159]

No EPA environmental standards have been promulgated for tritium; data are insufficient to assess the practicability of limiting the release of this nuclide.[160] Thus the state of development of the most effective tritium control technology, the voloxidation process, allows only a conjectural cost computation.[161] Yet in 1976 the NRC staff concluded that a tritium recovery system for a Barnwell-type reprocessing facility might be cost-effective even on the basis of the $1000/man/rem value.[162] The marginal cost-effectiveness of controlling H-3 is evidently but one of the many transnationally relevant questions which need to be answered in an appropriate transnational forum.

In conclusion, despite significant data gaps, the marginal cost-effectiveness of controls is in many respects reasonably well understood. In some cases the overall advantage of reducing the global collective dose commitment must be deemed to outweigh the economic and social costs associated with release control. While a judgment to this effect may prevail in some countries like the U.S., it might not in other advanced industrial societies, let alone in less developed nations with nuclear power industries. In the final analysis, multilateral agreements, providing for specific discharge modalities and limits, alone can do justice to the dominant value issues involved in controlling transnationally effective routine effluents.

D. *Waste Management Concepts Involving the Use of International Commons*

1. Introduction

The preceding discussion centered on waste management practices within national territory producing incidental but significant transboundary effects. The following pages, by contrast, will focus on the

158. 40 C.F.R. § 190.10 (1980).

159. *See* U.S. ENVT'L PROTECTION AGENCY, *supra* note 52, at 95. This standard has, however, been criticized as too stringent in that it does not allow for possible variation in the discharge mode. For example, a higher release of I-129 into the marine environment is claimed to be possible at the same level of radiological significance. *See* POLVANI REPORT, *supra* note 4, at 87.

160. POLVANI REPORT, *supra* note 4, at 82 and EPA FES, *supra* note 147, at 6.

161. *See, e.g.,* RADIOLOGICAL SIGNIFICANCE REPORT, *supra* note 27, at 147-48.

162. BARNWELL FES SUPP., *supra* note 99, at IX-14.

increasingly important phenomenon of management operations conducted outside national territory, in areas not subject to exclusive national jurisdiction and control.

The international commons[163] that might be used for radioactive waste disposal includes oceans, the Antarctic,[164] celestial bodies, and outer space. In addition, for reasons of convenience, international watercourses which receive nuclear wastes will be analyzed here as well. At this time, only oceans and international watercourses are used for disposal of radioactive materials. Conceptually, however, waste disposal into outer space constitutes a fairly advanced management scheme.[165] Nuclear waste disposal practices of interest here are thus discharges of liquid effluents from enrichment, power, and reprocessing plant operations into the above named aquatic environments, solid waste dumping into the oceans, and the more recent idea of placing high level radioactive wastes beneath the seabed.

Increased national uses of common environmental areas during recent years has heightened the conflict between waste disposal and other uses. For example, contamination of fishing grounds and preemption of other important human activities in shared environments may be at stake. However, in many situations in which, for example, the oceans serve as waste repositories, alternative on-land disposal though perhaps not always within national territory will be available. Therefore, if mutually exclusive claims to use of the shared environment exist, utilization for waste management purposes might have to be disallowed.[166] The initial task consequently is to clarify when and if such use of oceans is incompatible with important other uses. A necessary prerequisite for sound decisionmaking is accurate data on the radiological hazards associated with any contemplated waste management operation. Environmental discharges of radioactivity, particularly through a pathway of internationally shared waterbodies, require a pre-release assessment of potential impact, as well as post-

163. This notion is to be understood in a jurisdictional sense only, denoting those areas which are *res communis omnium*.

164. Under the terms of the present Antarctic Treaty, the Antarctic does not really constitute an "international commons" as claims to territorial sovereignty in the area have been merely "frozen" for the duration of the Treaty. *See* Antarctic Treaty, Art. IV, *opened for signature* December 1, 1959, 12 U.S.T. 794, T.I.A.S. No. 4780, 402 U.N.T.S. 71. There is, however, a possibility that the future status of the Antarctic might be that of a "common heritage of mankind." Art. V of the Antarctic Treaty at present prohibits the disposal of radioactive wastes in the area.

165. For details, *see* U.S. DEP'T OF ENERGY, DRAFT EIS, MANAGEMENT OF COMMERCIALLY GENERATED RADIOACTIVE WASTE Vol. 2, App. R (DOE/EIS-0046-D: 1979).

166. Note that this already is a key consideration in the issuance of ocean dumping permits pursuant to the 1972 London convention. *See* note 196, *infra*.

event evaluation of the consequences[167] to provide a solid factual basis for accurate appraisal of the competition with other actual or envisioned uses.[168]

2. The Release of Radioactive Waste into Internationally Shared Aquatic Environments

a. Discharges into international watercourses

Under normal operating conditions liquid effluents from most nuclear establishments, including power plants, will be of a considerably lower order than the theoretical capacity of the international watercourse which receives it.[169] Whatever the final environmental impact limitation may be, it must reflect not only local environmental concerns but also ecological consequences in the river basin as a whole.

Discharges of low level routine radioactive liquid effluents are problematic for the simple reason that the water of any international watercourse is likely to be subject to extensive utilization. Even exceptional discharges of mildly contaminated waters are capable of causing controversy.[170] Any dumping is, of course, subject to restraints flowing from a well established body of general international environmental law,[171] which, as a minimum, subjects the national decision to international review if the contemplated release of radioactivity into the international river carries a significant risk of transnational harm or substantial interference with another nation's use

167. *See* NATIONAL ACADEMY OF SCIENCES, RADIOACTIVITY IN THE MARINE ENVIRONMENT 1, 4 (1971).

168. The pre-event assessment must be based on a critical pathway analysis. This approach identifies the route and estimates the concentration of the radionuclides at each step from the moment of its discharge to its uptake by man through the foodchain or its impact on man as an external radiator. Identification of the so-called critical population group, i.e., the group of people which because of its eating or living habits is the one most strongly exposed to the radioactivity released, and determination of the "critical radionuclide" are prerequisites for the ascertainment of maximum permissible discharge values to meet whatever maximum exposure levels may be applicable. Once identified, the critical radioisotope concerned may eventually control routine releases from a given plant in general. In more complex situations, however, "it may be necessary to specify separate limits for different radionuclides, according to their relative importance in the discharge, their radiotoxicity and their behavior in the environment." EUROPEAN NUCLEAR ENERGY AGENCY, ORGANIZATION FOR ECONOMIC COOPERATION AND DEVELOPMENT, RADIOACTIVE WASTE MANAGEMENT PRACTICES IN WESTERN EUROPE 70 (1971) [hereinafter cited as ENEA REPORT].

169. *Id.*

170. Note in this respect the public clamor over Metropolitan Edison's plans to purify the radioactive flood waters of the crippled Three Mile Island reactor and then dump the probably still mildly contaminated water into the Susquehanna River. N.Y. Times, May 26, 1979, at 24, col. 1.

171. This is apart from specific discharge limits that may have been agreed upon internationally in respect of certain river and lake systems.

of the shared resource.[172] In any event, in the overall scheme of things, and unless special circumstances prevail,[173] fresh water dumping represents a less likely nuclear waste management practice. It certainly is overshadowed by the global issues raised by ocean disposal of radioactive materials.

b. Releases into the marine environment

Disposal of low level liquid effluents into the sea entails problems similar to fresh water dumping. Significant differences exist, however, in that oceans are subject to less intensive multiple uses than international watercourses, and possess greater receiving and dilution capacities.

To date discharges of liquid effluents by pipeline into coastal waters have been a common practice. Likewise, dispersion into the marine environment[174] of liquid wastes or semi-liquid process slurries or sludge of large volume but low radioactivity is common.[175] All these dumping activities are preceded by detailed environmental impact analyses to avoid undesirable or dangerous concentrations of radioactivity in marine biota that could result in hazardous contamination levels in the marine food chain. External radioactivity as a significant health factor, particularly if coastal discharge areas are close to international boundaries, may have to be guarded against as well. Radionuclides might be washed ashore and absorbed by beaches or mud banks along estuaries[176] of another state's territory. The reliability of these impact analyses and justification of liquid low level dumping has depended on the accuracy of oceanographic models used to predict radioactivity concentrations in the dumping area. The exactness of oceanographic modeling, however, is a matter of controversy.[177] Moreover, ocean surface areas as well as the near-surface

172. *See* Handl, *supra* note 142, at 61-63.

173. An example in point could be the release of H-3 from the nuclear power industry in the upper Rhine area. POLVANI REPORT, *supra* note 4, at 81.

174. By pumping the wastes overboard into the wake of a moving vessel so as to achieve a maximum dilution effect. ENEA REPORT, *supra* note 168, at 73.

175. *Id.*

176. As to the relevance of the external radiation exposure pathway in the context of releases from the Windscale plant (at 2.5 km beyond the high-water mark), *see* Preston & Mitchell, *Evaluation of Public Radiation Exposure from the Controlled Marine Disposal of Radioactive Wastes (and Special Reference to the United Kingdom)*, in INT'L ATOMIC ENERGY AGENCY, RADIOACTIVE CONTAMINATION OF THE MARINE ENVIRONMENT, PROCEEDINGS OF A SYMPOSIUM, SEATTLE 10-14 JULY 1972 at 575, 585-86 (1973).

177. *See e.g.*, Van As & Forster, *Disposal of Radionuclides in the Sea*, 21 IAEA BULL. 24, 27 (No. 4-1979). Concentration of radionuclides in marine biota is, generally speaking, dependent on the temperature and salinity of water, the presence of stable isotopes and the chemical state of the radionuclide concerned. *See, e.g.*, EUROPEAN NUCLEAR ENERGY

water column—particularly in coastal areas—represent an important human environment. They are prone to significant contamination by liquid radionuclides since the latter may not be sufficiently dense or immiscible with seawater to prevent resurfacing.[178] In light of these considerations and the advances made in solidification of radioactive wastes, it might be advisable to permit ocean disposal of liquid wastes in only distant waters, and in exceptional circumstances which have been clearly defined internationally.

Most radioactive waste destined for ocean disposal is in a solid state. The impact of solid or solidified radioactive wastes on the marine environment is a function of type of waste, packaging, and location of disposal. Since solid waste packaging materials such as steel drums and cement yield to corrosion, water pressure, and decay heat, exposure of waste materials to seawater is inevitable.[179] Therefore, evaluation of type of waste and dumping location, especially the depth at which radioactive substances are deposited, is important to the environmental impact assessment.

Low level wastes, excluding long-lived radionuclides, appear less problematical. Exposure to seawater would occur after the waste had lost most of its radioactivity through decay of nuclides to stable or less radioactive materials. Provided that ocean currents dilute the remaining radioactive substances which will be subject to leaching, disposal at relatively minor depths and hence in areas subject to economic exploitation would appear feasible from a radiological safety

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AGENCY, ORGANIZATION FOR ECONOMIC COOPERATION AND DEVELOPMENT, MARINE RADIOECOLOGY: PROCEEDINGS OF THE SECOND ENEA SEMINAR, HAMBURG 1971 at 11, 16-17 (1971) and Penreath, *The Metabolism of Radionuclides*, *id.* at 97. Assessment of the latter is particularly difficult for coastal waters because of the complex topographical and meteorological variations which usually characterize coastlines. *See* Blanton, *Characteristics of Coastal Circulation Affecting the Transport and Dispersion of Materials Released from the Nuclear Industry* in COMBINED EFFECTS OF RADIOACTIVE, CHEMICAL AND THERMAL RELEASES TO THE ENVIRONMENT: PROCEEDINGS OF A JOINT IAEA/NEA/OECD SYMPOSIUM 225, 266 (1975) and Nishiwaki, *Behaviour and Distribution of Radioactive Substances in Coastal and Estuarine Waters* in INT'L ATOMIC ENERGY AGENCY, *supra* note 176, at 177, 177-78.

178. *See* INT'L ATOMIC ENERGY AGENCY, REVISED DEFINITIONS AND RECOMMENDATIONS OF 1978 CONCERNING RADIOACTIVE WASTES AND OTHER RADIOACTIVE MATTER REFERRED TO IN ANNEXES I AND II TO THE CONVENTION 6 (IAEA Doc. INFCIRC/205/Add. 1/Rev. 1: 1978) [hereinafter cited as IAEA DEFINITIONS AND RECOMMENDATIONS], *reprinted in* 18 INT'L LEG. MAT'LS 826 (1979).

179. According to one ERDA study, the time span involved is approximately ten years. U.S. ENERGY RESEARCH AND DEVELOPMENT ADMIN., U.S. NUCLEAR POWER EXPORT ACTIVITIES: FINAL ENVIRONMENTAL STATEMENT 2-22 (ERDA-1542, Vol. 1: 1976) [hereinafter cited as ERDA 1542]. Higher values are given in ERDA ALTERNATIVES, *supra* note 16, at 25.40, but these relate to canisters intended for geologic disposal. For the adoption of the same low value by an NEA expert group, *see* Oliver, *Sea Disposal of Packaged Rad Waste* in NUCLEAR ENERGY MATURITY: PROCEEDINGS OF THE EUROPEAN NUCLEAR CONFERENCE, PARIS, 21-25 APRIL 1975 at 355, 357-58 (1976).

point of view. However, a 1976 underwater survey of U.S. offshore dumping areas for low level waste revealed significant concentrations of radioactivity from traces of actinides and cesium[180] in the bottom sediments. Use of these sites had been discontinued in 1970.[181] At the Atlantic dump site with a depth of 9,300 feet (2800m), no commercially used fish were detected; at the Pacific site at 3,000 to 6,000 feet (900-1700m), sable fish, a commercially important food fish, were found near the wastes.[182] At a minimum, ocean dumping of solid wastes must accordingly be preceded by careful site selection based upon critical pathway analyses.

HLW and TRU-contaminated materials[183] commend themselves for exclusion from deep sea dumping. Such a policy, however, does not seem to be excessively prudent. While two hypothetical impact evaluations carried out independently by the former U.S. Energy Research and Development Administration[184] and the United Kingdom Radiological Protection Board[185] reported favorably on environmental and radiation safety aspects of disposing of solidified HLW on the floor of deep oceans, marine scientists take strong exception to dumping in deep sea areas.[186]

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180. Thus at the Pacific site plutonium contamination of surface sediments was found to be 2 to 25 times the maximum expected concentrations from weapons testing fallout; at the Atlantic site cesium concentrations were found to be 3 to 70 times the above comparative values. *See* Dyer, *Environmental Surveys of Two Deepsea Radioactive Waste Disposal Sites Using Submersibles* (paper presented at the International Symposium on the Management of Radioactive Wastes from the Nuclear Fuel Cycle, Vienna, 22-26 March, 1976), *reprinted in Radiological Contamination of the Oceans, Oversight Hearings Before the Subcomm. on Energy and the Environment of the Comm. on Interior & Insular Affairs,* H.R., 94th Cong., 2d Sess. 204 (1976) [hereinafter cited as OVERSIGHT HEARINGS]. Note that a 1978 survey by the Japan Fisheries Agency revealed 32 times more than the ordinary level of cobalt-60 and cesium-127 in the sediments of Sagami Bay, an important fishing area near Tokyo Bay, where secret dumping of wastes had taken place at least once in the mid-fifties. *See* 3 INT'L ENVT'L RPTR. 472-73 (1980).

181. OVERSIGHT HEARINGS, *supra* note 180, at 205.

182. *Id. See also* U.S. ENVT'L PROTECTION AGENCY, OPERATIONS REPORT: A SURVEY OF THE FARALLON ISLANDS, 500-FATHOM RADIOACTIVE WASTE DISPOSAL SITE 8-6 (Technical Note ORP-75-1: 1975).

183. As to the present international unlawfulness of the dumping of HLW, *see* notes 194-97, *infra,* and accompanying text.

184. *See* ERDA 1542, *supra* note 179, at 5-121.

185. Grimwood & Webb, *Assessment of the Radiological Protection Aspects of Disposal of High Level Waste on the Ocean Floor* 35 (NPRB-R48: 1976).

186. *See, e.g.,* Hollister, *The Seabed Option,* 20 OCEANUS 18 (1977). "Placing the high-level waste on top of the sea floor simply by kicking a canister off the fantail effectively puts the waste directly into the biosphere, as it is difficult to conceive of making a canister that would survive without leaking for hundreds of thousands of years in the corrosive marine environment. Any leak, either during the disposal operation or after, would inject radioactive material into the marine ecosystem. From samples, photographs, and current meter data, we know that the energetics of the biological and physical processes of the sediment/water interface (bethnic boundary layer) can be very high and very unpredictable." *Id.* at 19-20.

"Deep sea dumping, for all practical purposes, is irreversible under present technology."[187] Given the combined characteristics of high toxicity, quasi-permanence of transuranic elements, and limited knowledge of physical and biological processes that take place in oceans and the deep seas, dumping of HLW could create significant long run ecological problems.

3. The Regulatory Response to Ocean Dumping of Nuclear Wastes

Waste management operations involving the marine environment have a long history. As early as 1946 the United States disposed of radioactive wastes by ocean dumping.[188] While U.S. operations were discontinued in 1970, other countries, including European members of OCED under the aegis of the organization, Korea, and Japan,[189] have dumped in the past and are likely to continue sea disposal in the future.

At the height of United States and British dumping operations in the mid-1950s, the United Nations Scientific Committee on Effects of Atomic Radiation called for international coordination and agreement on releases of radioactivity which could result in significant radioactive contamination of the sea.[190] In 1958 the United Nations Law of the Sea Conference called upon the IAEA to promulgate standards and draw up internationally acceptable regulations to "prevent pollution of the sea by radioactive materials in amounts which would adversely affect man and his marine resources,"[191] and adopted the following provisions:

> 1. Every State shall take measures to prevent pollution of the seas from the dumping of radio-active wastes, taking into account any standards and regulations which may be formulated by the competent international organizations.

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187. ERDA 1542, *supra* note 179, at 2-22.

188. *See* Olivier, *Sea Disposal Practices for Packaged Radioactive Wastes* 2-3 (paper delivered at the International Symposium on the Management of Wastes from the LWR Fuel Cycle, Denver, Colo., 11-16 July, 1976).

189. South Korea recently admitted that over a five year period from 1968, it had dumped low-level wastes into its territorial waters off Ullung Do. *See* 3 INT'L ENVT'L RPTR. 210 (1980). As for Japanese operations in the past, see note 180, *supra*. As to its plans to initiate disposal of low-level wastes in the South Pacific by the fall of 1981, *see* 23 NUCLEAR NEWS 30 (No. 14-1980). Due to vehement opposition by members of the Pacific Basin Development Council, Japan appears now ready at least to defer its dumping plans. *See* 3 INT'L ENVT'L RPTR. 507 (1980).

190. Report of The United Nations Scientific Committee on the Effects of Atomic Radiation, 13 U.N. GAOR, Supp. (No. 17) 14, 38, U.N. DOC. A/3838 (1958).

191. *See* Resolution on Pollution of the High Seas by Radio-Active Materials, U.N. Doc. A/CONF. 13/L.56, in UNCLOS-I, OR (vol. II) 143-44 (1958).

2. All States shall co-operate 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 radio-active materials or other harmful agents.[192]

A subsequent panel of IAEA experts concluded that while wastes of low and intermediate activity could be disposed of safely into the sea under controlled and specified conditions, the release of high level wastes could not be recommended as an operational practice since little was known about the properties of the deep sea.[193]

This remains the present international regulatory outlook on ocean dumping. Apart from regional agreements such as the Baltic Sea Convention,[194] and the Convention for the Protection of the Mediterranean Sea against Pollution,[195] the 1972 London Convention on the Dumping of Wastes at Sea, a treaty of general applicability, is of interest here. This convention outlaws the disposal of high level wastes and other high level radioactive matter[196] defined by the IAEA as unsuitable for dumping at sea.[197] Disposal of radioactive materials into the marine environment which do not fall into this category requires a special permit, issued by competent national authorities after careful consideration of the characteristics and composition of the waste dumping location method of deposit, impact on competing uses of the sea, and availability of alternative land-based waste disposal.[198]

Although criteria for issuing special permits under the convention were substantially refined by the 1975 IAEA Recommendations and the 1978 Revised Recommendations, issued pursuant to authority granted the agency in Annex II of the London Convention, the scheme itself suffers from a significant shortcoming. National com-

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192. Art. 25 of the Convention on the High Seas, U.N. Doc. A/CONF. 13/L.53.

193. INT'L ATOMIC ENERGY AGENCY, RADIOACTIVE WASTE DISPOSAL INTO THE SEA 75 (Safety Ser. No. 5: 1961).

194. Art. 9 of the Protection of the Marine Environment of the Baltic Sea Area prohibits any dumping in the Convention area. *See* 13 INT'L LEG. MAT'LS 546, 549 (1974).

195. Art. IV of the Protocol for the Prevention of Pollution of the Mediterranean Sea by Dumping from Ships and Aircraft, together with Annex I, para. 7, bans the dumping of high-, medium- as well as low-level radioactive wastes. *See* 15 INT'L LEG. MAT'LS 300, 301, 304 (1976).

196. Art. IV of the London Convention, *reprinted in* 11 INT'L LEG. MAT'LS 1291, 1297 (1972).

197. As to the pertinent agency action, *see* IAEA DEFINITIONS AND RECOMMENDATIONS, *supra* note 178, at 3.

198. *See* Art. IV in connection with Annex III to the London Convention, *reprinted in* 11 INT'L LEG. MAT'LS 1291, 1311-13 (1972), and the additional recommended requirements under IAEA DEFINITIONS AND RECOMMENDATIONS, *supra* note 178, with regard to selection of a dumping site, packages for dumping, approval of the ship and its equipment, escorting officers and record keeping. *Id.* at 7-11.

pliance with international standards for ocean disposal of non-high level wastes is difficult to verify since contracting parties need only report data on national dumping permits and conditions to the appropriate international authority.[199] International supervision is essentially limited to an ex post facto evaluation, as the revised 1978 IAEA Definitions and Recommendations only suggest direct international observation of loading and disposal at sea.[200]

Effective international control, however, had been accomplished in 1977 through an OECD Council Decision Establishing a Multilateral Consultation and Surveyance Mechanism for Sea Dumping of Radioactive Wastes.[201] Under this decision the participating countries[202] are obliged to abide by the London Convention, IAEA Definitions and Recommendations, and any standards, guidelines, practices, and procedures adopted within the Nuclear Energy Agency (NEA) and in force at the time the waste management operation is to be carried out. Key sections of the decision are articles three and four which provide for notification by the country planning sea disposal and the opportunity for extensive consultations preceding actual dumping.[203] The improved regulatory scheme also provides for international supervision of national sea dumping operations by an NEA representative with substantial on-the-spot investigative and supervisory powers.[204]

Apart from the procedural obligations now incumbent on virtually every country with an active interest in nuclear waste disposal at sea,[205] the OECD decision has also committed these nations to compliance with detailed technical and operational criteria. Such standards are incorporated into the IAEA Recommendations[206] and OECD/NEA documents bearing on the packaging and sea dumping of

199. Art. IV. (1)c and 4 of the London Convention, *reprinted in* 11 INT'L LEG. MAT'LS 1291, 1299-1300 (1972). The international organization competent in this matter is IMCO. *See* IAEA DEFINITIONS AND RECOMMENDATIONS, *supra* note 178, at 11.

200. IAEA DEFINITIONS AND RECOMMENDATIONS, *supra* note 178, at 9.

201. OECD Doc. C(77)-115 (Final), *reprinted in* 17 INT'L LEG. MAT'LS 445 (1978). Of all nations with a special interest in the sea disposal option, only Japan abstained from what was otherwise a uniformly affirmative vote.

202. States which voted for the decision without reservations.

203. *See* 17 INT'L LEG. MAT'LS 445, 447-48 (1978).

204. *Id.* at 449.

205. Exceptions in this respect may be Korea and Taiwan, neither of which is a member of the OECD/NEA. Apparently Taiwanese plans do not exclude the possibility of ocean dumping in the future. *See* D. DEESE, NUCLEAR POWER AND RADIOACTIVE WASTE: A SUB-SEABED DISPOSAL OPTION? 32 (1978). Korea, on the other hand, has already carried out dumping operations and might do so also in the future.

206. *See* Annex II, paragraph D of the London Convention, *reprinted in* 11 INT'L LEG. MAT'LS 1291, 1311 (1972).

radioactive wastes.[207] They are binding on all countries concerned.[208] Consequently, dumping of unpackaged liquid waste in the deep ocean is now prohibited; dumping of unpackaged solid waste may be authorized only if it can reach the seabed intact.[209]

Given the internationally mandated notification and prior consultation procedure, the detailed substantive and procedural limitations applicable to actual management operations, and the degree of international supervision of operations themselves, dumping nuclear non-high level wastes should not result in significant contamination of the marine environment. These regulations apply to any marine area other than the internal waters of nations,[210] and international sea disposal criteria are continuously reviewed in the light of the latest scientific findings.[211]

4. Seabed Emplacement

a. The option from a technical viewpoint

This waste disposal concept, according to an ERDA report, is "not one of dumping as has been the practice with some wastes, which may or may not be detoxified in time by chemical or biological processes, but one of controlled emplacement in a geological formation whose coordinates happen to be in the ocean instead of on land."[212]

International attention has focused on deep seabed geologic formations as possible repositories for HLW, TRU, and long-lived radionuclides.[213] They are located on the ocean basin floors and flanks

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207. NUCLEAR ENERGY AGENCY, ORGANIZATION FOR ECONOMIC COOPERATION AND DEVELOPMENT, GUIDELINES FOR SEA DUMPING PACKAGES OF RADIOACTIVE WASTE (1979); and NUCLEAR ENERGY AGENCY, ORGANIZATION FOR ECONOMIC COOPERATION AND DEVELOPMENT, RECOMMENDED OPERATIONAL PROCEDURES FOR SEA DUMPING OF RADIOACTIVE WASTE (1979).

208. Pursuant to Art. 2 (b) of the 1977 OECD Decision, *reprinted in* 17 INT'L LEG. MAT'LS 445 (1978).

209. *See* Summary of the Statement by the IAEA Observer on the Revised Definitions and Recommendations on Radioactive Waste and Other Matter in *Report of the Third Consultative Meeting of Contracting Parties to the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter* (IMCO Doc. LDC III/12: 1978), *reprinted in* 18 INT'L LEG. MAT'LS 817, 823 (1979) and C.1 and C.3 of the IAEA DEFINITIONS AND RECOMMENDATIONS, *supra* note 178, at 831-33.

210. Art. III, paragraph 3 of the London Convention, *reprinted in* 11 INT'L LEG. MAT'LS 1291, 1296 (1972).

211. These reviews take place both within the IAEA and the Inter-Governmental Maritime Consultative Organization. Note also that a recent Canadian draft resolution on "procedures for effective application of the Convention" was introduced during a debate within IMCO on the 1978 IAEA Definitions and Recommendations. *See* 2 INT'L ENVT'L RPTR. 982 (1979).

212. ERDA ALTERNATIVES, *supra* note 16, at 25.31 (Vol. 5).

213. Note in this context the First International Workshop on the Seabed Disposal of High-Level Radioactive Wastes, at Woods Hole, Massachusetts, February 16-20, 1976. This

of the Mid-Oceanic Ridge. The ridge is a globe-encircling belt; at its center ocean plates which gradually move outward are constantly built up by crustal construction through injection of new molten basalt into the ridge. Although the flanks are young by geologic standards and hence lack deep sediments that have accumulated on older areas, they are seismologically stable, relatively inaccessible to human beings, and feature little flora and fauna.[214] These characteristics make deep seabed formations potentially suitable as HLW repositories for they may provide reasonable assurance that the waste radionuclides will decay to innocuous levels before they find their way back into the biosphere.

An even better waste disposal area appears to be the mid-plate, mid-gyre (center of great oceanic circular currents) regions of the ocean basin floors. Devoid of biological life and cataclysmic events, these regions also feature thick layers of bottom sediments.[215] These sediments or the underlying basalt rock formations are under consideration as effective nuclear waste isolation sites. Sediments act as additional barriers to the migration of radionuclides in case the borosilicate glass and canisters in which the HLW might be encased fail.[216]

Such failure, of course, is likely considering the enormous time span over which wastes remain significantly active.[217] Assuming that sediment emplacement represents a preferable solution,[218] these formations would very significantly slow the migration of radionuclides.[219]

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has resulted in coordinated research and development programs in France, the U.K. and the U.S., to further investigate the possibilities offered by sediments or bedrock underneath the seabed. *See* J. OLIVIER, PRESENT TRENDS IN RADIOACTIVE WASTE MANAGEMENT POLICIES IN OECD COUNTRIES AND RELATED INTERNATIONAL COOPERATIVE EFFORTS 7 (IAEA-CN-36/491: 1977).

214. *See, e.g.*, Hollister, *supra* note 186, at 18 and Hessler & Jumars, *Abyssal Communities and Radioactive Waste Disposal*, 20 OCEANUS 44 (1977).

215. For a comparative evaluation of key disposal parameters of the major ocean province, *see* Anderson, *Release Pathways for Deep Seabed Disposal of Radioactive Wastes* in OVERSIGHT HEARINGS, *supra* note 180, at 1009, 1012.

216. *See, e.g.*, *Report to the Radioactive Waste Management Committee on the First International Workshop on Seabed Disposal of High-Level Wastes, Woods Hole, Massachusetts, February 16-20, 1976* at 21-22 (SAND 76-0224: 1976). More recently, synthetic rock materials formed from a mixture of oxides have gained attention as being significantly superior to borosilicate glasses due to their exceptional resistance to hydrothermal leaching. For details, *see* Ringwood, *The Synrock Process: A Geothermal Approach to Nuclear Waste Immobilization* in NUCLEAR WASTE HEARINGS, *supra* note 23, at 468.

217. This is certainly true of glasses in relation to TRU waste.

218. Bedrock emplacement is so far technically feasible only at shallow depths (as against in deep seabed trenches). Because of the shallow crustal rocks' usual proximity to continents, they often lie beneath biologically productive ocean waters. *See* Hollister, *supra* note 186, at 19. This entails, of course, a greater possibility of waste radionuclides re-entering the biosphere. In any event, the environmental implications of emplacing nuclear wastes in crustal rock seem to be less well understood than those of sediment emplacement operations. *See, e.g.*, Anderson, *supra* note 215, at 1021.

219. *See* ERDA ALTERNATIVES, *supra* note 16, at 25.43 (Vol. 5).

In the case of deep sea dumping the water column would be called upon to take on a principal barrier function, which it might be unable to fulfill adequately.[220] By contrast, its role in any seabed emplacement scheme would be decidedly less crucial to prevent the reintroduction of significant radioactivity into the marine environment. Long-lived radionuclides escaping from seabed sediments will have been isolated for long periods and decayed to relatively innocuous levels of radioactivity. At this point, their dilution by physical dispersion would assure a negligible impact on the biosphere. Indications that sediments are an adequate nuclear waste retention medium[221] are at best preliminary. Research on emplacement techniques[222] and their effect on the sedimentary barrier are still needed.

Finally, newly discovered undersea chambers could prove to be ideal for permanent storage of nuclear and toxic chemical wastes. These caverns, located near the Galapagos Islands, lie beneath two miles of water, 150 feet of rock, and 50 feet of lava.[223] The vast pressure differential between the inside of the cavern and the ocean floor means that "anything dropped into a hole in the chamber would be sucked in, and the water would guarantee that it would not escape."[224] As promising as these potential sites appear, careful evaluation as a final HLW waste depository will require substantial time and effort.

b. The option in perspective

There is growing interest in seabed emplacement for high level and other wastes requiring long term isolation from the biosphere. This option is attractive because land area repositories are increasingly controversial[225] and many countries may not possess ideal geologic

220. To this effect, *see id.* at 25.41 (Vol. 4).

221. *See* Hollister, *supra* note 186, at 24, 25. Recently, Prof. Turekian of Yale University and Peter Rona, a geophysicist at the National Oceanic & Atmospheric Administration's Atlantic Oceanographic & Meteorological Laboratories in Miami characterized cracks in the eastern basin of the Atlantic ocean floor as effective potential radioactive wate disposal sites. Turekian & Rona, *Eastern Atlantic Fracture Zones as Potential Disposal Sites for Radioactive Waste,* 2 ENVT'L GEOLOGY 59, 61 (1977). For what amounts to an implicit endorsement of a geologic site in an environment with considerable dilution capacity (such as the seabed sediments), *see* de Marsily, *Nuclear Waste Disposal: Can the Geologist Guarantee Isolation?,* 197 SCI. 519, 526 (1977). For a more critical view, *see* APS REPORT, *supra* note 30, at S117-118.

222. For further details on sediment emplacement techniques such as free fall penetrometers or winch-controlled emplacement with free fall, *see* Silva, *Physical Processes in Deep-Sea Clays,* 20 OCEANUS 31, 36-37 (1977).

223. N.Y. Times, Dec. 9, 1979, at 70, col. 1.

224. *Id.*

225. As to the recent controversy in the U.S. over the storage of low-level radioactive wastes, *see* 22 NUCLEAR NEWS 48 (No. 15-1979). *See also* Lucas, *Nuclear Waste Management: A Challenge to Federalism,* 7 ECOLOGY L.Q. 917, 919-20 (1979). As to the situa-

formations for long term isolation.[226] Moreover, new doubts surround waste burial in salt formations, a key on-land geologic disposal option.[227] All this has spurred research into the technical and environmental aspects of seabed emplacement. France, Japan, the United Kingdom, and the United States have formed a seabed working group to promote the joint exploration of the seabed option. Canada recently expressed an interest in the group's activities;[228] other countries seem to be equally interested in its work.[229]

While key features of the seabed emplacement option are attractive, and technical problems solvable, the crucial issue to implementation will be public acceptance of this waste management strategy. The vastness and virtually unlimited waste receptive capabilities of the seas are factors that could determine public acceptance. On the other hand, seabed emplacement could be characterized as an irresponsible, nationalistic, and shortsighted policy which risks contaminating a crucial link in the global ecosystem.

At the present time, there is really no way to foretell which direction national public sentiment might swing, particularly in the U.S., a country critical to implementation of this strategy. On the international level troubles clearly lie ahead. The Soviet Union, for example,

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tion in Britain, *see, e.g.*, THE ECONOMIST, September 8, 1979, at 34. With regard to West Germany, *see* DIE ZEIT, September 7, 1979, at 12. As to Canada, *see* 3 INT'L ENVT'L RPTR. 51-52 (1980). As to the difficulty of finding adequate national disposal sites for hazardous wastes in general, *see* 10 ENVT'L RPTR. 2036 (1980) and *U.S. Aroused by Industry Plans to Ship Toxic Wastes Overseas*, N.Y. Times, Jan. 25, 1980, at A13, col. 5.

226. As to required disposal parameters (in particular, the long-term seismic stability of the site) *see* note 13, *supra* and accompanying text. As to the interrelationship of inadequate national landbased repositories and governmental interest in a seabed disposal option, see the discussion between Rep. Pritchard and Dr. Webster of NOAA, in *Ocean Dumping and Pollution, Hearings Before the Subcomm. on Oceanography and the Subcomm on Fisheries and Wildlife Conservation and the Environment of the Comm. on Merchant Marine and Fisheries*, H.R., 95th Cong. 313 (1978) [hereinafter cited as OCEAN DUMPING HEARINGS].

227. *See* the White House study of July 11, 1978, prepared by the Presidential Office of Science and Technology Policy, *reprinted in* N.Y. Times, July 12, 1978, at A13, col. 4. *See also* Carter, *Nuclear Wastes: The Science of Geologic Disposal Seen as Weak*, 200 SCI 1135 (1978). For further critical comments, *see* BREDEHOEFT, GEOLOGIC DISPOSAL OF HIGH-LEVEL RADIOACTIVE WASTES–EARTH-SCIENCE PERSPECTIVES 779 (Geological Survey Circular: 1978) and Kerr, *Geologic Disposal of Nuclear Wastes: Salt's Lead is Challenged*, 204 SCI. 603 (1979).

228. *See* Gera & Olivier, *OECD Countries Pursue Geological Disposal*, NUCLEAR ENGINEERING INTERNATIONAL, Jan. 1978, at 35-36. *See also* a report by a Canadian group of experts on nuclear waste management (EP 776), *excerpted in* 257 ATOM 74, 75 (1978) and the recommendations by the U.S. Interagency Review Group for adequate funding of research and development on deep ocean sediments in DRAFT REPORT TO THE PRESIDENT BY THE INTERAGENCY REVIEW GROUP ON NUCLEAR WASTE MANAGEMENT at xi (TID-28817:1978).

229. The Netherlands is a recent addition to the group, and Switzerland is expected to join shortly. *See* 22 NUCLEAR NEWS 80 (No. 11-1979).

has consistently taken a negative view of the use of the oceans[230] as nuclear waste repositories.[231]

A key issue, then, is whether or not emplacement of wastes in ocean floor sediments is prohibited under international law. Is such disposal equal to "dumping at sea" within the meaning of the London Convention?[232] Even if the answer is yes, the Convention does not prohibit dumping high level waste without qualification. Rather, it refers to "high level waste . . . defined by . . . IAEA, as unsuitable for dumping at sea."[233] In the light of other nations' opposition to the emplacement concept,[234] this legal issue may prove a decisive stumbling block. Removal of the provision would require skillful and patient international effort. Such efforts will be successful only if the public and opposing governments are persuaded that environmental and radiological safety issues are clearly understood and compare favorably with those alternative management options.

IV. CONCLUSIONS

The foregoing considerations show the inherently transnational ramifications of national nuclear waste management activities. Some of the transnational issues are overshadowed by weightier management problems on local and national levels. Whatever the relative importance from a national point of view, however, there can be no denying that at least in the long run any national management program can create significant transnational radiological consequences. Prevention of significant radioactive pollution thus requires international cooperation and coordination, the eventual outcome of which will have to be adoption of specific substantive and procedural management standards.

230. There may, however, be some evidence of prior Soviet ocean dumping. *See* D. DEESE, *supra* note 205, at 30.

231. "You considered various possible methods of disposing of high-level waste, including its emplacement of [sic] the seabed. Are investigations in this field still pertinent, considering that the dumping of high-level waste in the sea was prohibited by the London Convention of 1971?" D. I. Gusev in discussion of paper by Mitchell, *Options for the Disposal of High-Level Radioactive Waste,* in IAEA CONF., *supra* note 33, at 503, 512. Note also the recent reference by a Soviet lawyer to seabed burial of radioactive wastes as an example of "maricide" prohibited under international law. *See* Speranskaya, *International Legal Safeguards for the Marine Environment,* 10 INT'L AFFAIRS 86, 92 (1980).

232. For a more detailed discussion of this issue, *see* letter by David A. Deese to Congressman Udall, *reprinted in* OVERSIGHT HEARINGS, *supra* note 180, at 820, 821-22.

233. Annex I, para. 6 of the London Convention, *reprinted in* 11 INT'L LEG. MAT'LS 1291, 1310 (1972).

234. *See, e.g.,* Testimony of James M. Liverman in OCEAN DUMPING HEARINGS, *supra* note 226, at 198, 200.

Although the pace has recently quickened, overall progress in this respect has been slow. A number of factors account for this: 1) the tardiness with which national management strategies have evolved; 2) limited public awareness of the inherently transnational dimension of the management task; 3) the absence of dramatic, identifiable short term risks with the transnational impact potential; and 4) unwarranted doubts about the cost-effectiveness of standards which reduce or eliminate transnational effects.[235]

Decentralized as the international decisionmaking process continues to be, the principal responsibility for the initial formulation of necessary international waste management policies lies with individual nations. Countries with major nuclear power industries therefore will have to provide this leadership.[236] Such initiatives must eventually be replaced by joint international action. After all, only a coordinated approach can assure that waste management standards will reflect each nation's different environmental, development, or public health priorities, the interests of countries both with and without commercial nuclear power industries.

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235. As to the affirmative cost-benefit conclusions with regard to routine radioactive effluents from nuclear power facilities, *see* notes 152-159, *supra*, and accompanying text. Still, it could conceivably be argued that rather than spend a given amount of money on reducing, for instance, the transnational risk from globally-distributed gaseous radionuclides, the money might be spent more cost-effectively by sending shipments of grain to starvation-prone foreign nations. Saving lives abroad could be achieved in a much cheaper way. There are, alas, a number of problems with such a suggestion. First, benefits might accrue to individuals in a few receiving countries while the risk of fatal cancer is, of course, distributed globally; it would obviously be impossible to assure identity of potentially injured and actually "compensated for" individuals. Thus the inherently inequitable situation with regard to the distribution of nuclear power risks and benefits would not be remedied. Second, trade-offs of this sort would in any event presuppose either a centralized international decisionmaking institution or else decisionmaking through the market with perfect knowledge and willingness to trade on the part of the risk-exposed individuals or nations as necessary prerequisites. Obviously, no such global decisionmaking mechanisms exist. Moreover, in a world in which basic social needs may be met through a variety of strategies all of which entail some disadvantage or other, the full internalization of the social costs of each option is an essential precondition for a rational choice among competing alternatives.

236. *See* note 151, *supra*, and accompanying text. This includes both "consumer" and "producer" countries, i.e., those with industries at the "back-end" of the fuel cycle–the nuclear power countries proper–as well as "front-end" countries, like Australia or Gabon which are major uranium exporters.