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INTERNATIONAL ASPECTS OF THE MANAGEMENT OF LOW-LEVEL DUMPING OF RADIOACTIVE WASTES IN THE OCEANS

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INTRODUCTION

The environment, including man, has always been exposed to ionizing radiation from various natural sources. The notable characteristic of this natural radiation is that it involves the entire population of the world and that it has been at a relatively constant level over a very long period of time. On the other hand, the natural rate varies substantially from place to place. The various natural radiation sources include external sources such as cosmic rays, radioactive substances in rocks, soil and water, and internal sources in the form of naturally occurring radioactive substances in the bodies of man and other organisms. In the last century the exposure from natural radiation sources has been enhanced in some situations by technological developments, e.g., air travel, use of phosphate fertilizers, coal fired generating plants, use of natural gas, and radiation emitting consumer products. Other exposure to radiation from essentially artificial sources results from the medical uses of radiation (external and internal sources), nuclear explosions and the nuclear fuel cycle. Only the latter two sources could result in any significant additional radiation burden on the biota of the marine environment, and then to man from his use of marine resources.

Of particular interest in the last decade has been the increased use of the seas and oceans for the disposal of low-level radioactive wastes, both liquid and solid. In the case of liquid effluents, predominantly from the reprocessing of nuclear fuels, the immediate impact is upon the coastal waters of the country disposing of the waste, though there are potential long term implications for the oceans as well.[1] In the case of solid package wastes dumping is now limited to the deep oceans, i.e., deeper than 4000 meters. For most countries these depths lie beyond the proposed 200 mile exclusive economic limit. The concern here lies not only in the potential for contamination, by one or more countries, of the marine resources which most countries (and particularly developing countries) would consider part of the "common heritage of mankind," but also that such actions could result in an unacceptable radiation dose to those who use, or may in the future use, those marine resources. The prime consideration here is the protection of man. Of course, it is also necessary to consider the effects of radiation upon the different components of the ecosystem, not only because of the possible deleterious effects on the flora and fauna in general but because man may also be disadvantaged if important food resources are adversely affected.

INTERNATIONAL REGULATIONS GOVERNING RADIOACTIVE WASTE DISPOSAL

Probably the first international attention paid to the various dumping operations occurred in 1958 at the United Nations Conference on the Law of the Sea when Article XXV of the Convention on the High Seas was adopted. This article provides that all States dumping radioactive wastes at sea are to take measures to prevent pollution of the sea and to observe any standards or regulations formulated by the competent international organizations. It was at this stage that the newly formed International Atomic Energy Agency was requested by the conference to consider this matter further and to make recommendations with respect to the controls required for radioactive waste disposal. These were published by the IAEA in 1961 following the deliberations of a ten member country panel under the chairmanship of Professor H. Brynielsson of Sweden. Representatives from the United Nations; the Food and Agriculture Organization of the United Nations; and the United Nations Educational, Scientific and Cultural Organization participated in the work of the panel. The recommendations largely took the form of broadly guiding principles rather than detailed operational specifications, though some recommendations specific to dumping were made such as site selection requirements and package design.[2]

Dumping continued unilaterally by a number of countries until 1966 when the member countries of the European Nuclear Energy Agency (now the Nuclear Energy Agency of the Organization for Economic Cooperation and Development) agreed to study the possibilities for disposal of radioactive waste at sea on an international basis and to undertake joint disposal operations in conformity with agreed technical rules and safety procedures laid down by the NEA.

In the preliminary discussions to the United Nations "Human Environment" Conference in Stockholm in 1972, it became apparent within the intergovernmental working group on marine pollution that agreement could readily be reached on an international convention to regulate the dumping of toxic materials at sea. In December 1972 shortly after the conference, The Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter was agreed to and signed in London. The "London Dumping Convention" (LDC) was then the next step in international regulation of the deep sea disposal of radioactive waste and resulted in the prohibition of the dumping of high level radioactive waste or other radioactive matters deemed unsuitable for dumping at sea as defined by the IAEA. It also required that radioactive materials only be dumped at sea under a special permit issued by the national authority after taking due account of any IAEA recommendations as to the conditions to be observed in the issue of such permits. It is important to recognize, however, that the responsibility for issuing the permit and for determining that any required conditions are fulfilled rests squarely with the national authority and not with any international organization.

The IAEA addressed the new responsibility of making recommendations to be observed in the issue of dumping permits during 1973, and by 1974 a provisional definition of high-level radioactive waste (HLRW) unsuitable for dumping had been agreed upon.[3] In order to be consistent with the objectives and requirements of the London Convention, the definition was converted from release rates (Ci/y) to specific activities (activity per unit mass), i.e., Ci/ton based upon an arbitrary assumption of an upper limit of 10^5 tons for the annual mass dumped and calculated by averaging activity over no more than 100 tons.

This IAEA definition submitted to the First Consultative Meeting of the London Convention in 1976 also included recommendations on dump site selection, ship facilities including navigational aids, and the requirements for and functions of escorting officers. The definition was accepted as a provisional definition by the contracting parties to the London Dumping Convention in 1976, and the IAEA was asked to immediately begin review of it and related matters. The IAEA review began in September 1976 and proceeded through a series of consultant and advisory group meetings until March 1978 when a revised definition was agreed upon and forwarded by the IAEA Board of Governors to the Third Consultative Meeting of the LDC in October 1978 (Table I).[4] The revised definition was accepted, but the IAEA was requested to continue to review it and to develop associated advice as appropriate.

At the time that these developments were taking place, the Nuclear Energy Agency of the Organization for Economic Co-operation and Development (NEA/OECD) was revising its role in relation to radioactive waste sea disposal operations, taking into account the emergence of the legal framework established by the LDC and the IAEA Definition and Recommendations. Most NEA Member countries wished to maintain international co-operation in this field, mainly to continue to provide assurance that disposal operations would be prepared and carried out by individual countries in accordance with agreed international safety requirements. On the other hand, NEA would discontinue its previous involvement in the practical arrangements for joint disposal operations organized in the past under its auspices. Based on these considerations, a Multilateral Consultation and Surveillance Mechanism for Sea Dumping of Radioactive Waste was introduced by OECD in 1977[5] in which most NEA Member countries participate. The Mechanism provides for prior notification and consultation among Participating countries on the conditions proposed for dumping operations, as well as international surveillance of operations by NEA Representatives appointed for this purpose. Participating countries carrying out dumping operations undertake to apply NEA standards, guidelines and recommendations established under the terms of the Mechanism (consistent with relevant requirements of the LDC and the IAEA Definition and Recommendations). These include in particular standards of waste conditioning and waste package design and manufacture, identification of suitable dumping sites and relevant environmental and radiological assessments, recommended operational

Table I. IAEA Definition of High-Level Radioactive Wastes or Other High-Level Radioactive Matter Unsuitable for Dumping at Sea[1]

A.1.1. For the purposes of Annex I to the Convention, high-level radioactive matter unsuitable for dumping at sea means any waste or other matter with an activity per unit gross mass (in tonnes) exceeding:

(a) 1 Ci/t for α-emitters but limited to 10^{-1} Ci/t for ^{226}Ra and supported ^{210}Po;

(b) 10^{2} Ci/t for β/λ emitters with half-lives of at least 0.5 years (excluding tritium) and β/λ emitters of unknown half-lives; and

(c) 10^{6} Ci/t for tritium and β/λ emitters with half-lives of less than 0.5 years.

The above activity concentrations shall be averaged over a gross mass not exceeding 1000 tonnes.

A.1.2. The Definition must not be taken to imply that material falling outside the Definition is thereby deemed to be suitable for dumping.

A.1.3. Materials of activity concentration less than those in the above Definition shall not be dumped except in accordance with the provisions of the Convention, in particular Annexes II and III thereto, and the Recommendations set out in the Document, in particular Section B.1.2.

The Definition is based on:

(1) An assumed upper limit to the mass dumping rate of 100,000 t per year at a single dumping site; and

(2) Calculated upper limits to activity release rates from all sources (other than natural sources) of

(a) 10^{5} Ci/yr for α emitters (but limited to 10^{4} Ci/yr for ^{226}Ra and supported ^{210}Po);

(b) 10^{7} Ci/yr for β/λ emitters with half-lives of at least 0.5 years (excluding tritium) and β/λ emitters of unknown half-lives; and

(c) 10^{11} Ci/yr for tritium and β/λ emitters with half-lives of less than 0.5 years

at a single dumping site and also in the case of α emitters when released to an ocean basin of not less than 10^{17}m^{3}.

[1]IAEA (1978)

procedures, criteria for the suitability of ships selected for dumping, etc. The OECD Environment Committee is consulted with respect to all environmental policy aspects. The Mechanism is intended in many respects to provide for the regional type of consultation and co-operation that is foreseen by the London Convention as facilitating its own aims.

RADIOLOGICAL PRINCIPLES AS APPLIED TO DISPOSAL TO THE ENVIRONMENT

The question arises, therefore, how much radioactivity can one deliberately introduce into the marine environment, and at what rate, without causing adverse effects? There exists an international set of guidelines drawn up by the International Commission on Radiological Protection (ICRP) that can be used to set standards for the protection of the public. It is the responsibility of the national regulating agencies and the international agencies to use these guidelines to control the releases of radioactivity to the environment in such a way that the recommended limits are not exceeded.

The dose limit recommendations of ICRP are applied to individuals in identified critical group(s) in the population. If maximizing hypothetical assumptions are made, as in the case of the IAEA model, a value of 5 mSv (or 500 mr) is recommended for the annual limit. On the other hand, if actual critical groups are identified for a given disposal practice, then the ICRP recommends a limit of only 1 mSv (or 100 mrem) per year in a situation of continuous exposure.

It should be noted that from natural background there is an annual effective dose equivalent of about 1 mSv (100 mrem); as high as 0.5 mSv (50 mrem) from diagnostic medical irradiation; 0.01 mSv (1 mrem) from fallout and about 0.01 mSv (1 mrem) from various other sources. The natural background to which any one individual is exposed to will vary depending on the mineral content of the area he lives in, materials used in building construction and the altitude above sea level. Maximum levels can be as high as 2.5-3.0 mSv (250-300 mrem) per year.

The ICRP goes further than merely proposing exposure limits and recommends that each practice needs to be justified, i.e., that it produces overall a net benefit to the population being exposed; and that all exposure shall be kept as low as reasonably achievable, economic and social factors being taken into account. These two principles, in addition to that of dose limitation, are referred to as justification and optimization.

For the marine environment a variety of control procedures have been used. The approach first recommended by ICRP in 1966 had been used by a number of nations before then. This method involves the assessment of all the potential pathways and radionuclides that could result in exposure to particular groups of the

public. While it is recognized that there will be a number of pathways, it has been found in practice that for any given site one or two critical pathways to one or two selected critical groups of the public will prove so limiting that if exposure along the critical pathways to the critical groups is kept within the ICRP or nationally recommended dose limits, all other exposure pathways will result in a lower exposure. Similarly, although a large number of radionuclides may be released, only a few will predominate (the critical radionuclides) in the identified critical pathways. This method of determining discharge limitations was therefore called the critical pathway approach. The general steps involved are outlined in Fig. 1.

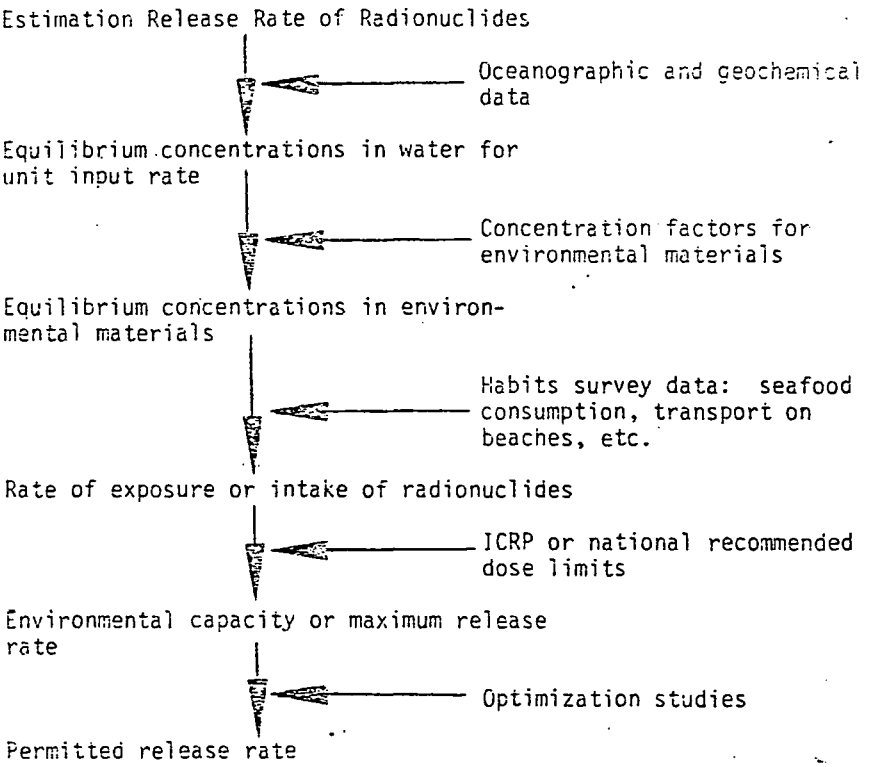

Fig. 1. Outline of the critical pathway approach to the assessment of release of radioactive wastes

The critical pathway approach requires considerable investigative effort, including physical, chemical, and biological oceanography; radioecology; fisheries; specific consumption and exposure data; model development; and expertise in the application of radiation protection principles.

The rate of release, calculated by this method, which would result in the defined critical groups of the public being exposed at the ICRP recommended dose limit, is referred to as the limiting environmental capacity of that site. This value is clearly an upper limit to the rate of release. However, since the ICRP also recommends that the dose limit be as low as is practical, this release limit will rarely be reached.

One of the ultimate requirements of any assessment based upon a model is field validation by measurement of concentrations of radionuclides in the components of the critical pathways to establish the actual radiation dose to the critical population(s). However, it would be very optimistic to assume that we can achieve this for a deep ocean site with the same degree of confidence and in the same time frame as for a coastal discharge site. Whereas the transit time in coastal waters, from discharge point to man, could be of the order of weeks, the transit time in deep oceans may be decades or even tens of decades, depending on the quantity of radioactive waste, the degree of containment and the rates of physical transport processes. Even then the concentrations are likely to be at the limits of detection. In order to approximate that radionuclide data which may in actuality require many decades to gather, generic models for ocean basins have been developed, and emphasis is now given to collection of site specific oceanographic parameters - physical, chemical and biological that need to be established in order to improve our understanding of the basic processes from which site specific models can be developed.

HISTORICAL DUMPING PRACTICES

The dumping of packaged radioactive materials into the ocean began with United States operations in the Pacific in 1946 and subsequently in the Atlantic in 1951. Between 1946 and 1970 approximately 60,000 curies of packaged, solidified, low-level radioactive waste was dumped at more than 35 ocean dump sites in coastal and offshore waters. The majority of the dump sites were located in the Atlantic Ocean, with the remainder in the Pacific. The largest proportion of the volume and radioactivity was dumped in only four of the sites -- two sites in the Atlantic, off the Maryland-Delaware coast, and two sites in the Pacific, off the California coast near the Farallon Islands. The United States discontinued dumping operations in 1970 on the recommendation of the US Federal Council on Environmental Quality. These recommendations were codified with the passage of Public Law 92-532, The Marine Protection, Research, and Sanctuaries Act of 1972. This act prohibits any sea disposal of high-level radioactive waste and designates the US Environmental Protection Agency as the responsible federal agency for establishing and administering the permit review and evaluation program for the ocean disposal of any waste

including low- and intermediate-level radioactive waste not prohibited by law. EPA as yet has not developed criteria for reviewing and evaluating site criteria and hence has not issued any permits for sea disposal of low- or intermediate-level radioactive wastes.

Between 1949 and 1966 the United Kingdom conducted dumping operations in the Atlantic Ocean and disposed of approximately 47,000 curies of packaged low-level radioactive waste. Most of the waste dumped by the US and UK was packaged in 55 gallon drums filled with cement. The packages were not designed nor required to remain intact for sustained periods after descent to the sea bottom, and it was assumed that all contents would be released almost immediately.

ASSESSMENT OF THE NORTH EAST ATLANTIC DUMP SITE

While a number of countries practiced ocean dumping of low level radioactive wastes in the 1950's and 1960's, there is presently only one site in operation, and this is under the auspices of NEA. It is situated within 10 nautical miles north and south of 46°00'N and 16°00'W - 7°30'W. Its area is about 4 x $10^3 km^2$. It is approximately 700 km from land (coast of Ireland or Spain) and the average depth of the site is about 4,400 m.

The amounts of radioactive waste dumped over the period 1967-1979, mainly by the UK, Netherlands, Belgium and Switzerland, are given in Table II.[6] Of the alpha activity 90-100% is contributed by $^{238,239,240}Pu$. In the beta-gamma activity category ^{137}Cs, ^{90}Sr, ^{60}Co and ^{241}Pu were the significant contributors.

Table II. Summary of Sea Disposal Operation into the North East Atlantic Ocean under OECD/NEA

Year	Weight (tons)	Radioactivity α (Ci)	Radioactivity β/λ (incl. ^3H) (Ci)
1967	10,900	250	7,600
1969	9,180	500	22,000
1971	3,970	630	11,200
1972	4,130	680	21,600
1973	4,350	740	12,600
1974	2,270	420	100,000
1975	4,460	780	60,500
1976	6,770	880	53,500
1977	5,600	950	68,200
1978	8,040	1,100	79,600
1979	5,415	1,415	83,175
TOTAL DISPOSAL	65,085	8,345	519,975

A variety of methods for packaging wastes have been used; generally they are incorporated into concrete, bitumen or plastic matrices within a steel and/or concrete container. It is presently accepted that regardless of package type, the containers remain intact at least 20 years on the average. In reported cases in U.S. Dump Sites where ruptured or damaged containers have been identified a significant proportion of the released radionuclides appears to have been retained by the ocean floor sediments in the immediate vicinity of the containers.

Although assessments of this site were conducted in 1967 and 1973, the OECD Mechanism of 1977 now requires that continuing review of the North East Atlantic site suitability be carried out. In 1978 the NEA convened a group of oceanographic and radiological experts to undertake such a review. The review concluded that although the site met the IAEA criteria, more data was required to meet all the London Convention requirements and to conduct a more comprehensive review of the long-term suitability of the site. However, it was deemed suitable for disposal for an additional year at rates comparable to previous years.

A further review was undertaken in 1979.[6] In the absence of a site specific model the IAEA generic model was used as a basis for the assessment. Because of its generic nature some of the assumptions, particularly on critical pathways, may be unduly restrictive for this particular site. However, since our knowledge of this area is not complete, modifications could not be made with sufficient confidence. Hence the assessment was made on the basis of the IAEA model, making allowance only for the limited duration of dumping. In Table III the rates of dumping at this site are compared with the IAEA release rate limits.

It should be noted that the IAEA limit for alpha-active wastes is based on the long-term processes, which only become limiting for the radionuclide of major concern, ^{239}Pu, after a very long period of time (i.e., about 40,000 years). Since the present operation has been conducted for less than 30 years the short term release rate limit, which for ^{239}Pu is ten times larger, should be used, reducing the effective percentage for alpha-active wastes to 0.08%. The NEA group of experts considered that overall it is unlikely that doses in fact exceed or even equal 0.1% of relevant ICRP dose limits. An estimated upper limit arising from past operations would be about 0.5 mrem/year.

The site was viewed by this group as suitable for continued dumping for the next five years at rates comparable to those reached in the past, with the provision that, should these rates be exceeded by a factor of ten, it would be desirable to reconsider the suitability of the site.

Table III. Comparison of Average Dumping Rate at North East Atlantic Dump Site with IAEA Release Rate Limits[a]

Group	Total amounts dumped (assuming no decay took place) (Ci)	Maximum dumping rate in any one year (Ci/y)	Average dumping rate (Ci/y)	IAEA release rate limits[b] (Ci/y)	% of IAEA release rate limit
Alpha activity	8.3×10^3	1.4×10^3	750	10^5	0.8
Alpha activity (Ra-group)	100[c]	10[c]	10[c]	10^4	0.1
Beta/gamma activity (except tritium)	2.5×10^5	4.3×10^4	3.6×10^4 [d]	10^7	0.3
Tritium	2.6×10^5	1×10^5	4.3×10^4 [e]	10^{11}	<< 0.1

(a) OECD/NEA, 1980

(b) INFCIRC/205/Add.1/Rev.1

(c) Estimate; no detailed information available over all years

(d) Average over 1975-1979

(e) Average over 1974-1979

As a result of this assessment, the group of experts recommended that investigations aimed at improving our knowledge of transport processes in the North-East Atlantic should be continued with a view to developing a site-specific model, rather than relying on the IAEA generic model, in order to permit a more accurate assessment to be made of potential radiation doses to man from these dumping practices. To this end, NEA arranged for consultations within a group of experts in November 1979 on the possibilities for a co-ordinated programme-plan for research and surveillance relevant to the current dumping site for radioactive waste in the North-East Atlantic. These consultations were followed by a meeting of scientists held in Lowestoft, England in March 1980, at the invitation of the UK Ministry of Agriculture, Fisheries and Food. Discussions were held with a wider cross-section of the oceanographic community and the preliminary outline prepared by the NEA group of experts was expanded in both breadth and depth.

Based on the results of this work, NEA convened a further ad hoc group of experts in March 1980 at which the proposed programme-plan was finalized[7] and practical arrangements for its implementation were discussed. The programme includes five distinct areas where research is needed to fulfill the proposed objectives, i.e., physical oceanography, geochemistry, biology, model development and radiological surveillance. The programme-plan focuses on those research aspects which are directly relevant to the preparation of a site-specific assessment.

Since the proposed programme-plan is directly linked to the obligations and objectives of the OECD Mechanism, the Steering Committee for Nuclear Energy (the supervisory body of NEA) had already concluded that it should be implemented with the participation, and under the auspices, of NEA. Following a recommendation of the group of experts, the Steering Committee agreed that an executive group should be set up within NEA to ensure overall co-ordination and supervision of the research and radiological surveillance programme-plan and to undertake evaluation of the results. The inaugural meeting of the executive group took place in Paris in July 1981. Several NEA Member countries confirmed their intention to participate in the programme. These are Belgium, Canada, Denmark, F.R. of Germany, Italy, Japan, the Netherlands, Portugal, Sweden, Switzerland, United Kingdom and United States. Japan will contribute indirectly by providing relevant data collected through their research programme in the Pacific ocean. The IAEA will also contribute through the research conducted at their International Laboratory of Marine Radioactivity in Monaco. Intergovernmental Marine Consultative Organization (IMCO) has been invited to be represented on the executive group in view of its responsibilities under the London Convention. The OECD Environment Committee will decide on a possible participation at a later stage.

A detailed work schedule and timetable up until 1984 was prepared by the executive group and working arrangements were made, including the setting-up of task groups for the five research areas identified in the programme. It is recognized that the development of a site-specific radiological model will certainly not be achieved by 1984, the date of the next review of the site required by the NEA Mechanism. However, useful research results can be obtained by 1984 which will contribute in reinforcing the scientific basis for the next assessment. Since centralized funding from NEA is not available for implementing the programme, the time-scale for completion will be dependent upon support from the NEA Member countries.

IAEA GENERIC STUDIES

As part of the continuing review of this subject the IAEA has underway or has recently completed a number of tasks, including specification of package design;[8] the criteria for the selection of dumping sites; specification of "de minimis" quantities of radioactivity for ocean dumping;[9] a review of the oceanographic basis of deep ocean dumping by the UN Group of Experts on the Scientific Aspects of Marine Pollution (GESAMP); and a review and update of Safety Series No. 5, "Radioactive Waste Disposal into the Sea" previously published in 1961.

NATIONAL AND INTERNATIONAL IMPLICATIONS

A recent analysis of international issues associated with ocean disposal of low-level radioactive waste[10] indicated a number of points which impact on US needs and policies and need resolution. The first is that the development of adequate international criteria and standards will assist the US in evaluating the option of using the oceans for the disposal of low-level radioactive wastes, redundant components of defueled US submarines and even high-level radioactive wastes. The technical criteria and standards developed by the expert groups of IAEA and NEA provide considerable expertise for the solution of the problems of waste disposal and should be used as the basis for US policies and decisions in this area. The US should continue to be involved in this international arena.

Secondly, it is essential that international cooperation in research and radiological surveillance be expanded, not only from a resource utilization standpoint but also to ensure compliance with the London Dumping Convention. Presently, effective US participation in these international efforts is hampered by the multitude of federal agencies who have mandated roles in the scientific, technical and regulatory aspects of the problem. There is an immediate need for the formation of an interagency technical advisory group consisting of at least EPA, DOE, NRC, NOAA, NSF and

the Navy to coordinate the potential research and radiological surveillance efforts of the US and to agree upon a basis for the US participation in the international arena. This would help solve the present problem of the US presenting different position at different meetings, thereby confusing international agencies and delegations from other countries.

Third, the delays in the agreements on international mechanisms, criteria and standards, sometimes as a direct result of a lack of coordinated U.S. policies makes the implementation of the intent of the London Dumping Convention and the NEA mechanism more difficult. The US needs to examine its own nuclear future and needs, and that of other countries to realize the importance of assessing the option of ocean disposal of certain low-level radioactive wastes.

And last is the unresolved question of how the US should apply the London Convention to the 200 mile exclusive economic zone. This issue awaits decision by the delayed Law of the Sea Conference. The US has a large expanse of coastline with the availability of 4000 plus meter depths within the 200 mile limit. This fact needs careful scrutiny of US rights versus international obligations for ocean disposal of low-level radioactive waste.

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