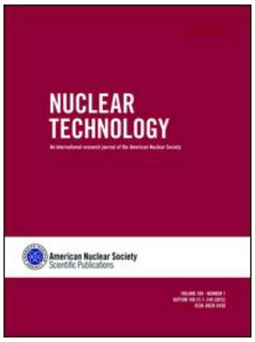

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RADIOACTIVE WASTE MANAGEMENT IN SELECTED FOREIGN COUNTRIES

RADIOACTIVE WASTE

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A panel of the National Academy of Science Committee on Radioactive Waste Management (CRWM) has been reviewing the status of waste management in various foreign countries. The objective has been to look mainly for differences between U.S. and foreign practices to identify policies or procedures that might improve technical practices or achieve equal results at lower cost. This paper is an informal summary of the findings that are expected to be reported by the CRWM in the next few months.

The panel on foreign activities of the National Academy of Sciences Committee on Radioactive Waste Management (CRWM) is preparing a report on waste management in other countries which is expected to be published in a few months. The report will take the interesting form of personal statements by the various panel members on the specific countries, some 12 or 13 in all, with which they are familiar, together with a more formal summary report, edited by the panel and the CRWM as a whole. This report is an informal "unofficial" condensation of that summary.

The panel report will make no claim to be comprehensive, and in practice it reduces to considerations of the wastes from chemical reprocessing of nuclear fuels. Within this context, the policies and practices of the selected nations are broadly similar, and relatively well-known to each other. The International Atomic Energy Agency (IAEA) has contributed substantially to this, as described by Jacobs[1] in another paper of this special issue.

Another agency, the Nuclear Energy Agency of the Organization for Economic Cooperation and Development (OECD-NEA) has made a number of interesting contributions for Western Europe. These include planning of major symposia, often in collaboration with IAEA, and the organization of several internationally cooperative sea dumpings in the North Atlantic Ocean. A document, "Radioactive Waste Management Practices in Western Europe" OECD-NEA (1971), is of exceptional interest. The tenor of the report is that waste is currently being handled in a manner that competently protects people from adverse radiation effects, but there are topics of continuing concern. In brief, these are as follows:

1. Storage of high-level wastes in liquid form is an interim solution.

2. Long-lived alpha wastes represent a virtually permanent hazard, with inhalation the critical risk factor.

3. No man-made structure can be guaranteed to provide containment on geological time scales. Therefore, deep geological formations offer better possibilities. Some criteria are given for suitability of bedded salt deposits and salt domes.

4. The alternative for long-lived alpha wastes of disposal in packaged form on the deep ocean bed, especially where the sea bed is sinking, is not rejected.

5. The issues of long-term buildup of ^{85}Kr and of tritium in the atmosphere are analyzed.

6. Lastly, vigorous attention is directed to the problems of ultimate decommissioning of nuclear facilities in the first half of the next century.

Essentially, these topics define the future strategy for Western Europe. However, the implied policy is unofficial, as the report is a scientist's report, neither seasoned nor sterilized, as the case may be, by the bureaucratic process.

In summary of worldwide trends, there is more or less general interest in and acceptance of the following steps:

1. *For High-Level Liquid Wastes.* Reduce to a relatively nonleachable solid, such as a glass, within a few years of generation of the waste. Then either store in a retrievable form in an engineered storage facility, or commit to ultimate disposal, most likely in a geological formation. The only arguable issue is the need for retrievability in the ultimate disposal mode.

2. *For Intermediate-Level Liquid Wastes.* Convert to relatively high-level solids (although generally these can be handled more easily than the high heat producing solids of the above section). The voluminous liquid portion becomes either an innocuous liquid, or at worst a low-level liquid waste.

3. *For Low-Level Large-Volume Liquid Wastes.* Continue to release these to the environment, but work toward reducing the released activities and concentrations. How powerful this effort will be depends on national interpretations of the concept of "lowest practicable level." It is probable that the U.S. working levels will be among the lowest attained, as they already are for nuclear power reactor releases.

It is quite likely, although difficult to prove, that this category of wastes will lead to more environmental exposure than all the rest combined. One could also point out that to a first approximation, if release levels are successfully reduced by a factor of 100 while the source term increases by a factor of $\sim$100 to the year 2000, one has effectively stood still.

4. *For Miscellaneous Solid Wastes Incidental to Processing.* Package and retain these more effectively in fewer and better defined locations. Particular attention is now being given to wastes that contain plutonium or other transuranium elements, since time reduces the activity so slowly. A key question, still unresolved, is the proper *indifference* level, i.e., the degree of contamination below which isolation is not required.

5. *For Gaseous Wastes Incidental to Processing.* Prepare to remove more effectively those contaminants that will accumulate in the biosphere, especially ^{85}Kr and tritium. (The U.S. concern for the very much longer lived ^{129}I was not noted elsewhere.) Reference to typical environmental impact statements for U.S. reactors shows removal efficiencies for noble gases of $\sim$99.998%. To add two more nines before the eight will truly tax technology.

In the remainder of this paper, a few of the highlights of observations in other countries will be presented. There is no significance to the *order* in which these countries are mentioned.

1. *France.* Until about 1970, French authors wrote confidently about the safety of waste management practices at all levels. Emphasis has now shifted to problems of the future, which are treated as global or international matters. This is a consequence of projection of the fission product and transuranium wastes to the year 2000, and the impracticality of amplifying the storage at Marcoule, for example, by a factor of 50 to 100.

The panel was particularly impressed by the French handling of wastes other than the main stream high-level wastes. The segregation of solid wastes and their incineration or compaction is superior to general U.S. practice. The extensive use of bitumen for encasement was noted. Particularly effective is the process for bituminization of low to medium activity liquid wastes by a combination of bitumen and emulsifier. In the first step, $\sim$80% of the water is removed as the remaining sludge is incorporated in the bitumen at 90°C. Removal of the remainder is done by heating to 130°C. The process owes much of its success to well-engineered equipment that was first developed for the plastics industry. An IAEA Technical Report, "Bituminization of Radioactive Wastes" (1970), is an excellent reference[3] for this topic.

2. *Federal Republic of Germany.* The program here was found to benefit from the relatively late start in nuclear energy, because it avoids the risk of locking into methods that are obsolescent. The West German research at Karlsruhe and Jülich, with basic research at university institutes, is well-conceived, timely, and coordinated to minimize duplication. It is a model that deserves U.S. study.

The most interesting feature is the practical use of a salt mine for centralized permanent disposal. This is the Asse Mine in a salt anticline formation 25 km from Braunschweig. Used as a source of salt and potash since about the turn of the century, the facility has 145 underground rooms providing 3.5×10^6 m^3 of storage space. Conventional drums for low activity solid waste (no liquid wastes may enter the mine) are to all intents and purposes simply "warehoused" there. In a separate chamber, intermediate-level solid wastes are accumulated with enough salt shielding to protect the operators. The operation of chief interest is the preparation for high-level wastes because of the analogy with the U.S. interest in a salt formation repository. Experimental work on heat transfer and strain induction with simulated hot sources is being done. By 1976 or 1977, borosilicate glass blocks will be introduced from the experimental reprocessing plant, VERA, at Karlsruhe. Each block will contain 250 000 Ci so that the operation will be a full scale test of ultimate disposal. The eventual German plan does not appear to be formally documented; it is expected to involve a national reprocessing plant built on the site of a salt dome or anticline other than Asse, to eliminate transportation of the final waste products.

Other notable features of the German program are the fundamental research on irradiated glasses and the search for more durable low solubility media—so-called glass ceramics or true ceramics.

3. *The U.S.S.R.* A point of interest here is the practice of injection of liquid wastes into permeable zones at depths of 1000 to 1500 m and pressures up to 50 atm. It seems likely that in the U.S. a combination of the appeal of early solidification, some pressures toward potential retrievability, and the controversial question of earthquake induction by high pressure injection will combine to make the approach undesirable.

4. *The United Kingdom.* This country has a well-conceived and integrated waste management program that successfully maintains all aspects below the limits recommended by the International Commission on Radiological Protection (ICRP). The British response to the lowest practicable level concept is probably not to press for levels as low as those now applied to reactor releases in the U.S. In this sense, the excellently studied releases to the Irish Sea would probably not be continued in the U.S. scene.

The main line wastes have been well taken care of in high quality stainless-steel tanks, but a projection of the size of the tank farms in the year 2000, plus other factors, have encouraged a firm decision to proceed with solidification (the British FINGAL glass process is a good one) and interim storage in engineered surface facilities. It appears that these facilities, originally conceived as air cooled will definitely be water cooled. As shown in the proceedings of this symposium, the U.S. Atomic Energy Commission (USAEC) is studying both cooling modalities, with perhaps some inferential preference for a passive air-cooling design.

Two British points are of interest:

a. The British are adamant on the need for reliable retrievability under any form of ultimate disposal.

b. The author was particularly impressed by the superior interrelationship between the disciplines of chemical engineering and radiation protection. In a detailed search for the reasons, a logically better organizational structure was not evident. Rather, the success seems to be some product of the more compact geography, a national pragmatic attitude (vulgarly known as muddling through), and the availability of highly qualified personnel. It appears that considerable benefit would accrue to U.S. programs if radiation protection and environmental science skills were integrated into the top planning levels of USAEC waste management.

5. *Canada.* High-level waste storage in Canada is unique because, in the CANDU system, there is no chemical reprocessing, and the fission products are left stored in a favorable ceramic form, namely the original nuclear fuel pieces. The analogy between their storage and the U.S. retrievable surface storage will be well covered in the symposium paper by Morgan.[4]

6. *Japan.* The Japanese practices are representative of what a progressively industrialized island nation with minimal land resources must do in its nuclear energy program. Either ocean dumping or export of high-level wastes to other countries becomes important. In addition to the forthcoming panel report, an excellent report was very recently published by the OECD-NEA.[5] Japan became a full member of the NEA in 1972.

7. *Other Countries and Areas.* The remaining countries and areas considered include India, Pakistan, Italy, Belgium, the Netherlands, and possibly Scandinavia. Time does not permit their coverage, and on the whole, inferences that might suggest improvements in U.S. practices (the principal objective of the panel study) are less effective.

The intended panel report will also include comments on ocean disposal, transuranium waste problems, potential world-wide contaminants, bituminization of wastes, plastics in waste packaging, public opinion, and perceived risks.

Six recommendations to the USAEC will be derived from the study; the principal ones can be sensed from the content of this brief summary.

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