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Present Trends in Radioactive Waste Management Policies in OECD Countries and Related International Co-operative Efforts

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It is generally recognised that the management of radioactive wastes, particularly those which remain hazardous for a hundred thousand years or so, should be a matter for close international co-operation in view of the need to preserve our global environment from radioactive contamination, whatever may be the sources, and of our relative inability to make long term predictions concerning the future of man on earth and his possible contact with wastes disposed of by the present generation. These considerations indeed reflect the general concern about radioactive waste and the basic question to be solved, e.g., will the present and coming generations relying on nuclear fission for their energy needs, be able to isolate the long lived radioactive wastes from the biosphere or transform them in such a way that human beings will never be submitted to unacceptable radiological risks? The magnitude of the problem is such that only a broad agreement at international level, notably on the objectives to be reached, can guarantee the adoption of satisfactory solutions.

Limiting the problem of radioactive waste management to long term considerations is certainly an over-simplification, but it nevertheless shows where the heart of the problem really is, and what the priorities should be if we ever want to convince the general public of our ability to solve it: <u>disposal</u> is the key issue; and what is done on an interim basis to satisfy safety requirements during waste handling, treatment, transportation and storage, is often regarded as of secondary importance, at least by a large fraction of public opinion. This is not a sufficient reason, however, to neglect these various aspects of waste management.

Thus, apart from the development of general waste management practices and policies, it is, in fact, essentially in the field of disposal that international co-operation is particularly desirable and useful. Consequently, discussion of the general objectives of radioactive waste management and of the various alternatives available to reach these objectives, confrontation of practices and policies proposed by countries having different nuclear programmes as well as different geographical and demographical conditions, co-ordination of R & D activities and promotion of joint efforts are all enjoying high priority in the programme of the OECD Nuclear Energy Agency. The present paper is an attempt to summarize the experience gained in OECD countries notably through this co-operation and to review the general trends in present and future radioactive waste management policies.

1. Review of Available Technology

Research efforts in the last 30 years have resulted in the development of many techniques suitable for the handling, "conditioning" (or preparation of the waste into a form suitable for storage and disposal) and disposal of most radioactive waste types. Some of these techniques are already widely applied on an industrial scale and it is important to review them briefly to assess the status of presently available technology. This can be done conveniently on the basis of Table I, which summarizes the average waste production throughout the nuclear fuel cycle for an electricity production of about 1,000 megawatt x year. This is roughly equivalent to the annual production of a large light water reactor and to the yearly electricity consumption of a city of about 1 million people on the basis of 1 kilowatt per person. The last column of the table indicates the main disposal options available.

For the few OECD countries which have a large uranium mining and milling industry, the problem of mill tailings cannot be neglected in view of the release of radon gas resulting from the decay of radium 226 left in the tailings. However, techniques now exist to limit radon concentration in the vicinity of tailings and administrative measures can be implemented to forbid the use of tailing materials, for example, in the building industry.

The fabrication of uranium fuel elements does not generate any significantly hazardous waste. The introduction of plutonium fuels will considerably change this situation; not only plutonium contaminated wastes will have to be treated and conditioned satisfactorily but the fuel fabrication processes themselves will have to be improved in order to minimize plutonium losses and the resulting waste production. Although the volume reduction and conditioning technology available for beta-gamma waste can be adapted to a large extent for alpha bearing solid wastes, significant improvements have to be envisaged for industrial application. Exchanges of information started only fairly recently between countries with the most advanced programmes in this field and there are good prospects for closer international co-operation on the R & D work which is still needed.

Nuclear power reactors have been in operation for many years in a number of countries and, as a result, most of the problems raised by the management of reactor wastes which, in general, are free from alpha contamination, have received satisfactory solutions. Conditioning methods are now well established, such as incorporation into concrete or bitumen, and new materials also offer attractive possibilities, such as polymer impregnated cement and thermo-setting resins. Disposal of these wastes is relatively simple in view of the limited decay period of the contaminating fission and activation products and suitable methods are available. They are essentially shallow ground burial, emplacement into deep geologic formations and sea dumping as already practiced by several European countries under NEA supervision. Many countries are however still storing waste at reactor sites but such a practice will have to be abandoned in view of the important storage space needed.

The main waste management problem is in fact raised by irradiated fuels, whether they are reprocessed or not. So far, except in Canada which has not yet taken a decision and perhaps in the USA where reprocessing is at present being questioned in view of the potential risks of diversion of the separated plutonium, OECD countries with nuclear programmes are in general planning to arrange for the reprocessing of spent fuel discharged from power reactors. Disposal of spent fuel would, in any case, be somewhat similar to the disposal of the high level wastes from the first extraction cycle of reprocessing plants. High level wastes contain essentially all the fission products, the unrecovered fraction of plutonium and uranium plus the other actinides. The main difference between the two options from the waste management point of view would be a simpler approach in the case of the "throw-away" alternative which would result in only one main waste stream; in addition, if spent fuels are disposed of directly, 100% of the plutonium produced would appear as waste instead of about 1% in the case of fuel reprocessing and subsequent recycling of the separated plutonium.

The technology to dispose of spent fuels directly as waste into suitable repositories may be considered available, but no real experience exists as yet. For high level waste from fuel reprocessing, several solidification processes are available, based almost exclusively on vitrification. Large vitrification plants are either under construction or planned, notably in France and the United Kingdom. Glass products are generally recognised as a suitable form for storage and disposal, which does not however prevent research work being continued on other products such as glass ceramics and metal matrices. All vitrification processes have been developed as a result of national efforts and some of them are now commercially available. International co-operation has played no significant role in this respect, apart from general information exchanges between interested countries.

Other waste types produced during reprocessing of spent fuels have also received a great deal of attention, and readily applicable techniques are at hand for low and medium activity liquid waste and for low activity solid waste, for both storage and disposal if the alpha content of the waste is negligible. When the actinide concentration cannot be neglected, these wastes have to be disposed of as long lived waste and they are presently stored pending the adoption of an ultimate solution. Cladding hulls are in this last category and their volume reduction and conditioning is the subject of increased R & D efforts.

Therefore, except for high level and the various types of alpha bearing waste, disposal alternatives are already being implemented. They include for example, ground burial in France, United Kingdom, and USA, disposal into deep geologic formations in the Federal Republic of Germany, and sea disposal on a joint basis in some Western European countries.

For the disposal of long lived radioactive wastes, stable geologic formations appear to most countries as the best choice. Such a mode of disposal may be implemented with conventional mining and radioactive waste handling techniques. The demonstration of the long term integrity of the containment afforded by geologic formations cannot, however, be demonstrated by short term in situ experiments or even by several years of repository operation and this question is discussed in greater detail in the next section.

The last group of waste to be mentioned is gaseous or volatile radionuclides such as iodine isotopes, tritium, krypton 85 and carbon 14. They appear essentially in gaseous effluents which are released into the environment by reprocessing plants. The retention and storage technology for these radionuclides still requires significant developments to be implemented at the industrial level, as also mentioned in the next section.

This very general review of the technological aspects of waste management activities is useful to assess the scope and significance of present R & D efforts and policies and, of course, to evaluate the probability of identifying and adopting adequate disposal solutions for high level and long lived alpha waste within a relatively short period of time.

2. R & D Aspects

Waste management, being regarded as one of the most serious obstacles to the large scale introduction of nuclear energy, received increased attention and priority as a result of the recent energy crisis in OECD countries. To progress rapidly in this field, measures were taken at both national and international levels to promote more efficient R & D activities. The OECD Nuclear Energy Agency had, accordingly, to expand very significantly its waste management programme and to give priority to two specific sectors particularly important for the very long term: the conditioning of high level waste and their subsequent disposal into geologic formations.

This priority reflected of course the situation in Member countries and particularly the concern of industry to have available fully demonstrated processes which could be applied on a large scale to satisfactorily close the nuclear fuel cycle.

High level waste conditioning

As mentioned above, the countries with advanced reprocessing programmes had already developed their own vitrification processes for high level waste and it rapidly became obvious that there was no real prospect for them to enter into co-operation arrangements on R & D activities on high level waste vitrification. On the other hand, on the basis of preliminary studies, done by the Eurochemic Company in Mol, Belgium, on the incorporation of high level waste into metallic matrices, wide interest was expressed in this new concept. Its principle consists in incorporating high level wastes which have been previously converted into granules by calcination, vitrification, or another process, into suitable metal matrices, which, in addition to preventing dispersion of the granules, would provide superior heat transfer properties. An international R & D project is therefore being promoted on this new approach, on the basis of the high level waste solidification programme at Eurochemic. Many countries are expected to join this programme, including Japan and the United States which are not members of the Eurochemic Company.

Some co-operation takes place also on the characteristics of high level waste solidified products, the testing of such products, and the criteria to be met for disposal. However, such features depend to a great extent on the actual disposal conditions and whatever is done at the international level will have to be adapted or interpreted to meet specific national or regional requirements.

Disposal into geologic formations

The increased priority given to R & D work in the general waste management field, as well as the possibility that some countries will have to arrange themselves for the disposal of the conditioned high level waste they may get back from reprocessing countries, resulted in the setting up of new or considerably expanded programmes on geologic disposal in about 15 OECD countries. The five-year programme on radioactive waste management of the Commission of the European Communities contributed to this general effort: about $15 million out of a total budget of about $25 million are devoted to the financing of up to 50% of the cost of R & D activities carried out by CEC Member States on geologic disposal until the end of 1979. To illustrate this general trend it is worth mentioning the USA budget in this field, which increased from $5.1 million in 1976 to about $38 million in 1977, i.e., a sevenfold increase. In Canada, Sweden and Switzerland, increased resources are also now available for geologic disposal studies.

Most activities concentrate on research work to confirm the suitability of known potential sites in salt, hard rock or clay formations, and on development work for in situ experiments, measurements, waste emplacement technology, etc. In addition, various studies aim at the assessment of the long term integrity of these formations and the general safety of this disposal concept. The results of these activities are reported regularly to the NEA Co-ordinating Group on Geologic Disposal which was set up in 1975 to organise the exchange of information between OECD countries, establish a detailed programme and time schedule of investigation based on national contributions, identify the areas requiring additional work and make proposals when joint studies or experiments are desirable in the field of geologic disposal. The NEA Co-ordinating Group's activities have already resulted in close co-operation, notably between countries interested in the same types of rock formations, for example, between Canada and Sweden which are focussing their work on granite. Co-operation also covers in situ and laboratory experiments, instrumentation, borehole plugging techniques and, above all, risk analysis and geologic modelling studies. This last topic is particularly suited for international co-operation, as the results achieved are of general interest and are likely to be more readily accepted and less subject to criticism than more restricted work.

· ·erefore, the NEA Co-ordinating Group on Geologic Dispo . has placed emphasis on this subject, since it considers that the long term integrity and reliability of waste containment within various types of geologic formations should be best demonstrated by means of theoretical models taking into account all relevant geological, geochemical and other environmental factors. A workshop is to take place on this subject at the end of May 1977, at Ispra, co-sponsored by NEA and the CEC which has offered its own waste management programme on theoretical studies and experimental work on geologic disposal for international co-operation within the framework of NEA. This workshop and the follow up work should enable the development of a well established and generally accepted methodology for safety assessments concerning geologic disposal. Demonstration experiments with actual emplacement of high level wastes in selected formations, realistic models on potential containment failure mechanisms, and the knowledge of geosphere migration phenomena may then be sufficiently advanced, possibly within a decade or so, to proceed with the large scale implementation of this disposal concept. It should be noted, however, that site experiments are often delayed by local opposition, even at the site reconnaissance stage, and this obstacle may prove, in some countries at least, more serious than budgetary or technical constraints. In such a context, it is easily understandable why the promotion of international demonstration sites has not yet been successful: countries with potential disposal sites are already meeting enough difficulties with local populations, and for the time being they want to avoid additional psychological, political and administrative problems which would inevitably result from joint ventures and the related waste imports.

Other R & D Work

Other sectors of waste management are also the subject of international co-operation. It would take too long to mention them in detail but a few of them should be listed briefly in view of their obvious international aspects. They concern essentially gaseous effluents, for which a retention and storage technology will have to be developed, and also some agreement at international level will be required concerning the measures to be adopted to limit their global impact and the dates for such measures; the conditioning of the various types of alpha contaminated wastes; the decontamination and decommissioning of nuclear facilities at the end of their useful lives; and the sea bed disposal of long lived waste. Following an international workshop organised on this last subject at the beginning of 1976, co-ordinated R & D programmes are being established in France, the United Kingdom and the USA, to further investigate the possibilities offered by sediments or bedrock underneath the sea bed.

3. General Policies and Current Trends

To the extent that they are still in a stage of formulation, general waste management policies in OECD Member countries have to take account of the possibilities of presently available technology and of likely progress to be achieved by R & D. Some of this R & D work may influence the orientations of future policies, such as the separation of actinides from the bulk of fission products which, if feasible, would result in a "1,000 year problem" for highly active beta-gamma waste with high cooling requirements, and in the production of another alpha bearing waste stream which might be possible to recycle (or transmute) or dispose of separately, taking into account the long term hazard and the absence of cooling requirements. However, such progress cannot be expected to be achieved in the near future and it is even possible in fact that, after a careful cost/risk/benefit analysis, actinide separation may finally not prove altogether desirable.

Even with such uncertainties in mind, general policies have however to be defined, particularly for the back end of the fuel cycle. They have national as well as international aspects insofar as the nuclear fuel cycle already requires international transport and trade. In addition, the siting of nuclear facilities may influence considerably waste management policies, as is notably the case in the F.R. of Germany where reprocessing of irradiated fuel, recycling and disposal of fissionable material, waste handling, treatment and storage are to constitute an integrated system concentrated at one site where it is also expected to dispose of the waste into a suitable underlying salt formation. Such concentration of nuclear activities may be attractive from an overall safety and waste management point of view and other countries are also considering its interest.

An NEA ad hoc group of experts has been examining in detail over the last two years all these policy considerations including the administrative, legal and financial problems. The task of this group was actually to review the present waste management situation in Member countries from the technical, safety and radiation protection points of view, to discuss general policies and to make recommendations, particularly concerning the international aspects of the problem. The Group's report, to be published in 1977, has not yet been finalised, but it is already possible to draw up some preliminary conclusions, which could be summarized in the following way:

(a) Given the nature and long term character of the radioactive waste management problem, respective responsibilities of governments and nuclear industries should be clearly established. The only solution conceivable is that the long term management of waste, that is, essentially storage and disposal, should remain under the direct responsibility of governmental authorities, to provide the best guarantee for maintaining administrative control and possible surveillance over disposal sites for the maximum period of time. Short term responsibilities should remain under the responsibility of nuclear plant operators, of course, under conditions specified in operating licences.

(b) In view of the lack of present arrangements for financing the disposal of long lived waste, the relative uncertainties concerning the ultimate cost of disposal, at least for some categories of waste, and the possible delays between waste production and the implementation of disposal schemes, some financial provisions appear desirable. Such provisions might take the form of funds and contributions could be levied according to the "polluter pays" principle, for example, on the basis of electricity consumption. Once set up these funds, which may be run by governments on a national or even regional basis, could be used also to finance additional R & D work on waste management.

(c) The nuclear fuel cycle is likely to become even more international in the future with probably only a few countries offering reprocessing services. In order to avoid proliferation of transports and disposal sites for the relatively moderate volumes of high level and alpha bearing wastes, optimized use of the most appropriate disposal sites will have to be envisaged on an international basis. This will imply the adoption of regional agreements based on alternatives which do not necessarily provide for sending back the waste from reprocessing countries to each country of origin.

(d) In this respect, the following scheme should be envisaged for high level waste:

- on-site solidification after an appropriate period of cooling in liquid form;
- interim on-site storage of the solidified products;
- transportation to a final repository, national or regional, which could be a deep geologic formation, with possible provision for retrieval of the waste during an interim period.

A similar scheme could be envisaged for cladding hulls and alpha bearing waste, their interim period of storage depending in fact, as for high level waste, on the availability of a disposal solution.

(e) For other types of less radioactive waste free from significant alpha contamination, notably reactor wastes, national disposal solutions should be sought in view of the much larger volumes involved and the less stringent disposal conditions. It would seem more attractive for a country to have its own centralised facility or facilities for the disposal of low and medium level waste, which may be, for example, a shallow burial site.

However, if sea dumping is the preferred solution, international co-operation is definitely required, as already implemented within NEA which has recently promoted the establishment of a multilateral consultation and surveillance mechanism for the sea dumping of radioactive waste, based on the 1972 London Convention on the Prevention of Marine Pollution, the relevant IAEA recommendations and NEA's own experience in this field.

(f) Parallel intensive R & D efforts should be pursued on the most promising waste management techniques and disposal alternatives, with a view to confirming the validity of the proposed solutions. Geologic disposal is a primary candidate for increased activities both at national and international level, together with sea bed disposal which may be considered as a form of disposal into undersea geologic formations.

These general conclusions emerging from the discussions of the NEA ad hoc expert group also reflect the fact that, given the present level of technological development, appropriate decisions may now be taken concerning the implementation of safe and sound waste management practices and policies. In this connection, the growing recognition of the need to proceed as rapidly as possible with the construction of large scale demonstration facilities for all steps of waste management may accelerate policy decisions and influence licensing procedures which have sometimes delayed considerably the start up of nuclear facilities. Such a demonstration would indeed be the last step before full scale industrialisation of waste management techniques, which should go along with industrial spent fuel reprocessing and plutonium recycling.

4. Conclusions

Radioactive waste management policies in OECD countries undoubtedly follow very similar trends, as shown by the now generally recognised merits of early solidification of high level waste after reprocessing, or by the number of countries embarking on R & D programmes on geologic disposal. This situation, which is relatively new, is due to a large extent to continuous exchanges of information and discussions at international level, as well as, of course, to the broad convergence of technical studies and views in the countries themselves. There are in fact no fundamental divergences of opinion in this field either on technical grounds or on policy orientations; and this suggests that, since technology is available for many of the waste problems resulting from the large scale introduction of nuclear energy, there is no reason to delay any longer decisions and practical measures to move from activities which have so far essentially concentrated on R & D to construction, operation and therefore demonstration of industrial waste management facilities, as is now required at the various steps of the nuclear fuel cycle. Storage and disposal facilities for the large volumes of reactor waste and high level waste solidification units associated with large capacity reprocessing plants are only two examples of what is needed in this respect.

Significant R & D programmes should and will however continue, particularly on geologic disposal, where the objectives should be to open demonstration repositories and to confirm with relevant safety assessments and models, the long term reliability of this mode of disposal. A great deal of co-operation already exists notably through the specialised NEA Co-ordinating Group on Geologic Disposal which is promoting various studies and experiments in this field.

Co-operation between OECD countries which enabled very intensive exchanges of information and views, has not however really led, in the past, to concrete joint projects on waste management, except in the field of sea disposal where up to eight European countries have participated in NEA-supervised operations since the first one, just 10 years ago, in 1967. Several reasons may be mentioned, such as the difficulty of adapting specifically designed national projects to wider international needs, public opinion and the associated political problems notably concerning geologic disposal, as well as commercial interests of firms already deeply engaged in this field. In fact, in spite of these difficulties, international co-operation may play a more significant role in the near future when the planned projects on geologic disposal or the high level waste metal matrix incorporation programme at Eurochemic are fully operational. All considered, it is already a very encouraging result indeed to see countries with the most advanced nuclear programmes adopting similar - if not completely harmonized - policies and therefore, by doing so, contributing to a uniformly high standard of safety in the field of radioactive waste management.

TABLE I

RADIOACTIVE WASTE PRODUCTION IN THE NUCLEAR FUEL CYCLE

(Solid or solidified waste equivalent to electricity generation of 1000 MWe x year in a light water reactor)

ORIGIN AND TYPE	VOLUMES (After treatment and conditioning)	ACTIVITY	MAIN DISPOSAL OPTIONS
1. URANIUM MINING AND MILLING - Solid waste	60.000 m^3 (40.000 m^3 if Pu recycle)	0.01 Ci/m^3	- Ground burial
2. FUEL FABRICATION - UO_2 fuels - UO_2-PuO_2 fuels (for an annual reload of 500-700 kg of Pu)	- 10-50 m^3	negligible 5-10 kg Pu	- Geologic formations
3. LIGHT WATER REACTOR OF 1000 MWe - Various solid wastes and conditioned resins	100-500 m^3 (*)	0.1-10 Ci/m^3 beta gamma	- Sea dumping - Ground burial at the surface or in deep formations

(*) Depending on reactor type and conditioning process.

TABLE I (Continued)

RADIOACTIVE WASTE PRODUCTION IN THE NUCLEAR FUEL CYCLE

(Solid or solidified waste equivalent to electricity generation or 1000 MWe x year in a light water reactor)

ORIGIN AND TYPE	VOLUMES (After treatment and conditioning)	ACTIVITY	MAIN DISPOSAL OPTIONS
4. REPROCESSING			
- Solidified high level waste (HLW)	3 m^3	80 MCi beta gamma + actinides (2 kg Pu for UO_2 fuels 5-10 kg Pu for UO_2PuO_2 fuels)	- Geologic formations - Sea bed disposal - Separation and Transmutation of actinides
- Compacted cladding hulls	3 m^3	0.8 MCi beta gamma + actinides	- Geologic formations - Sea bed disposal
- Low and medium level beta gamma solid waste	10-100 m^3	0.01 MCi beta gamma + alpha contamination	- Ground burial at the surface or in deep formations - Sea dumping
- Solid and solidified alpha waste	1-10 m^3	1-5 kg Pu	- Geologic formations