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Technical, institutional and economic factors important for developing a multinational radioactive waste repository

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FOREWORD

Countries planning and implementing nuclear energy programmes should assume responsibility for the safe management and final disposal of radioactive waste from their programmes. However, there are countries whose radioactive waste volumes do not easily justify a national repository, and/or countries which do not have the resources or favorable natural conditions for waste disposal to dedicate to a national repository project. These countries would benefit from multinational co-operation for the disposal.

Interest in the concept of a multinational repository for radioactive waste has been expressed by several Member States and the waste management community in the light of the potential benefit to the partner countries from the safety, technical and economic standpoints. However, such an approach involves many political and public acceptance issues and therefore a consensus among countries or regions concerned is a prerequisite.

In this context, it was deemed appropriate that the IAEA assess the technical, institutional, ethical and economic factors to be taken into account in the process of such consensus building. This report is intended to provide an assessment which can serve as a general basis for establishing a waste management policy and/or further assessing specific issues such as ownership and liability, institutional aspects and problems related to long term commitments.

The report was developed with the help of consultants and through an Advisory Group meeting held in 1996. K.W. Han of the Division of Nuclear Fuel Cycle and Waste Technology was the responsible officer at the IAEA.

EDITORIAL NOTE

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1. INTRODUCTION

1.1. BACKGROUND

Production of nuclear energy and applications of radioisotopes generate radioactive waste which require adequate management and, in the end, disposal. Various modes of disposal — ranging from near surface disposal to geological disposal — have been developed so far, and some of them are currently being used for different types of waste. On strictly technological grounds, which means the proper combination of waste immobilization through treatment, careful selection of the disposal environment and adequate engineering of the repository structure, it is believed that safe disposal of many types of waste can be accomplished in most countries and/or regions.

In parallel, one observes that most countries which must dispose of radioactive waste tend to develop national strategies, not only for collection, interim storage and treatment, but also for disposal. This tendency towards unilateral action illustrates the fact that radioactive waste is a sensitive political issue, making co-operation among countries difficult. It also illustrates acceptance of the principle that a country or community which enjoys the benefit of nuclear energy (or of the use of radioisotopes) should also carry the full burden of managing the generated radioactive waste.

This restrictive "national" approach has not always been the case, and several examples can be given of various forms of international co-operation in actual waste disposal. In the past, some countries accepted responsibility and custody of waste generated in other countries. This form of co-operation resulted from implementation of reprocessing contracts which, in the early years, did not contain clauses on the return of reprocessing waste to the country where the power was generated. Other examples are the return of US enriched spent research reactor fuel to the USA (a practice which was discontinued in 1988 and has recently been resumed), and the return to the former USSR of commercial spent fuel of USSR origin.

The endorsement in 1980 and 1985 by the US Congress of low level waste legislation, where individual States in the USA provide common disposal facilities for low level waste as members of inter-State compacts, is another example of regional co-operation, driven by both environmental and economic incentives. While the compact system is not international, several compacts' borders extend nearly one-thousand miles on the diagonal, and several compact partners will ship waste over a thousand miles for disposal.

Furthermore, the subject of possible international collaboration on the establishment of international repositories has been debated extensively within the Radioactive Waste Management Committee of the OECD/NEA [1], although with no positive conclusion. Preliminary studies on waste equivalence, which is an important issue if "swaps" or exchanges of waste are envisaged, were performed under the auspices of the European Commission [2].

In spite of past attempts for more international co-operation on radioactive waste disposal, beyond the area of R&D, the "national" approach still prevails today with regard to implementation and operation. Yet, in other sectors of the economy which generate hazardous waste, such as the chemical and non-ferrous industries, transfers and exchanges of waste among countries are current commercial practice for selected, even highly hazardous, materials. These practices aim at the optimal use of disposal opportunities in certain countries. Transfers were recently regulated by the *Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal* [3].

The question can be raised as to whether developing a strictly "national" facility for disposal of radioactive waste, especially if the country's waste quantities are small, is reasonable and will allow efficient use of limited resources and opportunities. Continued pursuit of this "national" approach may lead to misdirecting of scarce resources which, otherwise, might be used for other, equally important, social or economic purposes.

Given that co-operation in the disposal of other types of waste has succeeded, whereas there is no fundamental difference among hazards from radioactive and chemotoxic waste, and considering the issue of resource allocation, the concept of multinational repositories for radioactive waste would appear to make good sense. Several Member States already expressed interest in this concept, and it is therefore proposed that the IAEA assess the many factors involved in such a concept.

1.2. OBJECTIVE

Achieving consensus among countries involved in the development of a multinational repository is considered a prerequisite. Such projects will most likely result from a stepwise approach in which incentives are identified and evaluated, safety and impact assessment are carefully studied and many other factors are considered, such as duration of the project, lead time, financing, liability, legal and institutional issues, continuity, etc.

The primary aim of this report is to review and comment on these issues — generic as well as specific — and draw attention to matters to be considered. The report does not, however, offer solutions to all the issues identified. Some of these issues still need further development, and some belong entirely to the domain of national considerations within the Member States.

The report may also help international organizations and national authorities to evaluate perspectives and challenges related to the subject, to consider its practicality and, at least for some cases, its virtual necessity. Recommendations are formulated as to the next steps towards further implementation of the principle.

1.3. SCOPE

This report addresses, in principle, all types of radioactive waste which are to be disposed of in both near surface and geological repositories. These types of waste may result from nuclear energy generation, application of radioisotopes and sealed radiation sources, and may include low and high level wastes and short and long lived radionuclides. Industrial mining and milling waste is not specifically considered because it is currently dealt with locally. For the most common types of waste, specific issues are examined (see Section 3.12).

In addition, the report addresses basic issues related to the establishment of a multinational repository (legal, safety, institutional/technical, safeguards, etc.), potential benefits and challenges and also implementation issues.

1.4. STRUCTURE

Section 2 discusses the multinational repository concept in terms of needs and the role of a multinational repository, interaction between host and partner countries and formulation of a multinational repository. Section 3 identifies basic issues to be considered for establishing a multinational repository, and some specific issues relating to specific waste categories. Section 4 analyses potential benefits and challenges to be addressed in establishing a multinational repository, in general terms with specific scenarios for common modes of international co-operation. Section 5 outlines requirements for implementing a multinational repository.

2. THE MULTINATIONAL REPOSITORY CONCEPT

In this report, the term 'multinational repository' means a disposal facility in a country (host country or host) which is used for the disposal of radioactive waste generated in several countries (partner countries or partners). Such a repository could be operated and managed by the host country or by a multinational consortium.

For obvious reasons of transportation distance and specific interests, the concept might apply, in the first place, to geographically grouped countries. Though not a prerequisite, it is likely that co-operative waste disposal efforts will, in the first place, be regional given reduced transportation distances and traditions of co-operating in other areas.

A multinational repository is most likely to be located in a volunteering host country. This country must also be able to demonstrate an adequate level of technological skills, resources, and commitment for implementation.

Agreements among countries or responsible organizations establishing operational rules, safety requirements and licensing procedures, responsibilities, liabilities, financing mechanisms, long term issues, etc. would govern the construction and operation of the repository. Several different formulae can be envisaged depending upon quantities and types of waste, local policies, available skills, interests, and specific situations.

The disposal options considered for a multinational repository concept can range from near surface to geological disposal. The radioactive waste types to be disposed of will determine the technology.

One important reason for considering multinational repositories is that some countries generate such small volumes of some types of waste that it would be economically unreasonable to attempt final disposal in these countries. This would apply in particular in those cases where, even for small nuclear programmes, geological disposal is required because of the long half-life of some radioactive materials. Costs for site selection, site characterization, establishment and licensing of the repository would be disproportionate with regard to the size of the nuclear programme. A multinational repository could offer a substantial benefit to these countries as well as to others who might co-operate in its construction and use.

Regional collaboration for the disposal of low and intermediate level waste (LILW) from the use of radioisotopes and irradiation sources may be justified, primarily in countries with limited resources and/or insufficient technical capabilities, even if the total costs involved are much lower than for geological disposal.

3. BASIC ISSUES RELATED TO THE ESTABLISHMENT OF A MULTINATIONAL REPOSITORY FOR RADIOACTIVE WASTE

3.1. GENERAL

For any repository, a number of issues must be considered regarding the location (site selection), design, construction, operation, closure and post-closure control (if required). These are generic and apply to all repositories, whether they are national or involve several countries.

Since both single state or multinational repositories are the subject of existing, drafted and planned IAEA (e.g. RADWASS) and ICRP studies and publications [4–10] which address the above issues, they will not be examined in this study.

Rather, this section will deal with principles and issues which are specific to multinational repositories and which require more consideration. This section covers legal, safety related, technical, institutional, political, ethical, social, and economic issues.

3.2. LEGAL ASPECTS

In all countries with nuclear energy programmes and/or where radioisotopes are used for medical, agricultural and R&D purposes, special laws or legal arrangements define the procedures that have to be followed in the employment of radioisotopes and nuclear activities. The goal of these legal regulations is mainly to protect man and his environment from the toxic effects of radiation. The protective measures defined in the national legal arrangements are generally derived from guidelines developed by international organizations, i.e. ICRP, IAEA, etc.

It is likely that the legal and regulatory situation in countries willing to consider a multinational repository are similar and that protective measures could easily be harmonized among the partners.

Differences among partner countries concerning the licensing and control mechanisms for a nuclear project could be a matter of discussion to arrive at mutual agreement for regulations of the multinational repository. The same is true for the responsible national organization involved in this particular aspect. It is most probable that the procedures laid down in the host country would be applied.

Legislation in some countries may restrict the export of radioactive waste as well as import of foreign waste. If such countries wish to join a multinational repository project, their legislation will have to be amended.

Countries with limited use of radioisotopes, where existing regulations are inadequate for drawing up a convention of a partnership for the selection, design and operation of a multinational repository, could make use of existing international conventions, e.g. the *Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management* [11], etc., under which they could regulate their partnership and code of practice.

3.3. SAFETY PRINCIPLES

Safety criteria

Should a multinational disposal system be proposed, it is likely that the host country may have already adopted safety criteria (for waste conditioning, disposal, etc.) complying with international standards. Then it seems logical to apply them to the multinational repository (see Section 3.2). Where such criteria do not yet exist, they should be established by the candidate host country in collaboration with candidate partners. Consequently, the objective of controlled and optimal confinement should not be different for a national or multinational repository.

A key advantage of the concept of the multinational repository is to reduce the number of locations at which radioactive materials are disposed of. It is assumed that the organization in

charge of the multinational repository will enforce all safety criteria from adequate site selection procedures, to proper operation and long term care[1].

Risk assessment

A thorough risk assessment of the repository, covering the entire expected inventory of radioactive waste has to be performed and, depending upon the half-lives of the contained radioisotopes, it should cover the short, medium, and long term [12, 13]. On the basis of the risk assessment, waste acceptance criteria can be derived that might lead to revisions in the waste treatment and packaging practice of the partner countries and/or to the addition of other technical barriers in the repository.

Responsibility of present and future generations

Waste management should be conducted in such a way that the generation which produces the waste also bears the responsibility to manage it, except for some responsibilities and activities, such as institutional control which, by definition, can only be assumed by succeeding generations (see Section 3.8) [14].

Future generations should never be exposed to levels of radiation which would not be acceptable for the present population [14]. Furthermore, potential transborder effects (e.g. contamination through the groundwater pathway), have to be taken into account, e.g. when long lived radioisotopes are involved [14].

Licensing enforcement

Where national radiation safety agencies are already operational in the host country, they would normally be the sole authorities in charge of licensing, inspection and verification of the operations, and of establishing rules (if any are required) for post-closure control (see Section 3.2). However, the integration of experts or trainees from the partner countries would be an excellent mechanism for training and co-operation.

In general, with regard to the application of safety principles, there should be no difference between national and multinational repositories. The same criteria for the radioactive waste management and related studies, evaluations, and assessments, as well as licensing procedures should apply to both types of repositories.

3.4. TECHNICAL ISSUES

Inventories

Current inventories of all types of waste materials available for disposal must be established before serious consideration can be given to establishing a multinational repository. In addition, reliable estimates of future waste generation must be prepared. This could include a thorough

[1] An intermediate/preliminary step which might contribute to the creation of a multinational repository would be the centralized storage of certain types of waste, such as radiation sources. At present, small volumes of radioactive waste materials are stored near the point of use Storage conditions vary. Facilitating efforts to allow for centralized storage at a well regulated facility would provide immediate safety benefits and could well encourage the development of a multinational repository In addition to the obvious safety advantages of a multinational facility, there are also likely to be significant economic benefits, especially for higher activity waste produced by nuclear power plants.

review of the timing and techniques of decommissioning nuclear power plants and other nuclear or radioisotope handling facilities, the remediation of contaminated sites, if anticipated, and the establishment of any new nuclear enterprises that may generate substantial volumes of waste. As already indicated, the waste inventories should make the distinction between categories of waste according to the half-lives and potential hazard of the radionuclides contained in the waste, thus covering the short, medium and long term safety aspects. In addition, it should state the waste conditioning and packaging modes applied or foreseen together with the resulting waste form and package. Such information is crucial since it directly affects design characteristics of the planned repository like its size and other physical features, the need for additional barriers, possible long term control requirements, and consequently, cost.

Waste acceptance criteria

There should be agreement between the host country and its partners as to waste acceptance criteria. Because waste generators may wish to condition their waste prior to storing it on site or at a centralized facility before a multinational repository is available, waste acceptance criteria should be negotiated early in the process. Waste acceptance criteria are substantially determined by the type of repository, its technical barriers and waste types. As already stated under the risk assessment heading in Section 3.3, waste acceptance criteria can best be defined from the results of a risk assessment or safety analysis for the multinational repository.

It is possible that after initial waste acceptance criteria are agreed upon, changes in repository design or new scientific data may lead to modifications in the criteria. This problem might require the use of overpacks which conform to the new criteria or by additional technical barriers in the respective disposal area of the multinational repository.

Waste conditioning

In general, waste due to be disposed of in a repository also require conditioning, e.g. segregation, volume reduction, immobilization and packaging. Running a conditioning facility requires adequate technical skills and experience as well as due understanding of the characteristics and operational mode of the repository. Waste conditioning can be performed either in a centralized multinational waste conditioning facility possibly located at the site of the multinational repository, or in corresponding facilities in the partner countries. In the latter case, the host country has to specify waste conditioning conditions in view of meeting the waste acceptance criteria agreed upon.

In this context, the host country should be allowed to inspect and approve the waste conditioning installations in the partner countries and to agree upon suitable quality assurance and quality control systems to be applied in the waste conditioning steps. Furthermore, the operators of the multinational repositories should be allowed to verify the quality of waste forms and packages delivered from the partner countries for disposal.

Interim storage

Interim storage under well controlled conditions may be required prior to disposal in cases where the disposal facility is not yet in operation or for any other operational reasons (cooling, licensing, collection of sufficient quantities, etc.).

As with waste conditioning facilities, interim storage can either be carried out in a centralized interim storage facility or in storage buildings located in the partner countries, for instance at the waste conditioning facilities.

Transportation

Currently, all waste transferred to storage, conditioning or disposal facilities within or among Member States is transported under national transport regulations, derived from internationally accepted guidelines [15]. Waste destined for a multinational repository would be subject to the same guidelines.

Repository

The characterization and selection of a site as well as the design, construction and operation of a repository, whether near surface or geological, require substantial knowledge and experience in a broad range of disciplines, including civil engineering, geological and hydrogeological investigations, assessment of possible dispersion of radionuclides in the environment, impact assessment on living organisms, and long term risk assessment. Some of these steps may require long term R&D. If expertise in those areas is available in the host country and partner countries, it could be combined for more efficient investigations. Expertise can also be obtained from other countries with actual experience.

Mixed waste

Waste that contains both radioactive and non-radioactive hazardous components is termed 'mixed waste' and requires compliance simultaneously with regulations for radioactive and other hazardous materials, and possibly special technical consideration.

Technically, in many cases, mixed waste can be conditioned to remove or stabilize either the toxic or radioactive components. It is vital that central inventories identify any mixed waste and that suitable conditioning, waste acceptance and facility design criteria be adopted.

3.5. COSTS AND LIABILITIES

In determining whether to establish a multinational repository, the costs and liabilities to all affected partners must be weighed against the benefits. Cost sharing will extend over many years from site selection activities to site construction and operation. Post-closure monitoring and maintenance may involve even longer time periods. Long lasting financial arrangements are thus unavoidable whether the project will be run and financed jointly or whether the non-host partners only play the role of customers.

Costs

All multinational repositories will involve substantial costs, possibly ranging from some millions of US dollars for a spent radiation source facility to the order of a billion US dollars for a high level (HLW) repository. It is likely that for all high cost facilities the host country will require financial assurances and adequate monetary contributions from the partners and/or the waste generators.

Such support can come in several forms among which could be guarantees as to the amount and time at which certain waste streams would be available, or agreements as to the fees that could be charged for such waste. Such fees would have to be determined prior to operation of the repository. Similarly, a host country may expect cash contributions to cover up-front development and construction costs, as well as repository operation cost, repository closing cost and post-closure surveillance and monitoring cost. These could be drawn directly from the

national treasuries of partner countries or from fees assessed on waste generators who will use the multinational repository.

Liability

Financial provisions for future liability of the host country have to be considered seriously in the process of establishing a multinational repository, mainly for long term projects. Liability is closely related to cost. Several factors can lead to cost increases beyond the estimates and these have to be properly identified and evaluated, e.g. usual contingencies, changing safety requirements, actual experience, advanced state-of-the-art, unforeseen events, etc. Again it is important to define in advance whether a project is due to be run and financed jointly among partners or whether partners restrict their role to that of customers.

Choosing between the two following approaches — or any intermediary approach — may depend on institutional factors, half-lives of the predominant radionuclides disposed in the multinational repository, practical experience from other international joint ventures, etc. The following two typical cases are examples of how partners might deal with liability:

(a) At the time of receiving the waste, the host country for the repository project takes all responsibilities or liabilities for any possible future remediation. It is good practice that any unforeseen costs be covered by a kind of liability fund or government guarantee. In this scenario, all partner countries could contribute to the liability fund at the time of transfer of the waste.

(b) The host country and partner countries conclude an agreement by which the partners accept a partly open-ended situation and assume liability for improbable but not impossible future events which might require remediation.

Case (a) envisages a one-time transfer of liability and the creation of a liability fund or government guarantee to cover unforeseen future complications. This implies that after the transfer of the waste to the host country, the latter assumes the basic liability for the multinational repository. Any practical problem beyond the anticipated performance of the disposal facility would be addressed and corrected by the host country and, if needed, financed through the mechanism of the liability fund. Once it appears impossible to define the exact amount required to cover contingencies, the host country may wish to receive a relatively high fee at the time of waste transfer.

Choosing solution (b) from the beginning and arranging continued co-operation is another option, provided the partnership appears stable. Basically, each country would retain a pro rata liability for its waste contribution — measured by a combination of volume and radiotoxicity — and act or pay accordingly for future remediation as required. Keeping title and ownership of and liability for the waste could perhaps be a more convincing way for the partners to arrange for their disposal in multinational repositories.

As already stated, the definition of a contractual solution rests entirely with the partners of the multinational repository, and the above described cases and considerations should only be regarded as examples.

3.6. INSTITUTIONAL ASPECTS AND POLITICAL CONTINUITY

The foregoing considerations about cost, liability, safety regulations, etc. are closely linked to the institutional character of the project that involves national and multinational relations

among regulatory and licensing bodies, as well as with contractual partners. Since repository management may extend over decades or centuries, the facility may be run under an international convention or agreement. The political stability of the host and the partners is again a vital element. A repository is, by definition, a long term project, extending over centuries for most LILW or even much longer periods for repositories in deep geological formations, receiving HLW with long lived radionuclides. A repository project involves a relatively long lead time (possibly more than 20 years for HLW or spent fuel) and is then anticipated to receive waste during several decades. After closing the repository, a surveillance and monitoring period will almost certainly be carried out even for *shallow land burial* type repositories with LILW. This underlines once again the importance of the continuity factor not only from a contractual but also from a technical point of view (possibility/obligation to transfer/receive waste, waste acceptance criteria and quality of waste, control and monitoring, etc.). On the other hand, continuity is of equal importance for the proper functioning of the cost sharing arrangements and the respective payments.

3.7. OWNERSHIP OF WASTE MATERIALS

Ownership of waste materials requires early negotiations between the countries participating in a multinational repository project. As already discussed in Section 3.5, there is a strong interrelation between ownership of waste and liability.

Partners involved have to agree when in the process waste ownership is transferred to the host country operating the multinational repository and on the significance of the property transfer.

Transfer could occur at the time when the waste is inspected in the partner's conditioning facilities before transportation, or when the conditioned waste enter the host country at the national border, or at reception in the repository of the host country. It is conceivable that the transfer could occur at a later stage after which any new and additional costs are extremely unlikely to occur. This illustrates the importance of the ownership issue in any negotiation or contractual agreement between the host country and partners.

Transfer of ownership of spent fuel might be more complicated as spent fuel can also be considered as a potential resource rather than a waste, and as the transfer involves safeguards issues. If spent fuel is held for interim cooling period of 30 to 50 years, the date of ownership transfer can be delayed till the moment when the spent fuel will be disposed of in the repository. This allows sufficient time to negotiate that particular ownership issue, and it retains the possibility of reprocessing the fuel and reusing the fissile materials for continued production of nuclear energy.

3.8. ETHICAL ASPECTS

The ethical considerations that need to be taken into account in the case of a multinational repository are the same as those applying to national repositories. They are clearly related with the safety issues discussed in Section 3.3. The ethical considerations are embodied in the IAEA's Safety Fundamentals [14], in particular with regard to the protection of human health and the environment, with emphasis for the protection of future generations, the protection of third countries/parties beyond national borders, and the principle of avoiding undue burdens on future generations.

The above considerations can be reformulated with respect to multinational repositories in terms of the following principles:

- Safety standards must never be compromised whatever the terms of the agreement between participating countries.

- Future generations must not be unduly burdened as a result of the establishment of a multinational repository in any particular country. If the burden of potential monitoring and surveillance cannot be avoided by future generations, acceptable long term funding for these actions must be assured.

- Third party countries' interests must not be prejudiced in any way by the countries participating in a multinational repository project.

- Equity must apply amongst the partner countries, that is, a fair balance must exist between the burden transferred and the compensation received through the multinational repository agreement (see also Section 3.5).

- The agreement between the partner countries must be comprehensive, clear and distinct, with regard to all the substantial aspects mentioned in this report.

3.9. PUBLIC ACCEPTANCE

The public acceptance issue is inevitable and crucially important for national repositories. It might even be more important for multinational repository projects, serving several countries or communities. High safety standards, quality assurance on conditioning and disposal, cost sharing, transparency with regard to coverage of potential future costs, clear and convincing answers with regard to ethical concerns, etc. are thus essential in the process of obtaining public acceptance of a multinational repository project. The time span required to implement a repository has to receive adequate attention since reactions of the public are likely to evolve during that time period. Political consensus in the partner countries is an absolute prerequisite for getting public acceptance, or at least, a promoting catalyst on the way of achieving public acceptance. To maintain this consensus, substantial, well defined, transparent public information campaigns have to be established for the duration of the project.

3.10. SAFEGUARDS

High level waste most commonly results from reprocessing of nuclear fuel. As such it contains fissile materials that, under the terms of the Treaty on Nonproliferation of Nuclear Materials, is subject to national and international safeguards regulations including for disposal. This is a fortiori the case for disposal of spent fuel that (see Section 3.7) can be considered as a resource.

Well defined national and international safeguards regulations will have to be applied in the country of origin of the particular waste. This implies the drawing up of fissile material inventories, fissile material controls and regular international verification inspections (IAEA, EURATOM).

Therefore, if fissile materials contained in waste are considered for disposal, the multinational repository project, as well as any other national project, has to take into account specific requirements allowing for control and inspection activities [16].

3.11. R&D REQUIREMENTS

In general, projects for selection and operation of repositories involve important R&D and demonstration programmes. Such programmes cover geology, hydrogeology, retention properties of near-field and far-field environments, transfer mechanisms of radioisotopes to the biosphere, and mathematical modelling of the observed phenomena. The objective of all those R&D efforts is to assess over very long periods of time the impact of the contents of the repository upon the biosphere and to evaluate related risks. Whereas some aspects to be considered are formation specific, or even generic, others are site specific.

Collaboration and exchanges among national R&D projects on disposal are already well developed and successful. They might also be efficiently structured, even with cost sharing, in a project which aims at installing a multinational disposal facility. However, total needs for R&D are, in principle, not different whether one deals with a national or multinational repository.

3.12. SUMMARY OF DISTINCTIVE FEATURES

In general and in principle, basic issues for a multinational repository are not much different from those related to national projects. Nevertheless, some qualitative differences exist, and they are summarized below:

- Good and reliable information must be provided by several countries in a form adapted to the nature of the project–guarantees with common standards and definitions;

- Liability and stability of the partners must be set up in the preparation phase of the project. Also, if unforeseen complications appear in the course of the project, durability of the agreements is of paramount importance;

- Responsibilities of the partners must be clearly established and the quality of information, financial commitments, etc. must be assured;

- Since some burden is transferred from one country or community to another, the principle and nature of cost sharing or other forms of possible compensation must be clearly addressed;

- Safeguards questions have to be addressed in a timely and adequate manner;

- Due attention must be given to the regime of ownership of waste materials and the step in the process where ownership is transferred from the partners to the host. This issue is clearly related to the way in which long term liabilities are going to be shared.

3.13. FURTHER COMMENTS

The above mentioned conditions and restrictions may seem complex and difficult. However, the report was written to include consideration of long lived radioactive waste. Establishment of a multinational repository may appear much simpler if the multinational enterprise only covers short lived waste, as may be the case in some developing countries whose waste problems include only a few depleted sources and medical R&D waste.

The approach for disposal as well in a national or a multinational repository will highly depend upon waste specific factors, e.g. waste from medical applications of radioisotopes and

most spent radiation sources are short lived and near surface disposal may prove to be the most economical and technically easiest approach. On the other hand, long lived waste, in particular reprocessing waste and spent fuel, requires long term isolation from the environment and, consequently, geological disposal. Concurrently, institutional arrangement and long term financial guarantees may be fundamentally different depending upon the nature of the waste.

4. POTENTIAL BENEFITS AND CHALLENGES

It is a long accepted premise of radioactive waste management that contaminated materials for which there is no further use should be isolated in well designed, well constructed centralized facilities. The health and safety risks of leaving waste at the point of generation are obvious, and all countries with even moderate nuclear energy or industrial use programmes plan at least in theory to dispose of their waste in centralized repositories.

Given that different types of waste may require different types of facilities, and that there are a considerable number of countries throughout the world which utilize nuclear materials, the potential number of centralized facilities could be significant if each nation acts independently.

It is also a commonly accepted ecological principle that it is preferable to minimize the number of sites hosting radioactive waste.

There are a number of environmental, economic and public perception benefits associated with multinational radioactive waste repositories. There are, at the same time, several difficult challenges confronting any nation which intends to pursue a co-operative waste disposal effort. This section will discuss in some detail the potential benefits and perceived challenges involved in the multinational repository concept.

4.1. BENEFITS

4.1.1. Environmental benefits

Multinational repositories offer a number of potential environmental advantages. First, combining efforts can significantly reduce the number of sites containing radioactive materials which might pose a potential burden on future generations. Secondly, reducing the number of sites offers other environmental benefits, such as:

- Participating nations can pool their technical expertise in their efforts to site, design, construct and license the safest repository possible. This action is likely to improve the long term performance of the site.

- A greater number of countries co-operating means that a broader choice of geological sites, suited to safely contain the particular waste type and easily demonstrate the safety, can become available for investigation.

- More participating countries can mean that more funds will be available to obtain the best technical and material resources in the construction of the repository, leading to a safer site.

- Fewer sites will result in more standardization of conditioning requirements. This, in turn, could reduce the number of required waste conditioning facilities.

- Combining resources for a multinational repository could avoid the proliferation of small, under-funded facilities in countries which lack the technical and financial resources to construct a state of the art repository. Reducing the prospect of a number of marginally financed single country facilities is a major benefit of the multinational approach.

4.1.2. Economic benefits

In addition to the substantial environmental benefits of multinational repositories, there are numerous economic benefits for both the host and the partner countries.

Host country development costs

The costs of a single country developing a centralized repository for any category of radioactive waste is significant ranging from a minimum of several million US dollars to the order of billion dollars for a HLW disposal facility. Sharing a facility with a few partners can dramatically reduce a host country's expenditures. Further, since the host country will bear the burden of permanently housing the repository, (and since some partners may be saving the costs of establishing their own centralized facility) the host country may be able to negotiate an equitable contribution by its partners towards the total development costs of the project.

Long term care/remediation

Host countries can negotiate with partners to contribute to the long term care fund and other mechanisms established to address any unforeseen remediation problems that might develop in the future.

Reduced unit costs

Since nuclear repositories have high fixed costs regardless of how much waste is eventually sent to the locations, the additional volumes of waste from partners can help defray total costs and lower the unit charge for disposal below the cost for an individual country's disposal project.

Income generation

By agreeing to host a multinational repository for other countries, a country provides a welcome environmental, technical, and economic service to its partners. In recognition of this, partner countries may agree to pay the host country not only some or all of the costs of development, but also a profit on the operation of the site. In this way, a host country could generate additional income to be used for whatever purpose it chooses.

Partner countries — Share development costs

Some partners in a multinational agreement may have planned to construct their own centralized repository. A multinational agreement frees them from the full burden of development costs. Even a partnership with a few members can share development costs, which will significantly reduce costs to individual members.

4.2. CHALLENGES

For all the obvious environmental, safety and economic benefits of a multinational repository approach, there are nonetheless predictable challenges and complications, especially for the potential host country.

Environmental

A host for a multinational repository inevitably becomes the final resting place for radionuclides that will remain hazardous for hundreds to tens of thousands of years. There is no absolute correlation between the volume of waste and actual risk (the geology, design and performance of the site are much more important factors). Nonetheless, a host country is perceived as incurring a burden of housing several countries' waste for the duration of their hazardous life, even though the operational practices or rules of the repository will ensure the safety of the host country population.

Economic

A host country faces two different financial burdens associated with hosting a multinational repository, i.e. one is the development and operating costs, the other long term care and contingency funds for remediation.

Development costs

Centralized repositories are expensive, and one major incentive for establishing multinational repositories is to share costs. But the host country must have assurances that it can recover the portion of its costs which it expects to share. Regarding development funds, unless a host country collects the money up front, it runs the risk that partners may default on payments or leave the group before the project is finished. At the outset, continuity and reliability are important characteristics to look for in partners. Furthermore, payment mechanisms and procedures must be established to maximize the probability of obtaining full payment.

If a host country fails to provide a site or the site selected fails to get a license, then partner countries may lose their investment, plus be faced with the prospect of finding alternate and probably costly means of managing their waste. Again, the issue of continuity and reliability of all partners to agreements is paramount.

Operating costs

A host country anticipates that partners will provide a steady and predictable amount of waste to the multinational facility. Such business will cover the operating costs of the facility, keep unit costs down and contribute to the long term care fund. To assure that the partner's waste generators continue to utilize the facility for its operational life, enforceable, binding contracts and agreements to accomplish this goal are needed.

Long term care/remediation

As a consequence of the longevity of some radionuclides, it is prudent for the host country to collect the estimated costs for the extended care of the multinational repository waste. While the nature of the custodial care is the same as that for a single country facility, the means of collecting an adequate amount of money from sovereign countries for contingencies even in the very long future is far from certain.

If a host country collects too little to cover actual long term care expenditures or if the site requires costly unanticipated remediations (and the host country cannot collect from its partners or their waste generators), the host country will have to absorb the unreimbursed expenditures.

Public perception

Obtaining public acceptance of any nuclear waste facility has proved difficult in the past. The task of sustaining public tolerance is invariably complicated by offering to take waste that is viewed as foreign or 'others'. The direct benefits of a multinational repository are either abstract or are distributed disproportionately to parties other than the local community most immediately affected. Thus, the host country may not only need to provide the community with assurances that the facility is safe but also provide affected parties with some compensatory benefits, or face continued and perhaps increasing public opposition as the project proceeds.

4.3. SCENARIOS OF CO-OPERATION

The following scenarios are intended to describe typical situations from which a multinational repository might develop. The discussion is designed to highlight some considerations specific to the circumstances but not to fully explore all issues.

Scenario I

Several industrialized countries with relatively small nuclear energy programmes decide to co-operate for the disposal of their nuclear fuel waste.

The prospective partners in this group would be attracted to the multiparty concept because of the prospect of reducing the number of waste sites and saving resources by not developing individual sites. Prospective members should conduct preliminary studies on waste inventories and waste types.

If partners agree to continue, and no country volunteers, criteria and procedures for designating a host country and perhaps some initial site screening by all members should be conducted. In any event, member countries will have to pool their technical and financial resources in their quest for a multinational repository. Given that all members have generally equivalent, but small programmes, the host country may feel it is assuming a disproportionate burden. Host country reservations may be somewhat allayed by partner countries offering technical and monetary assistance to provide greater assurance that the facility will be well designed, constructed and operated; by contributing monetary benefits or compensations directly to the host country or community; and by emphasizing that facility construction and operation will provide long term and often well paying employment for the host country and community workers.

Scenario II

A country with a large nuclear energy programme offers disposal services to other countries with a limited production of radioactive waste.

It is assumed that the host country has the political will, the technical resources and the geology to develop a site.

Host country motivation can range from wanting to be a good neighbour, to a strong commitment to reduce the number of disposal sites worldwide, to a desire to share its development costs, to trading its offer to take radioactive waste from its partners for some other national goal to which all partners can contribute.

Partners will enjoy significant financial benefits by having their waste disposed of. They may wish to negotiate agreements that provide for accountability for funds they contribute to the host country development programme, as well as guarantees as to the safety and quality assurance standards maintained at the multinational repository. The host may already have a repository in operation. In the latter case the partners may have to accept technical conditions already in force in the host facility.

Scenario III

Countries with small nuclear energy programmes in varying stages of development seek assistance from each other. Among other issues is that of finding a suitable and common disposal option.

This scenario is intended to assist countries whose sole use of nuclear materials is in the industrial, research reactors or medical arena. While a repository dedicated solely to the disposal of medical waste and spent radiation sources could be constructed, it seems possible and preferable to handle these materials as part of a larger waste disposal project.

Scenario IV

A country without any nuclear expertise offers land for the disposal of radioactive waste to nuclear energy countries.

In this scenario there is no expertise available in the country offering its disposal services. It should consequently be made very clear that such an offer is, in principle, only acceptable when the offering country fully understands the implications of the facility construction and location. It also could violate existing agreements such as the *Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management* [11] which prevents transboundary movements of radioactive waste in countries which lack the necessary infrastructure to properly manage the waste. Development of such infrastructure, in co-operation with countries or international organizations having nuclear technology know-how, will be prerequisite for implementing the scenario.

The following possible benefits can be identified:

- It could be a model for a facility managed under the auspices of an international organization.

- Materials for which the safeguards procedures apply could be placed directly under an international or extraterritorial authority.

A specific disadvantage of this scenario could be the presumed relatively uneasy transportation routes.

Scenario V

Specializing of national repositories for specific types of waste and international exchanges.

Given local geological conditions, exchanges of waste types, preferably on a basis of mutual equivalence, can be envisaged. A good example could be the exchange of heat generating

HLW against non heat generating transuranic waste (TRU). Such exchanges would require agreement among parties on waste equivalence and measures of quality assurance and quality control.

4.4. REMARKS

Balancing the benefits and potential disadvantages of the multinational repository project it can be said that, at a technical and economic level, the benefits clearly prevail and very often the disadvantages can be minimized.

5. IMPLEMENTATION

Once a country or a group of countries is sufficiently interested in the concept of a multinational repository, they must begin the task of investigating how to implement a potential agreement. It is evident that, despite the numerous attractive environmental and economic benefits of a co-operative approach, the ultimate wisdom and success of an individual agreement depend on a number of technical, financial and political factors. A prerequisite for such an approach is the achievement of consensus among the relevant countries and regions, in particular regarding the transboundary movement of radioactive waste. The following section is intended to examine several of the key issues associated with implementation.

5.1. INITIATING AN INVESTIGATION

In the past, several countries have expressed an interest in serving as a host country for a multinational repository. Similarly, a number of countries have indicated their desire to dispose of their waste outside their borders. Given the various benefits to be derived from a multinational repository, the initiative to investigate the prospects may derive from private entities within a country or from the government itself. Regardless of who expresses the interest, it is clear that several important steps must precede any decision to commence formal discussions of a multiparty agreement.

Inventory definitions

First, the party or parties promoting further investigations must determine which waste type or types would be handled by the multinational repository. Having agreed on the waste types, potential partners should probably undertake a rigorous inventory for each partner of the existing and projected volumes, activities and form of all waste in the specified categories. Prior to these inventory efforts, partners would have to agree on a precise definition for each waste type.

Cost/benefit analysis

Once the inventory is complete, prospective partners may wish to confer on the potential benefits of a multinational repository for their specific members. Included in this assessment would be such factors as the precise total of accumulated and projected volumes for each waste type for which a multinational repository is under consideration, the number and cost of sites eliminated through co-operation, the reduction in unit costs of disposal through a high-volume multinational repository, the difference in transportation routing between a single versus several facilities, and other matters of importance to the partners.

Safety study

Many countries are concentrating their efforts on demonstrating the feasibility of safe disposal in their own country. Such a step could be a prerequisite to future negotiations on the implementation of the multinational repository. Once demonstrated to be safe, international co operation for common solutions may be easier.

Legal analysis

Before reaching any preliminary decisions to proceed with a multinational agreement, partner countries may also wish to determine which international, regional or national laws and regulations would apply to such a proposed facility. This information could affect both the cost estimate of a multinational repository and the selection of a host country.

5.2. IDENTIFYING A HOST COUNTRY

If preliminary investigations support establishing a multinational repository and prospective partners endorse the idea, members must address a range of questions, including who will serve as the host country for the facility. At least three methods of determining a host country seem likely.

Volunteer. The most expeditious situation is where one partner country volunteers, preferably a country with a well established nuclear programme and the likelihood of an acceptable repository site.

Incentive offers. If no country of a multinational group volunteers, the partners might wish to pool their resources and make a formal offer of monetary and technical assistance to any partner who volunteers.

Designated host country. If no country volunteers even with incentives, partners may wish to negotiate a process and criteria for designating one of their members as a host country. Partners would agree beforehand, having approved the procedures and standards, to abide by the resulting designation.

5.3. IDENTIFYING A PROSPECTIVE SITE

Once a host country is determined, it is likely that it will assume responsibility for selecting a prospective multinational repository site. If the designated host country does not have a well developed nuclear programme, technical experts from partner countries or hired consultants could conduct the investigation.

Partner countries could also negotiate with the host country to participate in site selection or to amend the host country siting criteria.

5.4. BINDING AGREEMENT

One of the most challenging tasks associated with establishing a multinational repository is negotiating agreements which provide all member countries with assurance that all technical, political, and financial obligations will be fulfilled. Because of the significant costs of some types of repositories and the accompanying extended time frames for development and, long term operation, enforceable agreements are required. There are few precedents for such agreements in the international arena.

Agreements for multinational repositories will vary depending on the total cost, length of operation of the facility, length of hazardous life of the waste type, and political status of the partners.

Since multinational repositories may be regionally oriented, prospective partner countries may wish to consider negotiating agreements under the aegis of existing regional organizations and codifying them as an addendum or codicil to a regional treaty.

5.5. PUBLIC INVOLVEMENT

Past experience indicates that establishing a radioactive waste repository is as much a political as a technical undertaking. Thus, the public sentiment of a host country must be assessed along with its geological suitability. Countries considering a multinational repository must have confidence that the host country can sustain public acceptance of the facility. Assurances regarding the safe transport and management of all waste materials, monetary incentives and a meaningful and well defined public participation programme could all be addressed in negotiations among partners to foster continued public support among host country citizens.

6. CONCLUSION

The report examines many rational arguments and potential benefits for the development and implementation of multinational repositories. It may be concluded that:

- the multinational repository concept does not contradict the ethical position taken in the reports referred to;

- the high ratio of fixed to variable costs for a repository ensures that considerable economics of scale will apply; and

- transport of nuclear materials today is so demonstrably safe that the greater distances resulting from a multinational repository will not have a significant impact on public health.

However, one should also be aware of the many political and public acceptance issues that may arise in opposition to the multinational concept. A prerequisite for such an approach is the achievement of consensus among the relevant countries and regions, in particular regarding the transboundary movement of radioactive waste. In this context, many countries are concentrating their efforts on demonstrating the feasibility of safe disposal in their own country. Such a step could be a prerequisite to future negotiations on the implementation of multinational repositories. Once demonstrated to be safe, multinational co-operation for common solutions may be easier.

GLOSSARY

Waste acceptance criteria: Those criteria relevant to the acceptance of waste packages for handling, storage and disposal.

Geological disposal: Isolation of waste, using a system of engineered and natural barriers at depths up to several hundred meters in a geologically stable formation. Typical plans call for disposal of long lived and high level wastes in geological formations.

High level waste: (a) The radioactive liquid containing most of the fission products and actinides originally present in spent fuel and forming the residue from the first solvent extraction cycle in reprocessing and some of the associated waste streams. (b) Solidified high level waste from (a) above and spent fuel (if it is declared a waste). (c) Any other waste with an activity level comparable to (a) or (b). High level waste in practice is considered long lived. One of the characteristics which distinguishes high level waste from less active waste is its level of thermal power.

Institutional control: Control of a waste site (e.g. disposal site, decommissioning site) by an authority or institution designated under the laws of a country or state. This control may be active (monitoring, surveillance, remedial work) or passive (land use control) and may be a factor in the design of a nuclear facility (e.g. near surface disposal facility).

Integrated approach: The term refers to a logical and preferably optimized strategy used in the planning and implementation of a waste management programme as a whole from waste generation to disposal such that the interactions between the various stages of waste management are taken into account so that decisions made at one stage do not foreclose certain alternatives at a subsequent stage. For example, the generation of waste is highly dependent on the design, planning and operation of a nuclear facility. (See also institutional control.)

Low and intermediate level waste: Radioactive waste in which the concentration of or quantity of radionuclides is above clearance levels established by the regulatory body, but with a radionuclide content and thermal power below those of high level waste. Low and intermediate level waste is often separated into short lived and long lived wastes. Short lived waste may be disposed of in near surface disposal facilities. Plans call for the disposal of long lived waste in geological repositories.

Near surface disposal: Disposal of waste, with or without engineered barriers, on or below the ground surface where the final protective covering is of the order of a few metres thick, or in caverns a few tens of metres below the Earth's surface. Typically short lived, low and intermediate level waste is disposed of in this manner. This term replaces 'shallow land/ground disposal'.

Repository: A nuclear facility (e.g. geological repository) where waste is emplaced for disposal. Future retrieval of waste from the repository is not intended.

Spent fuel: Irradiated fuel not intended for further use in reactors.

Waste package: The product of conditioning that includes the waste form and any container(s) and internal barriers (e.g. absorbing materials and liner), as prepared in accordance with requirements for handling, transportation, storage and/or disposal.

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