IS SAFE-KEEPING OF RADIOACTIVE WASTE PREFERABLE TO DISPOSAL?

THE IMPORTANCE OF SEMANTICS

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ABSTRACT

The internationally agreed objective of radioactive waste management is to manage radioactive waste in a manner that protects worker safety, public health and the environment, now and in the future, and, in keeping with the principle of sustainable development, to do so in a way that minimizes the burden passed to future generations. While waste management often entails a number of intermediate steps such as interim storage, the end state is usually considered to be final disposal. As with other terminology used by technical people, disposal is precisely defined within the waste management community to mean placing waste in a state with no intention of retrieving it. However, the term disposal is often interpreted by the general public, and, in some cases, by the broader technical community, in its usual sense to mean "to discard" the waste. This leads to a variety of false perceptions that are difficult, if not impossible, to correct. For example, disposal seems to imply careless action rather than a deliberate and careful activity to ensure the long-term protection of public health and the environment. Geological disposal is seen by some members of the public to be irreversible and to preclude the possibility of monitoring and remedial action. Disposal of used fuel is seen by some in the nuclear industry to preclude the eventual retrieval of the fuel, e.g. for reprocessing at some future date, and hence the squandering of a valuable energy resource. The authors believe that some of these mis-perceptions could be addressed by moving away from the use of the word "disposal" and adopting another term in its place, including a re-statement of the end objective. The objective would be to place the waste in a state of "Safe-keeping" where it could be left indefinitely, potentially forever, pending decision making in the future. Ideally, to minimize the burden placed on future generations, such Safe-keeping would not require further intervention to maintain safety, and to ensure safety, if institutional control were lost, it would be passively safe in the long term. To meet these requirements, the design of such a Safe-keeping system, for a given category of waste, would not differ markedly from the designs being considered and being implemented today for disposal. But the debate on the merits of proceeding may well be eased.

I. INTRODUCTION

The evolution and welfare of modern societies depend on technology and industrial processes, including the application of nuclear technologies. All industrial processes lead in one way or another to the production of wastes some of which cannot be recycled. Hazardous wastes require careful management to ensure protection of human health and the environment. The timescales over which some wastes remain hazardous - toxic chemicals and long lived radioactive wastes - extend well beyond the lifespans of current generations, - many thousands of years. Hence there is an ethical requirement to be concerned about the long term management of such wastes to ensure, to the extent reasonable, that future generations and their environment will not be harmed by wastes that we generate.

The application of nuclear technologies - in medicine, in a variety of industrial processes such as geological exploration, gauging, radiography, in research and development, and in the generation of electricity - lead to the production of radioactive wastes. The diversity of applications results in a variety of wastes -- gases, liquids and solids -- representing a variety of potential hazards depending on the concentrations and half-lives of the radionuclides and the physical and chemical nature of the waste.

The radioactivity in such wastes, at the time of production, may range from very low levels, as in waste resulting from the use of radioisotopes in medical diagnostic procedures, to very high levels, such as wastes arising from the reprocessing of used nuclear fuel, or in spent radiation sources used in radiography, radiotherapy, and sterilization. Wastes may be very small in volume such as spent radiation sources, or very large and diffuse such as the tailings from the mining and milling of uranium.

Ideally, the management and eventual disposal of the waste that arises from a given activity should be taken into account when determining whether or not to undertake the activity. Thus, waste production should be justified by the overall benefit to be derived from the activity giving rise to the waste taking into account the risks posed by the resulting waste and the options and costs for its management. While the generation of radioactive waste should, as a matter of principle, be minimized where economically feasible to do so, such wastes currently exist and will be continued to be produced in the future. Therefore, it must be managed to ensure protection of human health both now and in the future. The hazards of radioactive wastes are known and, consequently, it is handled with care, applying the principles of radiation protection.

Traditionally, society has managed its waste in one of two ways, by releasing it to the environment and relying on dilution and dispersal (DD), or by concentrating and confining (CC) it. Examples of dilution and dispersal include the release of gases from the combustion of fossil fuels (gasoline, coal, oil, natural gas) and from chemical processing plants and the release of liquids from domestic and industrial facilities. Within the past century, it has become apparent that, unless carefully controlled, dilution and dispersal can lead to significant negative health and environmental impacts, i.e., urban smog, acid rain, contamination of groundwater with organic compounds and heavy metals, such as mercury. Today, potential global warming arising from the emission of greenhouse gases is a matter of international concern.

Solid wastes do not lend themselves to disposal by dilution and dispersal and have historically been disposed of by being accumulated in waste heaps, a form of concentration and confinement. Examples include the use of outhouses and latrines for human waste, piles and landfills for household garbage, heaps of mine tailings and the disposal of waste from chemical and other industrial processing facilities in landfills. As with dilution and dispersal, experience has shown that concentration and confinement needs to be undertaken in a well managed and controlled manner to prevent negative environmental impacts, such as the contamination of groundwater.

In managing radioactive wastes, potential long term effects and our ethical responsibility to future generations have emerged as particular concerns. Three principles are considered to be important in this regard:

(a) The generation that produces the waste should bear, to the extent possible, the responsibility for managing it without imposing undue burdens on future generations;
(b) Future generations should not be exposed to risks, resulting from the actions of the current generation, that are unacceptable to the current generation;
(c) Decisions taken by the current generation regarding the management of wastes should not, in principle, prevent future generations from taking a different decision.

The responsibilities of the current generation include constructing and operating storage facilities, providing a funding system for the long term management of the wastes, developing, demonstrating and at the appropriate time implementing the technology for such long-term management.

A major consideration in managing radioactive waste is the fact that its radioactivity, and hence its radiotoxicity, decreases with time. The shorter the half-life, the greater the rate of decrease in the radiotoxicity of the waste, and at the same time the shorter the half-life, the greater the intensity of the radioactivity. Thus, by the very nature of radioactivity, the more intense the radioactivity of a given waste, the more quickly its radiotoxicity decreases.

Today, some radioactive wastes, particularly liquid and gaseous process streams containing small quantities of radioactivity, are managed by release into the environment (DD). Such releases are carefully controlled, in accordance with the principles of radiation protection, particularly the ALARA principle, to ensure that human health and the environment are protected.[1] In this way we meet our ethical responsibility to future generations, although for all practical purposes dilution and dispersal preclude future generations taking control of the waste. This fact needs to be considered when making a decision in favour of release and hence dilution and dispersal.

Disposal is seen by the radioactive waste management community to be the preferred strategy for the long term management of radioactive waste. As stated by the NEA Radioactive Waste Management Committee "from an ethical perspective, including long-term safety considerations, our responsibilities to future generations are better discharged by a strategy of final disposal than by reliance on stores which require surveillance, bequeath long-term responsibilities of care, and which may in due course be neglected by future generations".[2] As with other terminology used by technical people, disposal is precisely defined by the waste management community to mean "the emplacement of waste in an approved, specific facility (e.g. near surface or geological repository) without the intention of retrieval. Disposal may also include the approved direct discharge of effluents (e.g. gaseous and liquid wastes) into the environment with subsequent dispersion.".[3] The objective of disposal, as seen by the waste management community, is to "isolate wastes from the biosphere for extremely long periods of time, ensure that residual radioactive substances reaching the biosphere will be at concentrations that are insignificant compared, for example, with the natural background levels of radioactivity, and provide reasonable assurance that any risk from inadvertent human intrusion would be very small.".[4]

But the term disposal is often interpreted by the general public, and in some cases, by the broader technical community, in its usual sense to mean "to discard" the waste. This leads to a variety of false perceptions that are difficult, if not impossible, to correct. For example, disposal seems to imply careless action rather than a deliberate and careful activity to ensure the long-term protection of public health and the environment. Geological disposal is seen by some members of the public to be irreversible and to preclude the possibility of monitoring and remedial action. Disposal of used fuel is seen by some in the nuclear industry to preclude the eventual retrieval of the fuel, e.g. for reprocessing at some future date, and hence the squandering of a valuable energy resource. The authors believe that some of these mis-perceptions could be addressed by moving away from the use of the word "disposal" and adopting another term in its place, including a re-statement of the end objective. The objective would be to place the waste in a state of "Safe-keeping" where it could be left indefinitely, potentially forever, pending decision making in the future. Ideally, to minimize the burden placed on future generations, such Safe-keeping would not require further intervention to maintain safety, and to ensure safety, if institutional control were lost, it would be passively safe in the long term. To meet these requirements, the design of such a Safe-keeping system, for a given category of waste, would not differ markedly, if at all, from the designs being considered and being implemented today for disposal. But the debate on the merits of proceeding with instituting long-term Safe-keeping may well be eased, and the objective maybe clearer.

This idea is developed further below.

II. LONG TERM SAFE-KEEPING OF RADIOACTIVE WASTE

Long -term Safe-keeping may be defined (in analogy with the objective of disposal) to be an indefinite and ideally ultimately passive solution for the containment and isolation of radioactive waste from the environment. Eventually, there would be no requirement for further intervention by humans, nor a requirement for institutional control in the long term. This does not assume that society would not maintain institutional control and oversight. Quite the contrary: it is assumed that, in the immediate future and for some substantial period, society and waste managers would actively work to maintain institutional control, including monitoring. But such Safekeeping facilities would be designed so that if control were lost for whatever reason - a relaxation of oversight, neglect, societal breakdown, or a deliberate decision that long term safety had been adequately demonstrated and active control could cease - the waste would remain safe. In placing the waste into Safekeeping there would be no requirement for retrieval but retrieval would be possible. Thus, future generations would have the possibility of recovering waste for whatever reason, e.g. to improve safety or to recover material for future use. The waste would be emplaced with the knowledge that it might well never be retrieved and the Safekeeping system would have to be designed accordingly but, as opposed to the definition of disposal which states explicitly that there is no intention of retrieval, Safekeeping does not require an explicit statement of intentions regarding future dispositioning of the waste. Rather it requires only a recognition that the waste may not be retrieved and hence such a system must be designed so that the waste need not be retrieved.

The ability to retrieve wastes, should a Safekeeping system fail to function as designed, is seen to be an important factor in addressing public concerns about geological disposal. Some participants in the environmental review of AECL's Concept for the disposal of Canada's Nuclear Fuel Waste[5] indicated a clear preference for storage rather than disposal because of the ability to take remedial action should something go wrong.[6,7] The Environmental Assessment Panel noted the following in its report[7]:

"The Canadian Nuclear Association supported disposal to minimize the burden on future generations and to remove a major barrier to their continued use of nuclear energy. But it suggested that wastes should be retrievable as long as society might consider recycling them, and that successful siting of a repository should not preclude long-term parallel storage.

Other participants argued against the AECL disposal concept and its timing on the following grounds:

- that relying on undemonstrated technology to achieve passive safety for many thousands of years was less acceptable than the assumption of societal breakdown and the loss of institutional control;
- that leaving wastes on the surface near heavily populated areas or seats of government would constantly remind people of its presence, thereby ensuring that institutional controls did not lapse;
- that, as long as nuclear power continues, the most hazardous waste inventory will always be stored at the surface, and ongoing care will be required not only for the wastes in storage but also for the power plants;
- that disposal would burden future generations because they would have limited options for managing the wastes, they would not want to leave the facility unmonitored, and they would find it expensive and difficult to retrieve the wastes if desired; and
- that science was likely in the relatively near future to develop a better solution than passive geological disposal.

Faced with these contradictions, many participants believed that Canada should not rush to implement disposal, but should keep the wastes in storage and look for a better solution."

In developing and implementing Safe-keeping strategies for wastes that contain predominately short-lived radionuclides, advantage can be taken of the fact that the hazard from such waste will decay to a level at which there is no residual radiological risk to human health or the environment after a suitable period of time - a few hundred years. For short-lived wastes, Safe-keeping strategies can include monitoring and active controls as an integral component since the required period of control is relatively short. Long-term passive safety can be achieved by limiting the inventory of wastes containing long-lived radionuclides.

Engineered shallow vaults are today being used for the Safe-keeping of short-lived wastes. France and Spain have begun placing low and intermediate level wastes (LILW) in recently opened shallow structures at Centre de l'Aube and at El Cabril, respectively, that are designed to allow unrestricted use of the site after about 300 years. At both facilities, the floors of the disposal structures collect any infiltrating water and channel it away from the structure for monitoring. The facility at Centre de l'Aube isolates wastes in structures built above the highest level of the water table. It features movable buildings that prevent rainwater from contacting the waste disposal area during operations.[8,9] At El Cabril, waste packages are placed inside modular concrete containers that in turn are stacked within engineered disposal structures.[10] If retrieval of waste should ever become necessary, the modular design would simplify the process.[11] In Canada, a prototype near-surface facility known as an Intrusion Resistant Underground Structure (IRUS) has been designed.[12] An IRUS unit would consist of a below-ground vault with reinforced concrete roof and walls and a permeable floor, located on a free-draining sand ridge above the water table. The multiple-barrier structure is designed to last for 500 years.

Some radioactive wastes, particularly used nuclear fuel and long-lived waste from reprocessing used fuel contain radionuclides with very long half-lives. The long-term management of such material has accordingly been given special consideration. An important consideration in developing strategies for such wastes is the fact that the long term hazard arises principally from the potential ingestion of such materials rather than from the risk of exposure per se.

The preferred method of waste management for long-lived radioactive waste heretofore has been based on deep geological disposal, utilizing a system of engineered and natural barriers (the multiple barrier system) to ensure long-term safety. While the objective of geological disposal is final and permanent disposition of the waste with no intention of retrieval, such disposal would not preclude the maintenance of institutional controls if society wishes nor does it preclude the retrieval of the waste by a future society.

One of the goals of geological disposal is to minimize the potential for inadvertent human intrusion by removing the waste from the surface. For this reason, such systems are planned to be constructed at a depth of hundreds of metres below surface so that normal activities at surface -- construction of buildings, underground transportation systems, etc. -- will not impinge on the waste. This does not foreclose completely the possibility that future generations might inadvertently intrude into the waste, for example, in exploratory drilling for minerals, but in siting a disposal facility, care can be taken to reduce the probability of such intrusion.

While there is consensus among waste management experts that geological disposal is the preferred strategy for disposal of long-lived radioactive wastes, it is recognized that pursuing this option "leaves open the possibility of adaption in the light of scientific progress and social acceptability, over several decades, and does not exclude the possibility that other options could be developed at a later stage".[2]

The strategies and indeed the designs developed for geological disposal are equally applicable to the concept of long term Safe-keeping. To illustrate this point several paragraphs taken from a paper presented at an International Workshop dealing with the environmental and ethical aspects of long-lived radioactive waste disposal are repeated below but using the words "Safe-keeping" rather than "disposal" with the exception of one paragraph where the words "disposal" are retained because they emphasize the public concern with disposal.[13]

"The Multi-Barrier System

The Safe-keeping concepts being developed internationally for deep geological Safe-keeping are based on a combination of engineered barriers and the natural barrier provided by the host geological medium. The key engineered barriers are a stable waste form, either used fuel or vitrified waste from reprocessing used fuel; long-lived containers into which the waste form is packed; clay-based buffer materials that separate the containers from the host geological structure and control the movement of water to, and corrosion products away from, the containers; and seals and backfill materials to close the various openings, tunnels, shafts and boreholes. There is international consensus that this approach can best achieve the goal of safely managing used nuclear fuel in the long term. The biosphere, although not a barrier per se, is an important part of the overall system because it contains the pathways for direct exposure of humans and non-human biota to contaminants. Consequently, its study must be part of any waste management program. A variety of geological media are under consideration, including crystalline rock (Canada, Finland, Japan, Sweden and Switzerland), clays and shales (Belgium and Hungary), volcanic tuff (U.S.A.) and salt (Germany and Spain).

In many countries, the approach to development of the Safe-keeping concept has been to consider the performance of the system as a whole, rather than focusing on performance requirements for individual components. This approach allows flexibility in implementation to be retained and it increases the likelihood of identifying any counterintuitive interactions or synergisms among system components that could adversely affect safety. Thus, the performance of individual components, such as waste containers, is analyzed in the context of the system. The goal is to develop a thorough scientific understanding of the performance of the different components of a Safe-keeping system and how these components interact and influence one another, so that the overall system can be designed to provide defence in depth.

Acquiring and building the necessary knowledge base is a continuing process, and in implementing Safe-keeping, flexibility must be retained so that the program can use and benefit from new information and understanding over time.

To date, however, no country has demonstrated deep geological disposal and public uncertainty remains. This is fuelled in part by the public's mistrust of the industry and of governments, and in part by their fears of radiation and their scepticism about the industry's ability to safely contain its waste for periods of thousands of years. Thus, the challenge that faces society and those charged with responsibility for management of nuclear fuel waste is to develop sufficient confidence in the technology to permit decision-making, regarding the implementation of disposal.

Considerable efforts have been made to evaluate the behaviour of deep geological repositories with time, and their long-term safety. Scientific methods exist to establish the safety of particular disposal sites and there is an international consensus among experts that "appropriate use of safety assessment methods, coupled with sufficient information from proposed Safe-keeping sites, can provide the technical basis to decide whether specific Safe-keeping systems would offer to society a satisfactory level of safety for both current and future generations".[14]

Much of the evidence needed to evaluate any site that would be considered for deep geological Safe-keeping can be obtained from geologic information developed as the site is characterized. Field studies, including studies of natural analogues can extend the short-term evidence from the laboratory studies to the longer times of interest-tens and even hundreds of thousands of years-and provide systematic evaluation and verification of the understanding incorporated in the mathematical models used to assess long-term performance of a disposal system.

Incremental Decision-Making Process

In developing Safe-keeping facilities for nuclear fuel waste, a number of countries are following a strategy of staged or incremental decision-making, as an integral part of the process. Each phase, its review and subsequent decision-making should be lead to an increased confidence in the technology. This is the case in the evolution and development of national programs in Belgium, Canada, Finland, France, Spain, Sweden, Switzerland and the U.K.. By proceeding with the development of waste management technologies in a staged manner, assessing safety can be separated from the implementation activities that often create public concern, such as the siting of a facility.

While the details vary from country to country, the basic elements involved in achieving Safe-keeping are:

- Conceptual and technology development/ demonstration, followed at the appropriate time, by site-specific activities beginning with site screening, to select one or more sites for detailed surface-based characterization studies.
- Surface-based site characterization leading, with appropriate review, to a selection of one or more sites for exploratory excavation and more extensive in-ground characterization, or to a decision to abandon the site.
- In-ground characterization studies leading to a decision, following appropriate reviews of the status of our knowledge, to initiate construction and then operation of a repository. During characterization, a site-specific facility would be designed. At this stage, performance assessments would also be done to assess the long-term performance of a facility at a given site with a given design.
- Construction and operation of a facility which will unquestionably involve ongoing review, reassessment and recommitment, leading, if appropriate, to continued use and eventually to a decision to cease operations and decommission. Initial operation of any facility will likely involve a demonstration phase. Sweden, for example, is planning on a demonstration emplacement of waste in a deep geological repository by about 2010. At an early stage of repository construction, possibly during the demonstration phase, or as part of sub-surface characterization studies, an area of the repository could be dedicated to component testing in the actual conditions at the site. Such testing might continue over the many decades of operation, and as part of confidence building, the components could be eventually retrieved and examined to establish how closely their behaviour conformed to the anticipated performance.
- Decommissioning and eventually, the sealing of all shafts, tunnels and exploratory boreholes to close the facility and to place it in a passively safe state. The results of component testing, operational reviews and monitoring, and post-operational monitoring would form the basis on which to make a decision when to close and seal the repository. The long-term safety of this system would need to be convincingly demonstrated, prior to closure.

This approach would utilize the observational method where information is continuously acquired and incorporated into the design. The observational method is central to the use of performance assessment analyses as part of the design and implementation process. Beginning during the site selection phase, assessments are made of the site condition using all available data. The understanding of the site is incorporated into models for use in design and in performance assessment studies.

Both the designs and the assessments become more refined as the knowledge of a site increases. As work proceeds, observation and evaluation of the actual conditions encountered are compared with the previous understanding which, if necessary, is then modified. This cycle continues throughout site selection, construction and operation, so that at each point when significant licensing and operational decisions need to be made, a long record of observation and a series of increasingly refined performance assessments are available on which to base the decisions.

Throughout this process, regulatory standards would apply and regulatory approval and licenses would be required at various points in the process. An extensive monitoring program beginning with the start of site screening activities, would be maintained throughout the process. Many years' worth of data from monitoring and studying the site and a series of increasingly refined evaluations would have been accumulated before the decision would be made to emplace the waste. After the repository had been filled with nuclear fuel waste, it would likely be maintained under surveillance for an extended period to confirm that it was behaving as intended. The decision whether or not to close the repository would then be made on the basis of the accumulated evidence and experience from the site selection, construction, and operational stages, a process extending over many decades.

Throughout the process, judgement regarding the performance of the Safe-keeping system would be based on an ever-expanding knowledge and experience base, a knowledge base that should lead to progressively greater confidence. Although uncertainty could not be entirely eliminated, the long history of past performance should provide the basis for building both public and technical confidence in the site and its future evolution, and the long-term safety and the performance of the facility.

This approach provides ample opportunity for ongoing review, and at any point in the process, if ongoing review and assessment indicates the objectives of Safe-keeping cannot be met, it is possible to cease operations and retrieve the waste."

III. PROLONGED STORAGE COMPARED WITH LONG TERM SAFE-KEEPING

Prolonged storage of waste is a form of containment and isolation; it differs from long-term Safe-keeping (and disposal) in that further handling or retrieval of the waste is intended at some time. Most issues and concerns involving prolonged storage pertain to long-lived wastes. Nuclear fuel waste worldwide is presently stored either in water-filled pools or in dry concrete or metal structures. Although heat and radiation intensity decay exponentially while the fuel is in storage, some of the radioactive waste material in used fuel represents a potential health hazard for millennia. Surface storage systems have design lifetimes on the order of decades, not centuries, and they require continued surveillance, maintenance and periodic replacement of systems. Even countries without nuclear power programs can have small but hazardous inventories of long-lived wastes derived from medical, industrial, and research-related nuclear applications. Continued storage of these wastes is necessary until one or more of the long-term waste management options are put in place.

There is a general recognition that storage must be considered an interim measure for waste. Even so, in many countries public debate continues to address the possibility that it is short-sighted to pursue a strategy of immediate geological disposal rather than of prolonged storage, which would ensure that future generations have all options available. In the Collective Opinion of the Radioactive Waste Management Committee of the OECD Nuclear Energy Agency pertaining to the environmental and ethical basis of geological disposal, the Committee noted:

> "The indefinite storage and monitoring strategy has indeed a number of technical and ethical arguments in its favour, particularly if it were to be accompanied by suitable efforts to ensure continued development or improvement of options for final solutions and to ensure that financial resources would be available when needed at all times in the future. One interpretation of the concept of sustainability would support such an approach, wherein one generation would pass on to the next generation a world with "equal opportunity", and so on for the generations coming after, thus preserving options and avoiding the difficulty of predicting the far future. According to this idea of a "rolling present" the current generation would have a responsibility to provide to the next succeeding generation the skills, resources, and opportunities to deal with any problem the current generation passes on. However, if the present generation delays the construction of the disposal facility to await advances in technology, or because storage is cheaper, it should not expect future generations to make a different decision. Such an approach in effect would always pass responsibility for real action to future generations and for this reason could be judged unethical.
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> A most significant deficiency of the indefinite storage strategy is related to the presumption of stability of future societies and their continuing ability to carry out the required safety and institutional measures. There is also a natural tendency of society to become accustomed to the existence and proximity of storage facilities and progressively to ignore the associated risks. Such risks would actually increase with time in the absence of proper surveillance and maintenance, leading at some indefinite future time to possible serious health and environmental damage. There are many well-known examples of bad environmental situations inherited from the past which show that this deficiency of a waiting strategy should not be underestimated.[2]"

As noted above, "From an ethical standpoint, taking into account long-term safety considerations, present-day responsibilities to future generations with regard to the management of long-lived radioactive waste are better discharged by a strategy of final disposal than by reliance on strategies which require institutional surveillance, bequeath long-term responsibilities of care, and may in due course be neglected by future societies whose structural stability should not be presumed."[2]

The concept of long term Safe-keeping is in most respects the same as disposal but by remaining silent on the issue of future intentions Safe-keeping reflects, in some ways, the advantages of indefinite storage, by ensuring that the waste can be retrieved, but it also addresses the desire to minimize the burden passed to future generations by relieving them not of the opportunity to take further actions but of the necessity to do so. At the same time, by requiring long-term passive safety, should institutional control be lost the potential for harm is greatly reduced compared with the consequences of loss of control of storage systems that are not designed to be passively safe.

IV. SAFE-KEEPING OF USED FUEL COMPARED WITH REPROCESSING

Within the nuclear community proposals for the direct disposal of used fuel have sometimes been criticized as a waste of a potential valuable resource. Better the fuel should first be re-cycled (i.e. re-processed) to recover the fissile material. The implementation of long term Safe-keeping of used fuel, by countries who today are not prepared to proceed with reprocessing, for whatever reason, would seem to be a reasonable approach that could diffuse this concern. The fuel would be retrievable and hence would not necessarily be considered a waste per se. On the other hand by placing it into a state of long term Safekeeping the owners and producers of the waste would be meeting their ethical responsibility to future generations by relieving them of the need to care for the fuel indefinitely.

The decision to retrieve or not for recovery of material (or for some other purpose such as improving the state of Safe-keeping) would be made by a future generation taking into account the costs of doing so and the benefit to be derived. Based on today's perspective and today's knowledge the most likely reason for retrieval would be to extract fissile and/or fertile material. The feasibility of retrieving used CANDU fuel from a geological repository was assessed as part of the environmental review of the AECL concept for the disposal of Canada's nuclear fuel waste.[15] Although not published, the cost of retrieval was also evaluated and it was estimated to be a very small fraction of the cost of reprocessing. Further, should a future generation decide to retrieve the fuel to reprocess it for recovery of one or another of its constituents, the radioactive waste from the reprocessing could be returned to a state of Safe-keeping in the same facility from which the used fuel was recovered. Thus, there does not appear to be a strong economic incentive not to proceed with putting used fuel into a state of long term Safe-keeping in a geological repository because of the potential for its future re-processing. Since in most countries the cost of geological Safe-keeping (based on studies carried out to date of disposal of used fuel or of high level waste from reprocessing) is a small fraction of the cost of the electricity generated in the course of producing the waste, the cost of establishing and operating a geological repository should not be used as an argument not to proceed with long term Safe-keeping of used fuel.[16]

V. CONCLUDING REMARKS

Substantial progress has been made in a number of countries in establishing facilities for the long term management (disposal) of short lived and low activity long lived wastes including the WIPP facility in the United States, the first deep geological repository to be put into operation. These facilities while designated as disposal facilities can also be equally well described as long term Safe-keeping facilities. The use of the latter terminology or some variant on it represents a small but hopefully useful shift in philosophy regarding the long term management of radioactive waste particularly the long term management of nuclear fuel waste. By avoiding the term disposal which often has pejorative connotations and emphasizing instead the fact that waste would be placed in a state where it could be left indefinitely if so decided by future generations but from which it could be retrieved if desired or necessary it is believed that public and scientific anxiety surrounding proposals for geological waste management could be reduced.

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