RETRIEVABILITY: IS IT THE EMPEROR'S NEW PROTECTIVE CLOTHING?

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ABSTRACT

Public safety and acceptance, and environmental safety are two common and closely related global cornerstones for the successful development of a deep geological repository for safe disposal of long-lived radioactive materials/wastes[a] (LLRM)(1,2). Unfortunately, lack of public trust and fear of the unknown are two primary reasons for hindered progress and abundant opposition to LLRM repository developments. As a case in point, despite more than 40 years of focused efforts around the world, the Waste Isolation Pilot Plant (WIPP) in New Mexico, United States of America (USA), is the only operating deep geological repository for LLRM at the end of year 2000. The WIPP repository was certified (3) for safe disposal of LLRM and permitted (4) for safe disposal of regulated hazardous constituents mixed with the LLRM by two independent regulators in 1998 and 1999, respectively, and it opened in March 1999. The world's next deep geological LLRM repository is scheduled to open in year 2010 (5). As follows, the costly and seemingly endless search for safe LLRM repositories continues both in the USA and abroad. Thus, any variation to the current strategy that might enhance LLRM repository progress must be carefully considered, provided the solution is:

- Scientifically and technically sound;
- Fulfilling ethical and financial commitments to both current and future generations; and
- Presented in unambiguous context and readily understood manner.

Two geological-disposal-related concepts currently being promoted as contributing to safety around the world are "retrieval" and "recovery" of the emplaced LLRM (e.g.,6,7). However, in the USA, these concept are fundamentally different (8,9), a fact that appears to be largely unrecognized. The retrievability concept involves ready access to the LLRMs emplaced in a deep geological repository during (and about 50 years after) the operational period to safeguard against any unexpected adverse conditions (8). The recovery concept involves the fundamental ethical and financial consideration that future generations should not be precluded access to the emplaced LLRM as a potential resource (2,9). Thus, two credibility issues associated with these concepts are:

1. Do they contribute to repository performance in terms of safety?
2. Do they need to be better defined such that the distinction between the two concepts is clear?

Based on a preliminary analysis, the conclusions of the author are:

1. Neither retrievability nor recoverability contributes to the safe performance of a deep geological repository for LLRM, indeed they may decrease post-closure safety.
2. A clear distinction needs to be made between the retrievability and recoverability concepts to avoid misunderstandings, misrepresentations, and loss of an already fragile public confidence in (a) the credibility of the radioactive waste management community; and (b) the feasibility of deep geological disposal of LLRM.

INTRODUCTION

Despite more than 40 years of costly efforts around the world to site, develop, and open deep geological repositories for safe disposal of LLRM, the WIPP (Fig. 1), is the only currently certified (3)/permitted (4), operating LLRM repository in the world. Barring any legal or statutory challenge, the world's next LLRM repository is scheduled to open in 2010 (5). As follows, the costly and seemingly endless search for safe LLRM repositories continues both in the USA and abroad. Thus, any solution that might enhance progress must be carefully considered, and presented and promoted in a manner that is scientifically correct and readily understood to gain the required scientific and public acceptance.

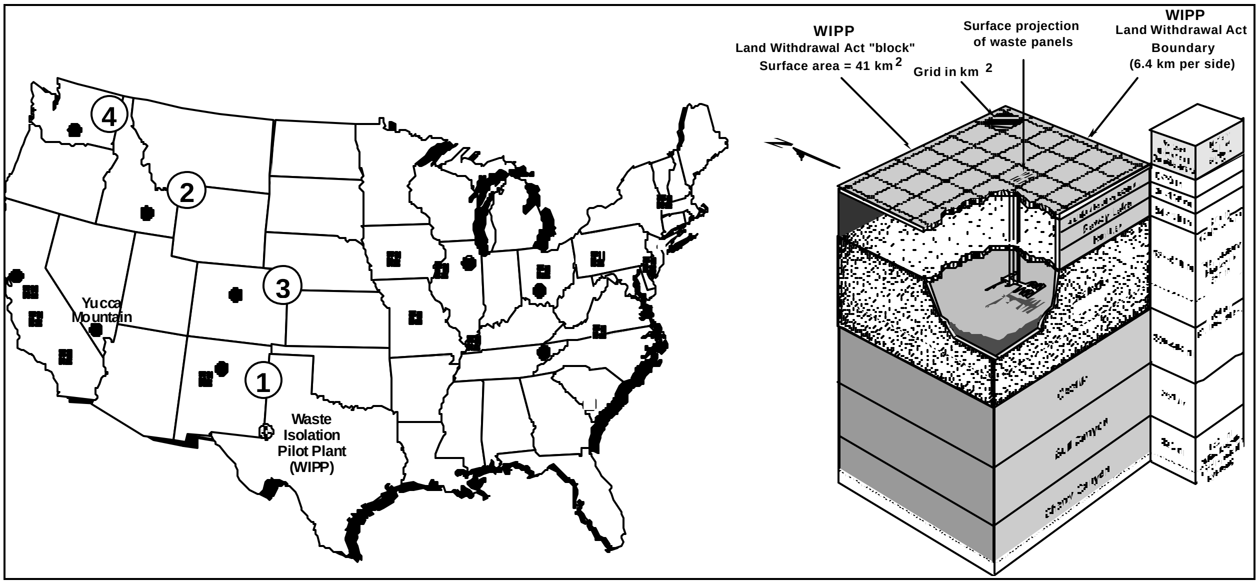

Fig. 1. The U.S. map (left) shows the locations of the WIPP and the candidate Yucca Mountain LLRM repository sites, and 10 large-quantity (circles) and 13 small-quantity (squares) transuranic radioactive waste TRUW generator and storage sites. The schematic WIPP Land Parcel (right) shows the 41.6 square kilometer (16 square miles), 1,828 meters (6,000 feet) deep, "controlled area" geosphere block.

In recent years, design and operational measures enhancing the ease with which the LLRM emplaced in a deep geologic repository could be retrieved have received increased attention and support among politicians, and international and national radioactive waste management organizations (6,7). The main perceived benefit is that the option of ready *retrieval* of the emplaced LLRM during the operational and early post-closure periods would convey a measure of safety that would mitigate public fear and promote public acceptance of the deep geological repository concept. A related, but different concept is *recovery* of the emplaced LLRW to allow future generations the option to: 1) treat it; 2) reuse it; 3) minimize its volume; and/or 3) employ alternate disposal methods/systems for it.

The recovery concept is based on the long-standing, internationally-agreed-upon principle (1,2) that future generations should not be precluded from recovering the LLRM emplaced in a deep geological repository during the post-closure period. In other words, it has nothing to do with repository safety. However, the distinction between the two aforementioned concepts is often unclear to the general public, and sometimes to professionals in the field. Furthermore, both of these terms are used to convey an implicit or explicit message that they contribute to the overall safety of a deep geological repository for LLRM. Since scientific credibility and public acceptance comprise, or should comprise, the two fundamental premises for political acceptance and survival of geologic disposal as a concept, the potential benefits of LLRM retrieval and recovery in terms of enhanced repository safety are discussed below in the context of the Rotary International Organization's four-way test:

1. Is it the truth?
2. Is it fair to all concerned?
3. Will it build goodwill and better friendships?
4. Will it be beneficial to all concerned?

The following discussion focuses on whether retrievability and recoverability contribute to or compromise the attainable post-closure safety of a deep geological repository for LLRM. The discussion contains two main parts. The first part addresses the potential impacts of LLRM retrieval and recovery on physical safety. The second part addresses the potential benefits of retrievability versus recoverability to current and future generations and environments. A summary of the author's conclusions follows the discussion section, and references indicated by numbers in parenthesis in the text are listed in a section after the conclusions section.

DISCUSSION

In a democratic society, *safety and public acceptance are common cornerstones to all repository development programs*. In simple terms, safety may be divided into two categories:

- Physical safety; and
- Emotional safety.

The term physical safety is used in this text to denote the degree of radionuclide containment and isolation function provided by the repository. The term emotional safety is used in this text to denote the peace of mind a human achieves when recognizing or believing that radionuclide containment and isolation function provided by the repository is high. Both of these safety categories need to be adequately addressed and maintained during all stages of a repository project. An occasionally insurmountable challenge to achieving this seemingly straightforward objective is that the information (or assurance) required in each category for adequate satisfaction varies among individuals. Since physical safety, typically, is a fundamental building block to emotional safety, the following discussion focuses of the inherent components of demonstrating physical safety. The discussion of safety is preceded by a concise discussion on the technological feasibility of retrieving LLRM from a deep geological repository, because if retrievability is not technologically feasible, it is not a viable, credible concept.

A landmark feasibility study on post-closure removal of LLRM disposed in a deep geological repository was presented in the 1996 WIPP Compliance Certification Application (10)(CCA). As illustrated in Figure 2, the WIPP repository is situated approximately 650 m below the surface in the lower half of a 250-million-year-old, 600-m-thick, virtually undisturbed and impermeable salt bed. When filled to its current statutory capacity (11), the WIPP repository will safely contain and isolate 175,584 cubic meters (m^3) (6.2 million cubic feet [ft^3]) of defense-related, transuranic radioactive waste[b] (TRUW) that includes 12 tons (26,455 pounds) of plutonium with a half-life in excess of 24,000 years, remote-handled (RH) TRUW canisters with a surface dose rate of up to 10 sieverts per hour (1,000 rems per hour), and approximately 50,000 m^3 (1,8 million ft^3) of regulated hazardous constituents. Contact-handled (CH) TRUW contained in standard 208-liter (55-gallon) drums or Standard Waste Boxes will be stacked three high in the disposal rooms and surrounded by bagged magnesium oxide (MgO) backfill. RH-TRUW contained in shielded canisters measuring 0.66 m (26 inches) in diameter with a maximum length of 3.07 m (121 inches) and a maximum weight of 3.63 tons (8,000 lbs) will be emplaced in pre-drilled horizontal holes in the walls of the disposal rooms. Current projections indicate that the salt surrounding the disposal rooms will gradually encapsulate the emplaced waste within a few hundred years, thereby creating a virtually impermeable monolith. The CCA was subjected to a regulator-facilitated public review that culminated in the regulator's favorable 1998 certification decision(3). The conclusion reached was that *LLRM emplaced in a rock salt repository can be removed with currently available technologies several thousand years after the repository has been closed*. In other words, the feasibility of retrieving the LLRM emplaced at WIPP has been carefully reviewed, discussed, and largely accepted by a broad range of stakeholders and the cognizant regulator. Furthermore, the technologies analyzed in the CCA are readily available and applicable to other rock types. As follows, post-closure retrievability of LLRM from a deep geological repository is a viable technological concept and the remaining issue is how retrievability design measures and operations would affect safety.

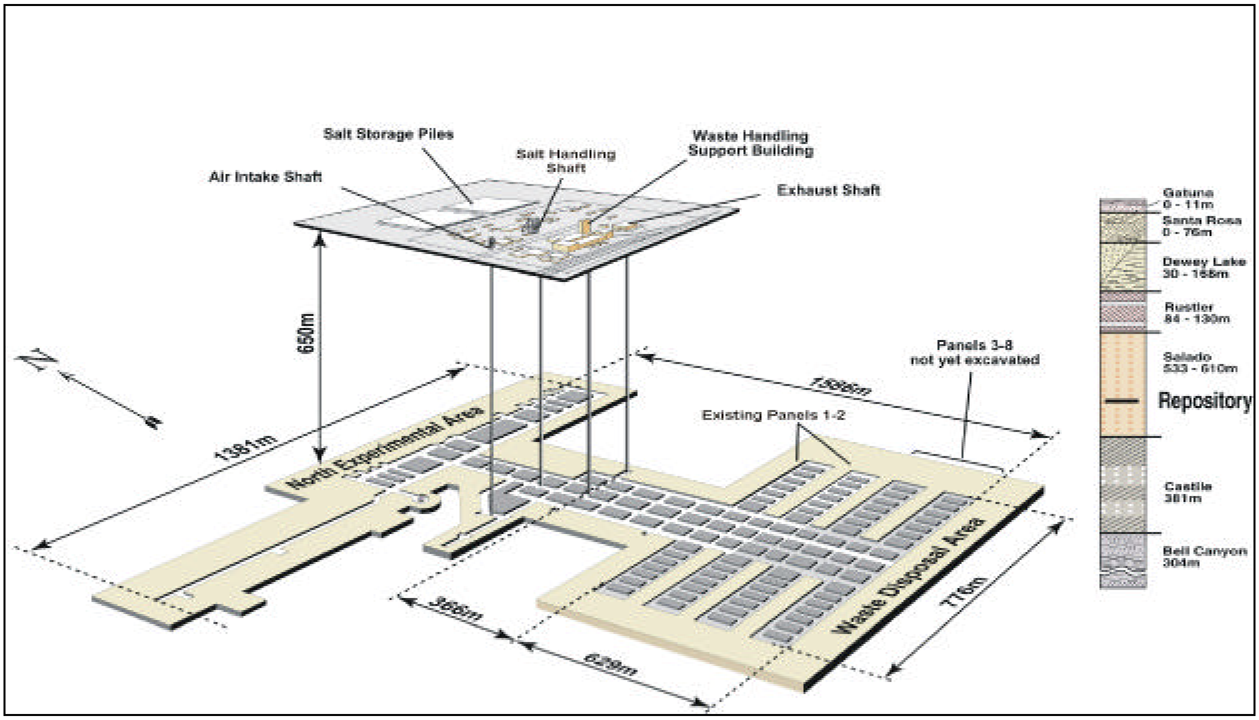

Fig. 2. Schematic illustration of surface and subsurface facilities, and main stratigraphic formations/units at the WIPP site.

Any effort to demonstrate the physical safety of a LLRM repository must address a broad range of issues. Many of these issues are across very large temporal and spatial scales, and involve uncertainties that are not readily conveyed to or understood by the general public. For example, the minimum radionuclide containment and isolation periods considered for LLRM repositories around the world vary between 10,000 years(9) and 250,000 years (i.e., approximately 10 half-lives of ^{239}plutonium) or longer. The only means to gauge LLRM-repository-safety for such long periods is probabilistic-based, predictive calculations, also referred to as safety and/or performance analyses (SAs/PAs). Furthermore, all SAs/PAs must consider a broad range of uncertainties. Primary sources of uncertainty are inherent model and parameter uncertainties. The distribution of the following basic "numerical" components govern conceptual model, numerical model, and parameter uncertainties:

1. Systems and processes that we know.
2. Systems and processes that we think we know.
3. Systems and processes that we know we don't know.
4. Systems and processes that we think we don't know.
5. Systems and processes that we don't know we don't know.

Typically, component 5, by definition, cannot be incorporated specifically in SAs/PAs. Its significance is assumed to be small and accounted for together with components 3 and 4 in "upper bound" values and sensitivity analyses.

The two basic components involved in long-term SAs/PAs for geologic repository and the related three main geological disposal processes and impacts/consequences that govern long-term repository SAs/PA are as follows:

1. The natural (barriers) system.
2. The engineered (barriers) system.
3. Natural-system-induced processes and impacts/consequences.
4. Construction-induced processes and impacts/consequences.
5. LLRM-induced processes and impacts/consequences.

The relationship between retrievability and each of these components, processes, and related impacts are addressed in a step-by-step approach below.

Clearly, retrievability is neither an element of the natural system nor an attribute of any natural-system-induced process or related impact. As follows, the remaining question is whether and how retrievability could affect the engineered systems and any engineered-system(s)-induced or LLRM-induced process and/or related impact.

Retrievability is not achieved by a specific engineered barrier that may be installed during the construction, operation, or closure of the repository that would contribute to radionuclide containment and isolation or reduce the uncertainty of SAs/PAs. As follows, retrievability does not contribute to physical safety, and its only remaining potential contribution to physical safety is in the areas of construction- and LLRM-induced processes and their impacts.

Construction-induced processes and their impacts are inherent in, and contingent upon, the rock mass quality, the opening design, and the excavation method(s) used; such processes could dominate LLRM repository SAs/PAs. The construction objectives are, therefore, to minimize the disturbance imposed by the construction of the repository and to minimize and confine the construction-induced processes and impacts to the disposal room and its immediate vicinity. If imposed, the retrievability requirement very likely will influence the construction design and the construction method; hence, retrievability very likely affect construction-induced processes and impacts. In other words, retrievability very likely compromises the optimal physical safety of a deep geological repository.

In terms of LLRM-induced processes and impacts, minimizing the disturbance imposed by the emplaced LLRM ensures that the LLRM-induced transient processes and impacts are short, reasonably well-defined, and cause only minor long-term safety impact. Even in the case of high-temperature-induced transient processes and events that result in uncertainties of a magnitude that affect both long-term safety and regulator and public confidence in (and acceptance of) the related SAs/PAs, none of the potentially adverse LLRM-induced processes and impacts is mitigated by retrieval because they are all related to a transient thermal pulse emanating from the emplaced LLRM.

Of course, a pre-installed retrieval system could accommodate ready access to and retrieval of the emplaced LLRM, which would improve workers' safety during the retrieval process and reduce the time and cost required for the retrieval operation. Conversely, a pre-installed retrieval system could also compromise workers' safety during the retrieval process and increase the time and cost required for the retrieval operation. Indeed, if the pre-planned retrieval program does not incorporate safeguards for the effects of the particular system failure, it could seriously compromise workers' safety and exacerbate the failure effects/consequences. Furthermore, retrievability contingencies incorporated into the design, which need to be maintained during and after the operation of a LLRM repository to accommodate ready post-closure access for future generations, are a costly, incompatible compromise of the performance objectives of the repository, which are to:

1. Provide optimal containment and isolation of the emplaced LLRM (environmental radiation protection) for both current and future generations and environments; and
2. Safeguard against proliferation.

By complying with applicable laws and regulations in the siting, design, construction, operation, and decommissioning/closing of a LLRM repository, the probability of a retrievability operation required due to repository failure is very low, but the related cost is significant. Accordingly, any attempt to promote and prescribe a retrievability requirement with reference to its ability to enhance the long-term, safe performance of a LLRM repository:

- Is scientifically unfounded and unjustified;
- Invokes considerable unfair financial obligations on the current generation; and
- Is counterproductive to achieving public acceptance of the deep geological repository concept and public confidence/trust in national and international radioactive waste management organizations.

As follows, in terms of physical safety, there is no apparent benefit in a pre-installed retrieval system. Specifically, the author's answer to step 1 of the Rotary International Organization's four-way test is:

> *It is not true that retrievability will improve the safe, long-term performance of a LLRM repository.*

Concerning steps 2 through 4 of the Rotary International Organization's four-way test, unquestionably, there are ethical, moral, and social responsibilities, as well as financial justifications, for recovering LLRM from a repository in the future. Although this generation is ethically and morally responsible for the safe disposal of its LLRM (e.g.,1,2,11,12), it must recognize that much of the LLRM considered for disposal today contains constituents whose existence is either limited or has considerable residual energy or economic value. Consequently, this generation must not deprive future generations of the option to recover the emplaced LLRM to:

- Treat it;
- Reuse it;
- Minimize its volume; and/or
- Employ alternate disposal methods/systems for it.

It should be noted that the above justifications pertain to the options provided to future generations to recover the LLRM for use, or to select a higher level of human and environmental radiation protection than that provided today, and do not relate to or enhance physical safety. Indeed, the fundamental global obligation of this generation, agreed upon in international guidance documents (2) and conventions (1), is to provide and implement a safe LLRM disposition solution that provides future generations a level of safety commensurate with that of this generation, but does not preclude future generations the freedom to access the emplaced LLRM. This obligation is normally provided for in current national laws and regulations. As follows, the decision for and the design, execution, risks, and cost of any future retrievability effort should be left to the affected generation to ensure that it is given the same globally manifested option. Specifically, the current generation must not preclude future generations the option to retrieve any emplaced LLRM. For the present, the primary responsibility of this generation is to select a suitable site and design, develop, operate, and decommission a safe, publicly acceptable repository for LLRM. Thus, the resulting conclusions relative to the four-step Rotary International Organization's four-way test are that a requirement for retrievability by this generation:

- Will not contribute to post-closure physical safety!
- Is not fair to all concerned!
- Will not build goodwill and better friendships!
- Is not beneficial to all concerned!

A requirement for retrievability does, however, convey a subtle, but incorrect message that this generation does not have the ability to design and decommission a safe LLRM repository and/or does not have confidence in its ability to project the post-closure performance of a deep geological repository for LLRM. As demonstrated to a broad range of stakeholders and the cognizant regulator at WIPP, this is clearly not the case.

CONCLUSIONS

Based on the above discussion, the author's main conclusions are:

1. Both retrievability and recoverability are technically feasible concepts.
2. Neither retrievability nor recoverability contributes to the safe long-term performance of a LLRM repository.
3. The fundamental differences between the retrievability and recoverability concepts, as defined in this paper, are poorly understood. The concepts, their respective goals and objectives, and applicable time frames must be clearly defined to remedy this problem.
4. Whereas the recoverability concept conveys a positive public message, the retrievability concept, as defined in this paper, conveys an incorrect negative public message that this generation cannot design and/or is uncertain about its ability to project the long-term safety of a LLRM repository.
5. A clear distinction needs to be made between the retrievability and recoverability concepts to avoid misunderstandings, misrepresentations, and loss of an already fragile public confidence in (a) the credibility of the radioactive waste management community; and (b) the feasibility of deep geological disposal of LLRM.

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FOOTNOTES

a. For the purpose of this paper, LLRM mean materials/wastes containing radioactive constituents requiring more than 300 years of containment and isolation from the general public to be rendered "harmless", i.e., be below the related regulatory concern.

b. Pursuant to applicable law(11), TRUW destined for WIPP must be defense-related and contain at least 3,700 becquerels (100 nanocuries) of alpha-emitting, transuranic (atomic weight/number greater than ^{92}uranium) isotopes with half-lives greater than 20 years, per gram of waste, but the canister surface dose rate may not exceed 10 sieverts per hour (Sv/h) (1,000 rems/h). There are two categories of TRUW: 1) contact handled (CH) that may have a maximum canister surface dose rate of 0.002 Sv/h (0.2 rem/h) and 2) remote handled (RH) that may have a canister surface dose rate between 0.002 Sv/h and 10 Sv/h.