Hindawi
Journal of Energy
Volume 2018, Article ID 7546158, 8 pages
https://doi.org/10.1155/2018/7546158

Research Article

Public Acceptance as a Driver for Repository Design

Ian G. McKinley,[1] Sumio Masuda,[2] Susie M. L. Hardie,[3] Hiroyuki Umeki,[4] Morimasa Naito,[5] and Hiroyasu Takase[6]

[1] *McKinley Consulting, Oberer Rainweg 15, 5070 Frick, Switzerland*
[2] *Nuclear Safety Research Association, 5-18-1 Shinbashi, Minato-ku, Tokyo 105-0004, Japan*
[3] *Intera Incorporated, Swiss Branch, Hardstrasse 73, 5430 Wettingen, Switzerland*
[4] *Japan Atomic Energy Agency (JAEA), 4-33 Muramatsu, Tokai-mura, Ibaraki 319-1194, Japan and now at Nuclear Waste Management Organization of Japan (NUMO), Mita NN Building, 4-1-23 Shiba, Minato-ku, Tokyo 108-0014, Japan*
[5] *Japan Atomic Energy Agency (JAEA), Geological Disposal Research and Development Department, 4-33 Muramatsu, Tokai-mura, Ibaraki 319-1194, Japan*
[6] *QJ Science Ltd., Queens Tower A 8-801, 2-3-1 Minatomirai, Nishi-ku, Yokohama 220-6007, Japan*

Correspondence should be addressed to Ian G. McKinley; ian@mckinleyconsulting.ch

Received 7 March 2018; Revised 18 April 2018; Accepted 12 June 2018; Published 24 July 2018

Academic Editor: Simone Bastianoni

The Japanese geological disposal programme for radioactive waste is based on a volunteering approach to siting, which places particular emphasis on the need for public acceptance. This, as established in law, emphasises the development of a repository project as a partnership with local communities and involves stakeholders in important decisions associated with key milestones in the selection of repository sites and subsequent construction, operation, and closure. To date, however, repository concept development has proceeded in a more traditional manner, focusing particularly on ease of developing a post-closure safety case. In the current project, we have attempted to go further by assessing what requirements stakeholders would place on a repository and assessing how these could be used to rethink repository designs so that they meet the desires of the public without compromising critical operational or long-term safety.

1. Introduction

Since it is impossible to simulate geological disposal on anything close to relevant spatial and temporal scales, the performance assessment approach has been developed and used since the 1970s in order to develop and evaluate geological disposal concepts (e.g., [1–3]). Performance assessment requires knowledge of a diverse range of scientific and technological fields, based on earth sciences, engineering, chemistry/materials science, and mathematical modelling, extending to more exotic areas like extremophile microbiology, archaeology, and forecasting human sociopolitical evolution (to the extent that this is possible). Such performance assessment provides an overview of concepts for geological disposal [4–6] and their associated safety cases to a small number of experts, although, even here, the exponentially expanding knowledge base has forced increasing reliance on a further level of abstraction provided by advanced knowledge management tools (e.g., [7]). Such advances to facilitate understanding of complex solutions to the management of radioactive waste by experts contrasts with the lack of progress in educating nonexperts and involving them in the dialogue that is essential to the implementation of repository projects in many countries, including Japan.

A fundamental reason may be the fact that the concept of geological disposal is inherently “invisible” and therefore nonexperts are currently presented with an array of scientific and technical data that provide them with little understanding of the associated safety case. An analogy here is trying to explain a Beethoven symphony by presenting the general public with an orchestral musical score—which may be completely transparent to an experienced conductor but opaque to lesser mortals, even though the fundamentals are clear when they listen to the music being performed. Our

Table 1: Requirements on a repository identified by a “voice of the market” survey of Japanese stakeholders (e.g., from [15]).

Geological disposal safety should be visible	Radiation and its effects should be visible
	Phenomenon occurring underground should be visible
	Future conditions should continue to be monitored
Reversibility and retrievability should be ensured	Reversibility of the disposal business should be preserved
	Waste retrievability should be ensured
	Repairing action should be adaptable in the event of radioactive material leakage

challenge is thus to enhance public understanding of the safety of nuclear waste disposal concepts, even in a country on the Pacific “Ring of Fire” like Japan, by introducing “visible” components or functions into the visitor centres that will be present at, or even directly incorporated into, the incredibly robust repository designs that have been developed.

2. Background

Deep geological repositories for the more toxic radioactive wastes—high-level waste (HLW) from reprocessing and spent fuel (SF) if it is directly disposed of—are predominantly based on concepts developed in the 1970s and ‘80s. For the case of wet host rocks (i.e., excluding salt or disposal above the water table), multibarrier concepts have been developed that focus on ease of making a post-closure safety case (e.g., [1–3]).

Over the last couple of decades, as some repository projects move closer to implementation, increasing focus has been placed on practicality of construction and operation, quality assurance of the as-emplaced engineered barrier system (EBS), and safety of operation. Indeed, following the accident at Fukushima Daiichi (termed “1F” in Japan), this last aspect has been a special concern in Japan, leading to designs of “resilient” repositories [8, 9]. Although these may look novel, emphasis is still very much on ensuring post-closure safety using well-established EBS materials—especially steel, bentonite, and concrete [10].

Since the beginning of the 21st century, in recognition of the key role of public acceptance, the original nomination approach to repository siting has been increasingly replaced with one based on volunteering [11–13]. This immediately had an impact on repository design and, thus, instead of starting from an established reference concept prior to siting, in some countries a catalogue of concepts has been developed to allow designs to be tailored to the geological conditions found at volunteer sites [14]. This is particularly important for countries like Japan, characterised by a great diversity of potentially acceptable geological settings. Such catalogues may include a wide range of options for different EBS components but, again, these are clearly based on repository designs that were established in the past.

In Japan, the volunteering process was initiated over a decade ago but, as yet, no volunteers have come forward. Indeed, following 1F, public fear of radiation [16, 17] and distrust of the nuclear industry [18, 19] have increased markedly, making it even more difficult to convince municipalities that volunteering would not expose them to health risks. In such a sociopolitical environment, establishing dialogue with stakeholders and showing willingness to address their concerns is particularly important. Such willingness should include an openness to rethink established ideas and consider completely new approaches to repository design.

3. Stakeholder Requirements

Although repository implementers and regulators rightly focus on the need to ensure post-closure safety for periods of hundreds of thousands or even millions of years, nontechnical stakeholders tend to be concerned about safety over much shorter periods—decades or centuries. Although the timescale is shorter, the requirements in terms of demonstrating safety may be much trickier. In the technical radwaste community, consensus has developed that the case to show long-term safety can be based predominantly on the results of mathematical models, which extrapolate established knowledge over required periods. This is not convincing to the general public, however, who would like a much clearer, more visceral demonstration of safety—including extensive monitoring or even inspectability—in addition to assurance of ease of retrieval/recovery in the event that something goes wrong (some key requirements based on a survey of Japanese stakeholders are summarised in Table 1).

Concepts that meet such monitoring/inspectability requirements have—at least to some extent—been proposed in the past (e.g., [20]), but it is difficult to backengineer such functionality into conventional designs. This is predominantly because inspectable options like CARE [21, 22], involving emplacement of massive multipurpose canisters (“MPCs” for transport-storage-disposal) in caverns, are intended to remain open for an extended period of time—potentially a couple of hundred years—during which retrieval is straightforward and almost any form of monitoring can be included (e.g., leak identification if casks are filled with an easily detected inert gas). This contrasts with traditional disposal in small tunnels, where buffer/backfill is emplaced along with the waste packages and any form of monitoring is technically problematic—either subject to degradation within the bentonite or risking compromising the performance of the EBS.

During the CARE extended storage period, it is even possible to inspect waste in the caverns as the MPC casks used are self-shielding and such inspection—even by visitors—is carried out regularly in equivalent surface stores

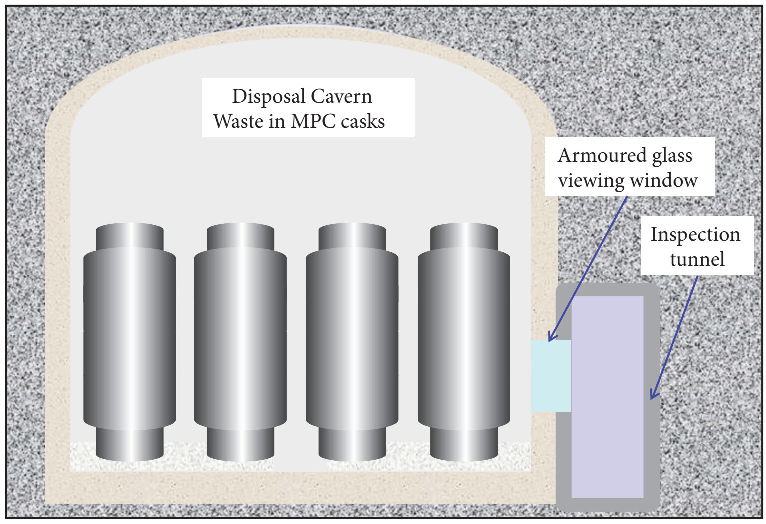


Figure 1: Variant of CARE concept allowing inspection during storage phase.

(e.g., http://www.zwilag.ch/). In a deep repository, allowing visitors into underground workings could be problematic. However, based on experience with other nuclear facilities (e.g., http://www.jnfl.co.jp/en/business/hlw/), viewing disposal caverns would be possible from a separate gallery (Figure 1), which might be accessed from a nearby underground research laboratory (URL) and thus have a completely independent entry control system.

This does, however, raise the interesting question of how much of a repository needs to be inspectable. As discussed in a workshop that included both technical experts and nontechnical stakeholder groups, this could range from a full-scale simulated repository at a site-specific URL to a part of the repository specifically designed for inspectability and monitoring (e.g., like the "pilot repository" concept in Switzerland, https://www.ensi.ch/en/waste-disposal/deep-geological-repository/), to a partly inspectable and a partly remotely monitored repository or to a fully inspectable repository. This would need to be agreed with local stakeholders, but it seems prudent to assess a spectrum of options that covers all potential requirements.

An inherent problem that arises with extended storage options like CARE is that, during the open phase, they require continual supervision with maintenance and refurbishment as and when required. They are also inherently more vulnerable to perturbations than the normal, immediately infilled designs—especially in weaker host rocks. Indeed, there is the need to consider scenarios assuming some form of perturbation that causes the repository to lose all services for an extended period of time—or even be abandoned—due to some natural (e.g., flooding) or anthropogenic catastrophe (e.g., civil unrest or regional warfare). Ensuring safety for the CARE option in such a case is very difficult, although resilient variants have been developed to reduce such concerns [8, 9].

In addition, some stakeholders have noted the desire to maintain monitoring or even inspectability after closure. Here the CARE concept offers no benefit compared to other designs.

4. Reconciling Apparently Contradictory Requirements

On the basis of repository concepts considered to date, the requirements to close the disposal zones as quickly as possible (for safety and tunnel stability reasons) and to maintain extensive monitoring and, potentially, inspectability are inherently contradictory. Nevertheless, identifying such contradictions is the key to the "TIPS" process (explained in [8, 9]), which has often been used in Japan to facilitate lateral thinking leading to development of solutions that resolve such conflicts. Here it has to be realised that the original concepts were developed four decades ago when constraints in terms of technology and materials understanding were much more severe than at present.

To illustrate this principle, the option of infilling a CARE-type cavern with a transparent resin instead of conventional bentonite could be considered (Figure 2). Resin technology is advancing rapidly and, for example, tough, transparent silicones are now commercially available which are stable, plastic, and relatively radiation resistant. Although further assessment is required to identify formulations that would meet all requirements, followed by confirmation testing, there appears to be no fundamental constraint on this concept. Indeed, if an inorganic scintillator is added, such a resin could additionally "visualise radiation," allowing not only waste packages to be inspected, but any leakage of radiation to be readily identified. Although this application is novel, both resins for waste conditioning and scintillators for radiation detection have been used for many decades.

For this option, monitoring could be remote via robust video cameras or potentially combined with a number of noninvasive geophysical techniques, and it could actually

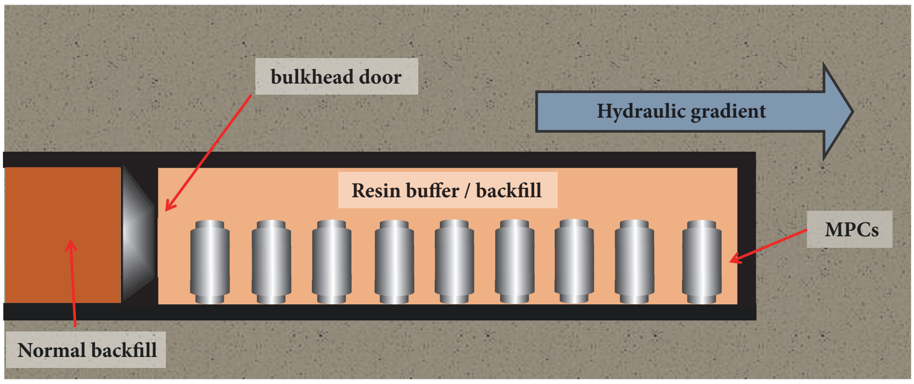


Figure 2: CARE variant infilled with resin.

include visitor inspection if access via the URL is maintained even after closure of part, or all, of the main repository. With appropriate maintenance, there is no fundamental time limit to the time that such access could be maintained, or special technical problems with sealing it after stakeholders decide that closure is acceptable. It is notable that such an option would require large volumes of resin, which may be expensive compared to other backfill options. As already noted in CARE studies, however, the large casks could be laid on their sides and surrounded by high quality buffer, while remaining void space is infilled with a cheaper backfill (e.g., crushed rock). This option would, nevertheless, allow the viewing tunnels to be used to inspect the caverns and ensure that the casks are intact for as long as considered necessary (Figure 3).

Although such a backfill resolves conflicts between early infilling and ease of inspection, it has to be ensured that long-term post-closure safety has not been compromised. In current safety cases in Japan, the bentonite buffer has two key roles, protection of the overpack containing HLW so that lifetimes of >10^3 years can be guaranteed and, to act as a colloid filter after overpack failure [23–25], so that solubility limits can be applied to some important radionuclides. A tailored resin may be able to equal, or even surpass, the performance of bentonite in the former role as it is effectively impermeable. However, if degradation is more rapid than expected or if some form of fracturing may occur in the future, ensuring colloid filtration would be difficult. Biodegradation of resin may also result in complexants that increase solubility and decrease sorption of some key radionuclides

The basic principle of the longevity of resins can be illustrated by their natural analogue—amber—which can be shown to protect even delicate organic structures over timescales of many millions of years (Figure 4). This is consistent with the very low microbial activity levels found in hyperoligotrophic environments, of the type expected in suitable deep geological settings.

Nevertheless, if uncertainties in the long-term barrier properties of resin cannot be resolved, a variant may be to combine bentonite and resins, based on a prefabricated EBS module (PEM) concept [26]. This could be implemented for the MPC option as indicated in Figure 5. Such an option would of course allow only the exterior of the PEM handling shell to be inspected and may be acceptable, especially if scintillator in the resin could indicate if there was any loss of complete containment.

In all cases, infilling will inevitably make retrieval of waste packages more difficult. Retrieval from a cavern would be easier than from tunnels (due to greater clearances) and, indeed, if retrieval was driven by an observed anomaly, it may even be possible to retrieve an individual waste package. Techniques have already been demonstrated for excavation of conventional backfills and there would be no fundamental problems associated with removal of resin.

5. Integrating Inspectability with Resilience

As previously noted, resilience in the event of operational perturbations has already been a topic for advanced disposal concept development. The resultant designs included variants on the CARE concept that provide more defence in depth for some of the more serious perturbation scenarios, but still require an extended period of open storage to allow decay of radiogenic heat, plus more exotic options that allow compact emplacement to be combined with early closure. An example of the former, which replaces the large CARE storage casks with smaller PEMs (prefabricated EBS modules in which waste within an overpack and an annulus of buffer is contained within a thin handling shell), is shown in Figure 6.

This variant includes a number of HLW packages in the overpack within each PEM (e.g., 6) but still does not have as high an emplacement density as the standard CARE casks (up to 21 packages per cask). The required cavern space would be greater but, as the thermal loading is less, it would be possible to close the caverns earlier for this option and, as the buffer is already included in the PEM, backfilling could be a much simpler option in the event that it needed to be done rapidly (e.g., as a result of a perturbation of some kind). Both a viewing gallery and backfilling with resin can be directly included into this basic concept as above for the previous CARE case.

A more radical option includes high-density emplacement within a cavern that uses a system of heat pipes/heat

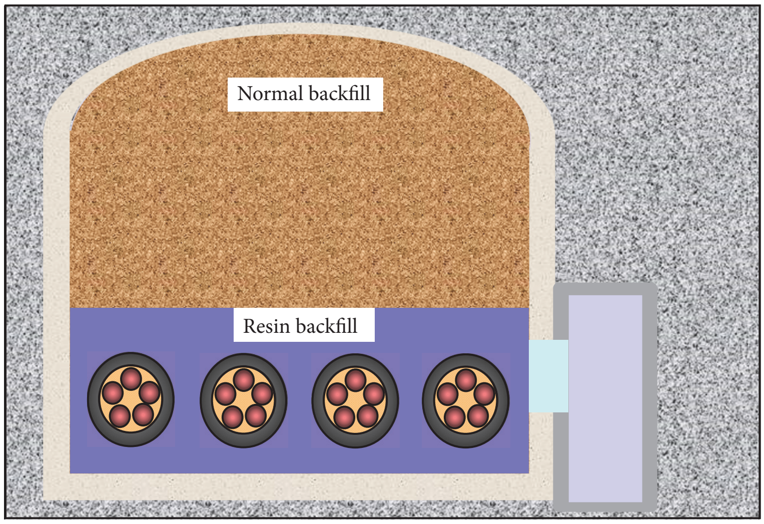


Figure 3: Optimised CARE cavern backfilling option.

Figure 4: Example of insect preserved in amber for millions of years (image https://commons.wikimedia.org/wiki/File:Ambre_Dominique_Moustique.jpg).

pumps to allow the cavern to be closed immediately after waste emplacement. This design features "mini-PEMs" (again containing both buffer and steel overpack), which are emplaced into pits in a large steel monolith, similar in concept to the HLW storage facility at JNFL Rokkasho (Figure 7).

The heat pumps allow heat to be actively harvested from the cavern, even after it is closed, based on well-established and commercially available technology. An additional system of heat pipes would allow heat to be spread passively into the surrounding rock to keep maximum temperature within specific limits, even in the event of loss of active heat management (discussed further [9]). The heat pipes would also limit near-field temperatures after closure, although their effective lifetimes would be limited. For the vitrified HLW considered here, however, the period of greatest concern lasts for only a few decades after closure and thus gradual loss of performance over a century or so would not have a great impact. Although such mini-PEMs are inherently less easy to inspect, the steel pit caps of the reference design could be replaced with glass or Perspex allowing the contents of pits to be inspected until the entire cavern is backfilled. Again, both pits and the lower part of the cavern can be infilled with transparent resin (and scintillator, if desired), to allow inspectability to be extended as long as required.

6. Safety Case and Environmental Impact

In-tunnel repository concepts require excavation of a huge number of small diameter tunnels: for the reference Japanese HLW inventory of 40,000 waste packages the total length would be in the order of 200 km. With such extensive excavation together with parallel construction and operation over a period of about 40 years, this will inevitably lead to conventional safety risks even if tunnels are backfilled and sealed as soon as possible after waste is emplaced. Higher density emplacement in large caverns significantly reduces the total length of excavations (typically by a factor of 10–20 or more) and allows more sophisticated shoring options to be included, thus potentially reducing conventional risks.

Cavern options tend to have more resilience than tunnel disposal due to the large space available, which makes waste handling much easier and, in the event of perturbations, provides more clearance to facilitate recovery, especially if using teleoperated technology. Incorporation of a high quality cavern liner and a bulkhead door capable of withstanding flooding at full hydrostatic head would also contribute to greatly decreasing the risk of operational perturbations (discussed further in [8, 9]).

By taking a more realistic approach to assessing HLW overpack (or MPC) longevity, it is quite likely that, for a suitable site, complete containment can be ensured for tens of thousands of years and an average lifetime would lie in the order of 10^5 y or more (e.g., [27]). Under such circumstances the requirements on the buffer are relatively low. Nevertheless, an improved knowledge base would be required to serve as the basis for assessing the impact of a resin buffer/backfill on radionuclide release and transport. Of course, if a design incorporating both bentonite and resin is considered, this may be less problematic as long as it can

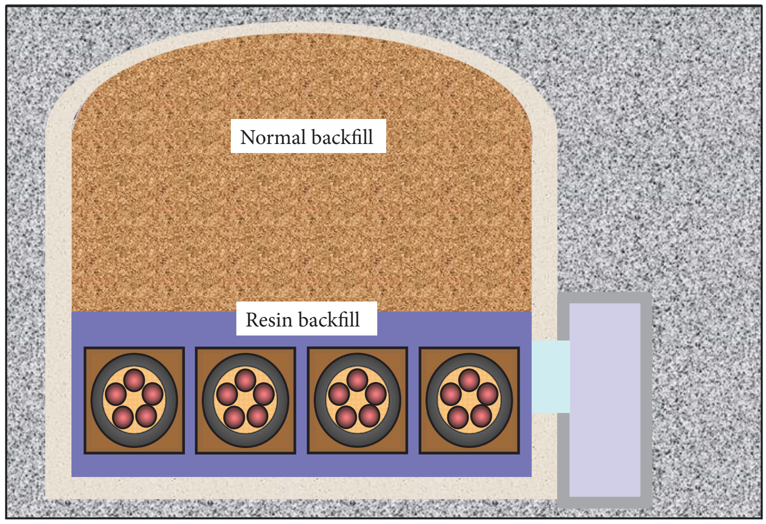


FIGURE 5: MPCs enclosed in prefabricated modules containing compacted bentonite buffer.

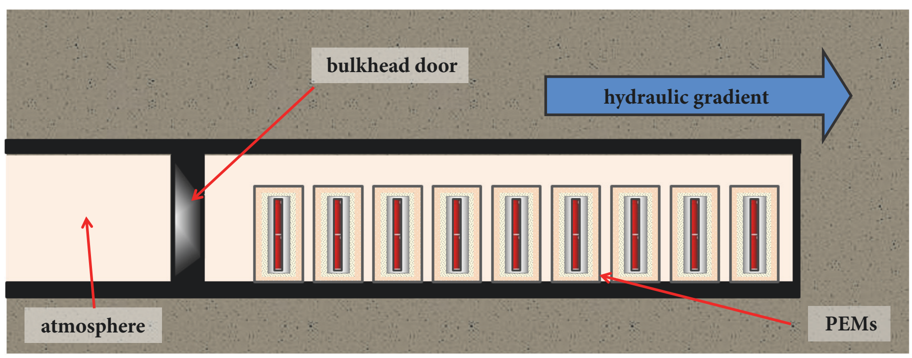


FIGURE 6: Cavern emplacement variant using PEMs.

be demonstrated that the resin degradation products do not reduce bentonite performance.

The lower total excavated volume of caverns would reduce the environmental impact (and cost) of repository construction. Heat management via an extended open period would also allow the repository footprint to be reduced, although the longer operational period would inevitably have associated costs. The costs/environmental impact of replacing a bentonite-based buffer/backfill with a resin have not been assessed as yet. The steel monolith design would probably increase the quantity of steel used per waste package, but the impact could be reduced by utilising recycled nuclear steel from power plant decommissioning. The larger quantity of steel would, additionally, provide benefits in terms of maintaining a redox trap for radionuclides for longer periods of time.

7. Overview and Future Perspective

This paper provides a new perspective on the repository design process resulting from the particular boundary conditions of the Japanese programme. However, as stakeholder acceptance becomes an increasingly important issue in other national programmes, we expect similar initiatives to arise elsewhere. Despite the clear organisational inertia which resists departing from the long-established conventional designs, it seems clear that viewing the design process from a new perspective, with special consideration of the huge advances in science and technology over recent decades, may allow development of novel concepts that not only meet stakeholder wishes but also provide benefits in terms of both pre and post-closure safety.

It is emphasised that the present study only illustrates principles and, to assess practicality and the pros and cons compared to more traditional options, site-specific boundary conditions would need to be taken into account. Although much of this assessment would be technical, stakeholders could be actively involved in the key area of weighting different requirements, particularly those associated with socio-economic or environmental impacts and the ethical aspects of balancing near-term risks with those occurring only in the distant future.

If such ideas are taken further, supporting R&D will be needed to bring system understanding up to the level of conventional designs and confirm that the benefits noted can be ensured without any compromise in terms of safety. If

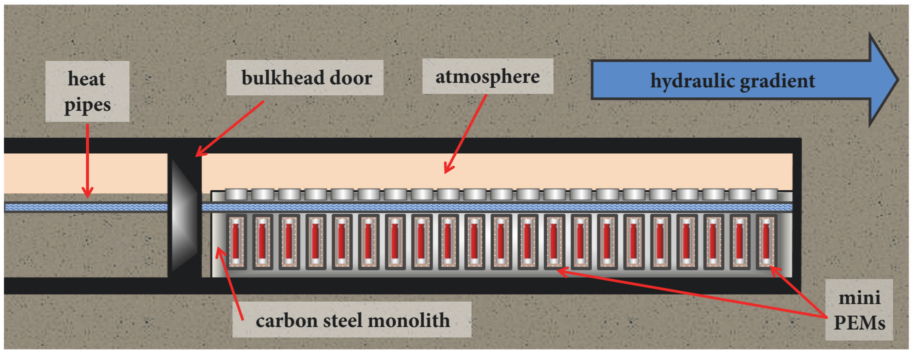


Figure 7: In-cavern monolith.

there is wider interest, however, this could well be a topic particularly suited to international collaboration.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

Acknowledgments

This study was partly performed as a part of "the Project for Validating Assessment Methodology in a Geological Disposal System," funded by the Ministry of Economy, Trade, and Industry of Japan.

References

[1] SKBF/KBS, *Final storage of spent nuclear fuel – KBS-3, 1 General*, Svensk Kärnbränsleförsörjning AB, 1983.

[2] Nagra, *Project Gewähr 1985, Feasibility and Safety Studies for Final Disposal of Radioactive Wastes in Switzerland*, NGB 85-01, 1985.

[3] PNC, "Research and Development on Geological Disposal of High-Level Radioactive Waste: First Progress Report (H3)," PNC TN 1410 93-059, 1993.

[4] H. Umeki, "Key Aspects of the H12 Safety Case," *Materials Research Society - Proceedings*, vol. 663, 2000.

[5] D. Mallants, J. Marivoet, and X. Sillen, "Performance assessment of the disposal of vitrified high-level waste in a clay layer," *Journal of Nuclear Materials*, vol. 298, no. 1-2, pp. 125–135, 2001.

[6] J. W. Schneider, L. Johnson, P. Zuidema et al., "Deterministic and Probabilistic Analysis Supporting the Safety Case for a Proposed Deep Geological Repository in Opalinus Clay in Northern Switzerland," in *Probabilistic Safety Assessment and Management*, C. Spitzer, U. Schmocker, and V. N. Dang, Eds., Springer, London, 2004.

[7] H. Makino, K. Hioki, H. Umeki, H. Takase, and I. G. McKinley, "Knowledge management for radioactive waste disposal: moving from theory to practice," *International Journal of Nuclear Knowledge Management*, vol. 5, no. 1, p. 93, 2011.

[8] H. Umeki, I. G. McKinley, A. Honda et al., "Introducing resilience into geological disposal concepts," *Nuclear Engineering International*, pp. 24–26, 2015.

[9] H. Umeki, H. Fujihara, and I. G. McKinley, "Developing resilient concepts for geological disposal of waste in Japan," *Proceedings of Global*, 2015.

[10] I. G. McKinley, W. Russell Alexander, and P. C. Blaser, "Development of geological disposal concepts," *Radioactivity in the Environment*, vol. 9, pp. 41–76, 2007.

[11] D. Easterling and H. Kunreuther, "The Dilemma of Siting a High-Level Nuclear Waste Repository," in *Studies in Risk and Uncertainty*, H. Kunreuther, Ed., p. 286, Boston Kluwer Academic Publishers, 1995.

[12] H. Umeki, S. Masuda, and I. G. McKinley, "Advanced repository concepts required for NUMOs volunteering approach to site selection," *Proceedings of Global*, pp. 262–267, 2003.

[13] K. Kitayama, H. Umeki, H. Ueda, I. G. McKinley, and K. Kaku, "A structured approach for stepwise tailoring of repository concepts to volunteer sites," in *Proceedings of the 10th International Conference on Environmental Remediation and Radioactive Waste Management, ICEM'05*, pp. 1698–1702, gbr, September 2005.

[14] NUMO, "Development of Repository Concepts for Volunteer Siting Environments," NUMO-TR-04-03, 2004.

[15] Geological Disposal Technology Working Group, "Public comments on draft "Summary of Criteria for Nationwide Scientific Screening by the Geological Disposal Technology Working Group"," Reference material #3, 29th working group meeting (in Japanese), 18 October, 2016.

[16] P. Slovic, J. H. Flynn, and M. Layman, "Perceived risk, trust, and the politics of nuclear waste," *Science*, vol. 254, no. 5038, pp. 1603–1607, 1991.

[17] W. A. Gamson and A. Modigliani, "Media Discourse and Public Opinion on Nuclear Power: A Constructionist Approach," *American Journal of Sociology*, vol. 95, no. 1, pp. 1–37, 1989.

[18] E. J. Bromet, "Emotional consequences of nuclear power plant disasters," *Health Physics Journal*, vol. 106, no. 2, pp. 206–210, 2014.

[19] B. Richardson, J. Sorensen, and E. J. Soderstrom, "Explaining the Social and Psychological Impacts of a Nuclear Power Plant Accident," *Journal of Applied Social Psychology*, vol. 17, no. 1, pp. 16–36, 1987.

[20] R. P. Rechard and M. D. Voegele, "Evolution of repository and waste package designs for Yucca Mountain disposal system for spent nuclear fuel and high-level radioactive waste," *Reliability Engineering & System Safety*, vol. 122, pp. 53–73, 2014.

[21] S. Masuda, H. Umeki, I. McKinley, and H. Kawamura, "Management with CARE," *Nuclear Engineering International*, vol. 49, no. 604, pp. 26–29, 2004.

[22] I. G. McKinley, F. B. Neall, P. A. Smith, J. M. West, and H. Kawamura, "Evolution of the Cavern-Extended Storage (CES) Concept for Flexible Management of HLW," *Materials Research Society - Proceedings*, vol. 807, 2003.

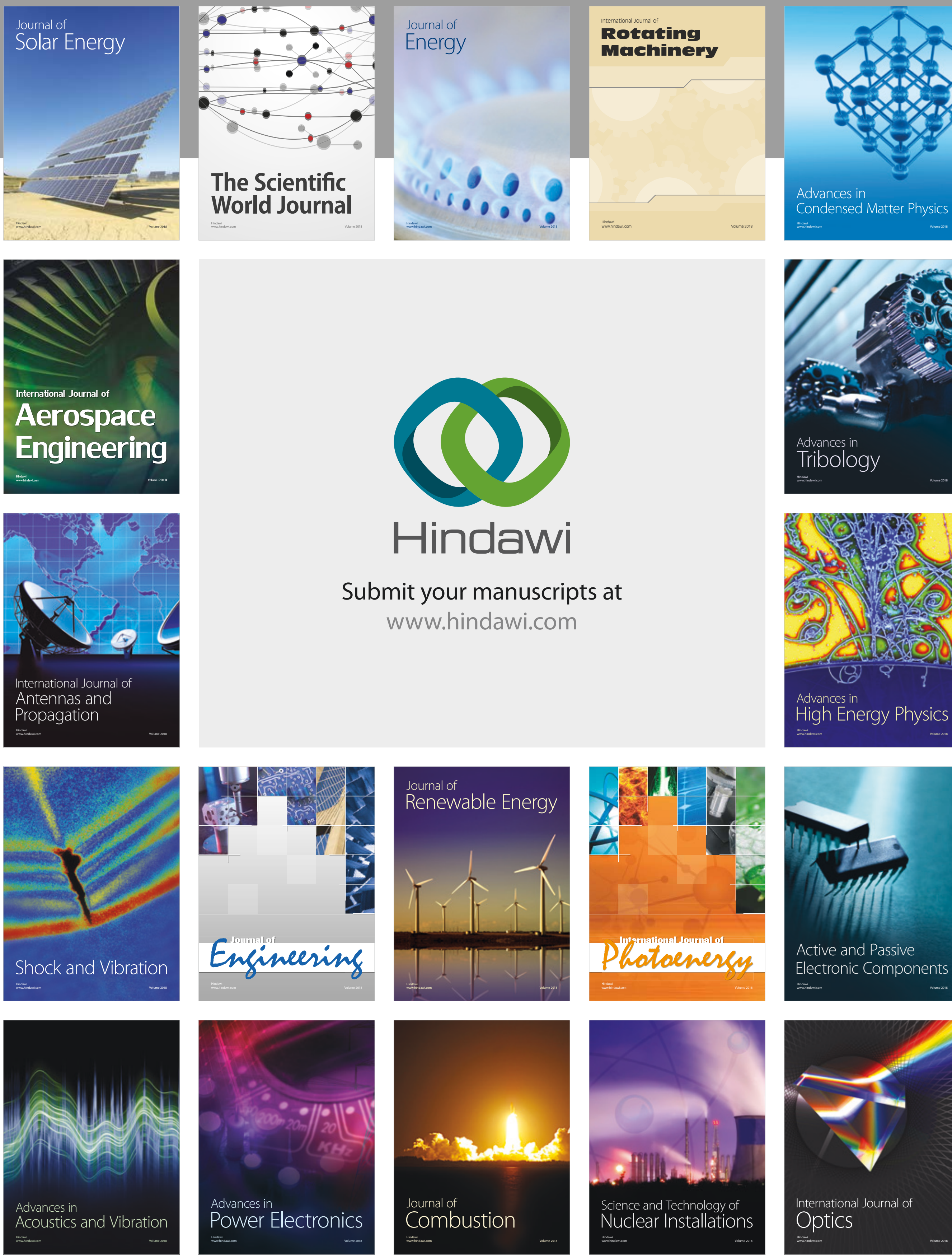
[23] A. Möri, W. R. Alexander, H. Geckeis et al., "The colloid and radionuclide retardation experiment at the Grimsel Test Site: Influence of bentonite colloids on radionuclide migration in a fractured rock," *Colloids and Surfaces A: Physicochemical and Engineering Aspects*, vol. 217, no. 1-3, pp. 33–47, 2003.

[24] S. Kurosawa, M. Yui, and H. Yoshikawa, "Experimental Study of Colloid Filtration by Compacted Bentonite," *Materials Research Society - Proceedings*, vol. 465, 1996.

[25] T. Missana, U. Alonso, N. Albarran, M. García-Gutiérrez, and J.-L. Cormenzana, "Analysis of colloids erosion from the bentonite barrier of a high level radioactive waste repository and implications in safety assessment," *Physics and Chemistry of the Earth*, vol. 36, no. 17-18, pp. 1607–1615, 2011.

[26] I. G. McKinley, M. Apted, H. Umeki et al., "Cavern disposal concepts for HLW/SF: assuring operational practicality and safety with maximum programme flexibility," in *Proceedings ESDRED workshop*, Andra, poster 06-1-06-10, 2008.

[27] I. G. McKinley, F. B. Neall, E. M. Scourse, and H. Kawamura, "What really happens to the "vanishing overpack"?" *Materials Research Society - Proceedings*, vol. 1475, 2012.


Journal of Solar Energy
The Scientific World Journal
Journal of Energy
International Journal of Rotating Machinery
Advances in Condensed Matter Physics
International Journal of Aerospace Engineering
Hindawi
Submit your manuscripts at
www.hindawi.com
Advances in Tribology
International Journal of Antennas and Propagation
Advances in High Energy Physics
Shock and Vibration
Journal of Engineering
Journal of Renewable Energy
International Journal of Photoenergy
Active and Passive Electronic Components
Advances in Acoustics and Vibration
Advances in Power Electronics
Journal of Combustion
Science and Technology of Nuclear Installations
International Journal of Optics