

FUNDAMENTAL CONSIDERATIONS ABOUT RETRIEVABILITY OF HLW FROM A DEEP GEOLOGICAL REPOSITORY

E. Biurrun, J. Lempert

Deutsche Gesellschaft zum Bau und
Betrieb von Endlagern für Abfallstoffe mbH (DBE)
Peine, Germany

ABSTRACT

In the past years retrievability of HLW and of spent nuclear fuel after their disposal in a deep geological repository is increasingly receiving attention. Fundamental technological aspects of waste retrieval from a deep geological disposal are outlined in this paper based on a comprehensive analysis of a previous study. Main tasks in analyzing the generic feasibility of waste retrieval are described as well as limiting factors. The analysis of the feasibility in principle showed that in practice limits for waste recovery stem only from the available technology.

As a contribution to the ongoing discussion the present paper analyzes the limits to retrievability from a repository not originally conceived to be easily retrievable. It focuses on a repository in a salt formation, but provides some reflections valid for granite and clay.

INTRODUCTION

In some countries waste retrievability is now a part of the set of requirements a repository must comply with, not only for HLW and spent fuel, but also for all other long-lived radioactive wastes. In a number of other countries there is a prospect that such a requirement will be introduced in the near future.

This surprising development stems more from psychological rather than technical considerations. On the one hand some discomfort is perceived by a wide portion of the general public with the perspective of building a facility seen as an irreversible disturbance of the environment, and that on the basis of incomplete knowledge. On the other hand the sheer length of the time period of waste isolation required induces reticence even in people with an otherwise positive attitude towards technology in general and nuclear power in particular. A repository concept devised and engineered so as to allow easily reversing the process of disposal, whenever in the future it is considered necessary or advantageous, is thus considered more likely to gain public acceptance.

Unfortunately, ensuring retrievability of the disposed HLW and spent fuel for a long period of time entails distinct operational hazards, and might even impair achieving the very aim of geologic disposal of permanently isolating the waste from the biosphere. A careful evaluation is necessary to ensure an optimum balance of these contradicting goals.

RETRIEVABILITY OF HLW FROM A REPOSITORY IN SALT

It is purposeful to clarify at first some potentially confusing concepts, such as reversible and retrievable disposal, widely used in the current international discussion. In its document on Strategic Areas in Radioactive Waste Management [1] the NEA-RWM Committee states that „storage“ indicates the possible intention to retrieve the waste, and “disposal” indicates the lack of such intention and a passively safe long-term solution. This is, e.g., in line with the definitions used in the German Safety Criteria for the Disposal of Radioactive Waste in a Mine [2]. In such a context terms now widely used as “retrievable disposal” seems contradictory.

In this paper retrieval is understood as the removal of the waste from its emplacement in the repository, regardless of the original intentions. Disposal is understood as the waste emplacement in a repository without a-priori intention of retrieval.

In analyzing the generic feasibility of waste retrieval the following steps are meaningful:

- To analyze whether spent fuel and HLW disposed of in a repository in a salt formation can be recovered, should the need arise, and under which conditions.
- Provided this retrieval is possible, to consider which measures, either organizational arrangements or technical features, could ease the retrieval task.
- To assess thereafter the impact of such measures and features onto the repository design with a view on its operational and long-term safety.
- To finally check whether there are some specific aspects of salt as a host rock having an influence onto the ability to retrieve the waste if considered appropriate.

In case such an influence exists, it is additionally worthwhile to know:

- Whether in view of waste retrieval the advantages of salt as a host rock outweigh eventual disadvantages.
- How a repository in salt would compare with a repository in clay or in crystalline rock.

The capability of retrieving spent fuel and HLW (here generically called HLW) from a repository in a salt formation was comprehensively analyzed in a previous study [3]. In a comprehensive system analysis on spent fuel direct disposal in a salt dome a very detailed, site-specific repository design was developed. While analyzing long-term safeguards aspects of this repository design the question arose, whether fissile material could be inadvertently retrieved from the repository after ending the active safeguards measures, i.e. after repository closure. The study conclusively showed that spent fuel retrieval, and thus fissile material diversion, would be in principle at any time possible after repository closure. But the amount of fuel accessible for retrieval appeared to be under the conditions of the study dependent upon the time after disposal to which the spent fuel is to be recovered. Furthermore, some limits to the capability of recovering the spent fuel became apparent. Their detailed analysis unveiled a strong dependency of the recovery capability from the study’s boundary conditions. Limiting factors were:

- A repository design optimized to minimize underground space requirements, i.e. with maximum host rock heating (compact repository).

- A strict compliance with all applicable regulations in regard to radiation protection and mining working conditions for manned, hands-on operation (no intervention conditions, no remotely controlled equipment).
- Exclusive use of existing mining technology, and of standard industrial equipment.

Within these boundary conditions the host rock temperature in the waste near field proved to be the factor limiting the capability of HLW retrieval. An exhaustive review of the state-of-the-art in mining technology lead to identifying 100 °C as the approximate upper rock temperature limit for retrieval. But even with the very dense repository layout assumed as reference repository in the mentioned study it would have been possible to remove a significant portion of the waste inventory at any time.

A qualitative evaluation of retrieval capability was later carried out assuming foreseeable technological further developments and limited use of special-purpose, remotely controlled machines. With this, as well as, eventually, by slightly reducing the repository thermal load density, full waste retrievability is achievable at any time after disposal. And this without trading-off operational or long term safety to facilitate retrieval. Therefore, a specific retrievability requirement seems to be unnecessary.

THE LIMITS TO HLW RECOVERY CAPABILITY

It is interesting to analyze whether above results are valid for the repository conceptual design studied only, or if they are generally valid, irrespective of design details. Eventually, the retrieval ways and means conceived during the mentioned work can be adapted, with appropriate changes, to a wide range of different situations. Moreover, it is worthwhile to analyze whether or not there are insurmountable limiting conditions to our capacity of retrieving waste from a deep geological repository, i.e. such conditions that would render HLW retrieval impossible, independently of the available ways and means.

Fundamental answers to these questions are provided by the physics of open and closed systems. The process of diluting and dispersing waste, e.g., by dumping gaseous or liquid effluents into the atmosphere or into the sea, are irreversible processes in thermodynamical sense, leading to a substantial increase of the system's entropy. Obviously, in such cases total waste recovery after discharge is impossible.

Unlike this, disposal of waste by concentration and confinement into a closed system is a reversible process in thermodynamical sense. There is no fundamental limit to total waste recovery by transferring it into another closed system, provided a discharge over the system boundaries has not taken place. Consequently, as long as the containment system - the system boundary in thermodynamical sense - remains intact, complete recovery is in principle possible. And in thermodynamical sense "containment system" does not refer to an intact waste package, but to any defined boundary or boundaries separating the volumes containing the waste from those free of radionuclides at a given time. Obviously, having the waste totally confined in the primary container - the waste package - would be a substantial asset under all circumstances. But waste containment in the near field, or in the host rock, would also suffice the thermodynamic requirements, making waste retrieval possible as a matter of principle.

FACTORS AFFECTING RETRIEVABILITY

After analyzing the feasibility in principle of waste retrieval attention can focus on the ways and means to carry out HLW recovery. By analyzing the technological constraints, still under the assumption that the repository was not designed to facilitate retrieval, features and interrelations easing or hampering waste recovery can be identified.

It is rather straightforward that a robust waste package guaranteeing complete waste containment for the time span during which retrieval could be envisaged would be an important factor affecting retrieval capability. This would be the case for most waste disposal concepts currently considered, with waste container total tightness requirements of some hundreds to some thousands of years.

The influence of the temperature field in the waste near field upon retrievability is a factor needing a dedicated analysis on a case by case basis. In most repository designs lower temperatures will reduce the requirements upon the retrieval equipment. But a high thermal load density is a key feature for ensuring long-term safety of repositories in salt or in welded tuff. A balancing of easy retrievability against improved long-term safety is needed in such cases.

With regard to mechanical stability, re-entering a drift in a high temperature environment by re-excavating the backfill in a ductile host rock like salt would entail much less hazard than in hard, brittle rock like granite. A softer, ductile rock - such properties are enhanced by higher temperatures - can accommodate much higher stress redistribution from excavation-induced rock unloading without failure than hard, brittle rocks. Moreover, the thermal stresses resulting from a given thermal load are markedly lower in softer rocks. Having account of all of this, waste retrieval from a repository in granite will be, as for salt, strongly dependent from the retrieval time and the repository concept and features. But in the tendency it would be more difficult, hazardous, and expensive than from a repository in salt.

The technical feasibility of safely retrieving HLW from a repository in clay would strongly depend upon the repository concept, as well as on the retrieval time and the then achieved degree of re-saturation of the host rock with groundwater. Keeping a repository in clay open over a longer period for easy retrieval will involve major technical difficulties, considerable costs, and high hazards. Depending upon the repository concept and the properties of the rock, re-entering a once closed and sealed repository in clay would require a paramount effort. The risks associated with possible operational accidents during retrieval could well outweigh the risk of leaving the waste in place. In any case, HLW retrieval from a repository in clay would involve the biggest technical effort, the associated hazard would be the highest of all usually considered host rocks.

In addition to the mentioned robust, durable waste package, a shielded container would be an asset for waste retrieval from any host rock, since it would allow hands-on operation and substantially reduce the need of using remote equipment. Additionally, it would considerably ease intervention, e.g., for repairing faulty machines, which is likely to become necessary while overcoming unexpected situations.

Engineering barriers in the waste package near field will have to be removed prior to retrieval. A resilient near field backfill or buffer materials, as, e.g. concrete backfill or concrete borehole plugs, would be a strong retrieval hindrance. Their removal would entail the danger of damaging the waste

package. Trouble-free accessibility to the waste near field by using an expendable backfill material, which can be mined out with simple means without damaging the waste package would be a clear advantage.

CONCLUSIONS

This paper focuses on some fundamental technological aspects of waste retrieval. A more comprehensive approach should also consider ethical aspects as practice justification, inter-generation fairness, and sustainability, as well as factors like public confidence and public acceptance. Furthermore, the operational risks for the repository staff and the public during the accessibility period, the optimum balance between operational and long-term safety, and the availability of means for repository long-term monitoring deserve careful attention.

The analysis of the feasibility in principle of waste retrieval showed that in practice limits for waste recovery stem only from the available technology. There appears to be no insurmountable constraints to retrieval capability as long as the HLW remains contained in the waste package and its near field. Technological further development of ways and means will render retrieval feasible for most repository concepts and increasingly easier with the course of time. And that assuming that the repository was not designed to facilitate HLW retrieval.

A comprehensive analysis carried out for the detailed design of a repository in salt not intended to be easily retrievable unveiled the limiting conditions for waste recovery. A later review of the study's outcome allowed to identify repository features having the highest impact onto waste retrieval feasibility. These features and their effects onto processes in the repository development were analyzed considering first salt as the host rock, and later extended to tuff, crystalline rock and clay at an outline level. The analysis provided some hints for optimizing the repository design in view of an eventual retrieval.

It seems possible in principle to totally recover the HLW from a repository in salt or crystalline rock. Such a waste retrieval will not require keeping the repository open for a long period of time, or introducing costly additional measures and features. Retrieval from a repository in clay will most likely demand a substantially bigger effort, and will entail greater hazards. A detailed study along these lines addressing the technical feasibility of retrieval from repositories in different candidate host rocks appears meaningful to substantiate the previous conclusions.

REFERENCES

- [1] Strategic Areas in Radioactive Waste Management – The Viewpoints and Work Orientations of the NEA Radioactive Waste Management Committee. Nuclear Energy Agency, 1999.
- [2] Sicherheitskriterien für die Endlagerung radioaktiver Abfälle in einem Bergwerk. Bundesanzeiger 35 (1983) Nr. 2, S.45-46.
- [3] Zur Rückholbarkeit endgelagerter Brennelemente. E. Biurrun. Deutsche Gesellschaft zum Bau und Betrieb von Endlagern für Abfallstoffe mbH (DBE) Abschlussveranstaltung Direkte Endlagerung, Forschungszentrum Karlsruhe, 7. Dezember 1995