

## THE INTERNATIONAL RETRIEVABILITY SCALE

### A DIALOGUE TOOL ON THE MANAGEMENT OF RADIOACTIVE WASTES USING GEOLOGICAL REPOSITORIES

Disposal of long-lived radioactive waste in engineered repositories, located in suitable deep underground geological formations, is being researched, developed and demonstrated as the reference solution to protect present and future generations and the environment. In some countries, actual implementation of geological repository projects is only a few years away. Reversibility implies a disposal programme that is implemented in stages and that keeps options open at each stage, and provides the capacity to manage the repository with flexibility over time under specified conditions. Retrievability is the possibility to reverse the step of waste emplacement. It is generally recognized that it is important to clarify the meaning and role of reversibility and retrievability for each country, and that provision of reversibility and retrievability must not jeopardise long-term safety. A generic Retrievability Scale has been developed that is widely applicable to most countries' programmes in order to support dialogue amongst all interested parties.

#### The mission and life-cycle stages of a geological repository

The mission of a geological repository is to provide definitive protection of humans and the environment from any hazard that the radioactive waste would pose over time. When the waste is emplaced, there is no intention to retrieve it. Also, as permanent safety is intended, it is necessary to plan for closing the repository once all the waste is disposed of. Waste storage is not an alternative to disposal; rather it is a step in the management strategy leading to final disposal.

A geological repository involves three main phases (Fig 1) whose duration varies amongst national programmes depending on design and each country's approach to decision making:

- The **pre-operational phase**: during this phase, the repository is designed, the site is selected and characterized, the man-made materials are tested and the engineering demonstrated, and the licenses for building and operation are applied for and received. A baseline of environmental conditions is also obtained
- The **operational phase**: this phase may be divided in three sub-phases:
  - ✓ The **emplacement phase**: the waste packages are emplaced while new underground galleries are also excavated. The environmental conditions are continuously monitored and compared to the baseline data. R&D continues, and the regulator

performs regular inspections for operational safety and reviews of the long-term safety case. Partial backfilling and/or sealing operations may also take place.

- ✓ The **observation phase**: after all waste packages are emplaced, it might be decided to monitor parts of the repository and to keep some accessibility to at least part of the waste while additional performance confirmation takes place.
- ✓ The **closure phase**: access from surface to the underground facility is removed. Backfilling and sealing are performed according to design.
- The **post-operational phase**: after closure, safety is assured through the intrinsic, passive provisions of the repository design. Nevertheless, it is plausible to expect continued monitoring of the baseline environmental conditions, and some monitoring from the surface. International safeguards controls would continue to apply. Societal memory would continue, and archives and landmarks may record details of the repository or remind future generations of its existence. Loss of control and memory would only take place following major unpredictable events, such as situations of war or anarchy.

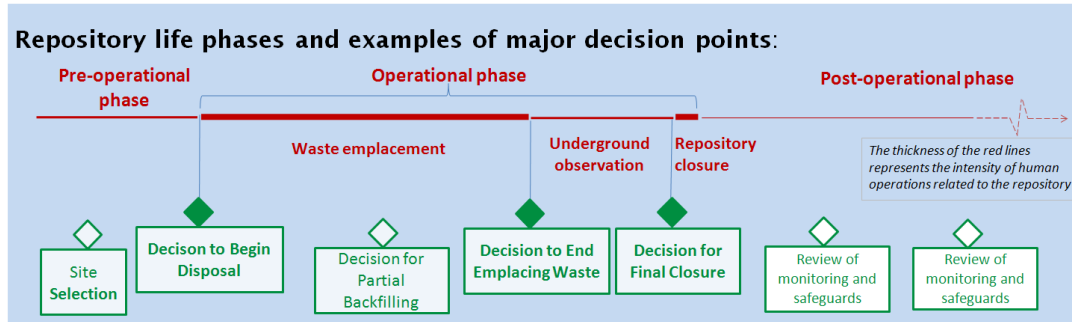


Figure 1

**Reversibility, retrievability, recoverability: what are they?**

**Reversibility** refers to decision-making during project implementation: it involves ensuring that the implementation process and technologies maintain as much flexibility as possible so that, at any stage of the programme, reversing one or a previous series of decisions may be achievable if needed (Fig. 2). Each major authorization in repository implementation (Fig 1) can be seen as a reassessment of whether the reversibility option should be exercised. A “reversible” approach to repository implementation implies some degree of retrievability.

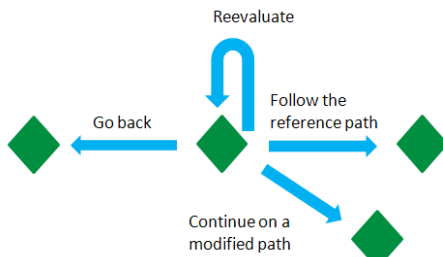


Figure 2: Reversibility of a decision

**Retrievability** is the ability to retrieve whole waste packages. Retrievability is part of the safety concept in a storage facility. Retrievability is not part of the long-term safety concept of a waste repository, as waste should never be emplaced in a repository when the long-term safety case is not robust. Retrievability provisions may help operational safety, as they provide additional flexibility for the management of an unexpected situation during operation.

Whereas retrievability refers to whole waste packages, **recoverability** refers to the waste materials *per se*: even if the package is degraded, its radioactive materials may still be recovered using appropriate techniques. If the waste materials dissolved and migrated away from their initial emplacement

location, recovery would require mining and milling techniques similar to ore extraction.

Retrieval and recovery of waste may be requested one day for reasons other than safety, e.g., if the waste were to be re-categorized as a resource. Licensing of a repository rests however on safety considerations. During the operational phase, reversibility and retrievability translate into practice a precautionary approach to waste disposal. During the post-closure period, waste recovery is facilitated by the confinement and containment design of any geological repository. Waste is practically never completely irrecoverable, albeit possibly at great effort and expense. The retrievability question is thus one of degree rather than of the presence or absence of the possibility to recover the waste. Research and development in the field of retrievability may provide avenues for lessening the degree of difficulty (Fig 3).

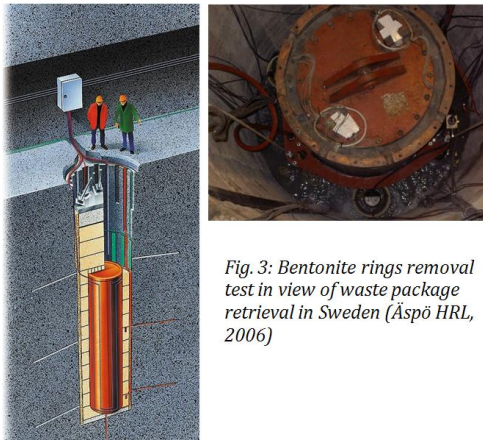


Fig. 3: Bentonite rings removal test in view of waste package retrieval in Sweden (Åspö HRL, 2006)

**A retrievability scale for stakeholder dialogue**

One of the key issues for local stakeholders considering hosting a geological disposal facility for radioactive waste is ease of waste retrieval from a repository. The ease will vary according to the accessibility of the waste during its lifecycle. A scale has been developed to illustrate qualitatively the degree and type of effort that is needed to retrieve the waste according to its

lifecycle before and after its emplacement in a repository (Table 1 and Fig 4). The scale also shows the correlation between the effort needed for retrieving the waste and the corresponding degree of passive safety of the repository. The more difficult is retrieval, the higher is the cost.

**Stages in the waste lifecycle and retrievability: a textual description**

The life cycle of waste can be reduced to 5 stages, as identified in Table 1. For each stage, the table also identifies the main elements of passive safety and active control, as well as the degree and type of retrieval effort.

**Stage 0** represents as-produced waste at its place of origin. **Stage 1** represents waste which is stabilized<sup>1</sup>, packaged and placed in an interim store. **Stage 2** is conditioned waste moved

from interim storage to a repository facility a few hundred meters deep. Passive components enclosing the waste emplacement cell are put in place in **Stage 3**: backfill (against rock disruption) and/or sealing (against water circulation). The access galleries to the cell still need active monitoring and maintenance, e.g. ventilation. These galleries are backfilled and/or sealed in **Stage 4**, which may coincide with the closure of the whole disposal zone in which the gallery is located or indeed of the whole disposal facility. At this stage monitoring or maintenance of the disposal zone (or the whole underground facility) is no

<sup>1</sup> The type of package may be a steel drum, a concrete container, a steel primary package inside a concrete or steel container, etc.

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longer necessary, but the facility may still be monitored remotely. **Stage 5** is the final disposal state. Although the integrity of the waste packages cannot be guaranteed, the waste is still confined within the facility. By this time, the level of radioactivity has

reduced or, in the case of short-lived radionuclides, has completely decayed. Safety will not depend on maintenance or monitoring. However, measures intended to ensure preserving memory of the site may continue.

**TABLE 1: Waste retrievability stages, ease of retrieval effort, and specific elements of passive safety and active controls.**

State and Location of the Waste	Ease of retrieval	Specific elements of Passive Safety	Specific elements of Active Control
0 Unconditioned waste	Direct access to waste.	Storage vessel and storage building	Active management of waste and storage facility including security controlled area
1 Packaged waste in storage	Waste package directly retrievable; the earlier conditioning steps may or may not be fully reversible	Waste form and its container	Active management of store including security controlled area
2 Package in disposal cell*	Waste package retrievable by reversing the emplacement operation	Hundreds of meters of rock Engineered disposal cell	Active management of disposal cells and disposal facility. Security controlled area
3 Package in sealed disposal cell	Waste package retrievable after underground preparations	Backfill/sealing of disposal cell	Possible monitoring of disposal cells. Active management of access ways to disposal cell seals. Security controlled area
4 Package in sealed disposal zone	Waste package retrievable after re-excavation of galleries and possibly of shafts	Backfill/sealing of access to cells	Possible monitoring of disposal cells. Detailed records and institutional controls for at least several decades, including international safeguards.
5 Waste in sealed repository	Package degraded degrading with time. Waste ultimately only recoverable by mining	Reduction in level of radioactivity. Geology and engineered-man-made barriers ensure long term confinement of the waste within the engineered underground facility.	Records preservation, regulatory oversight and international safeguards as long as possible. Specific provisions for long-term memory preservation, including site markers

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\* Depending on the national programme and on the type of waste, the waste package emplacement room may be a vault, a cell, a section, etc. The term "cell" used here is generic to all these cases.

**Stages in the waste lifecycle and retrievability: a graphical description**

The connection between retrievability and passive safety along the lifecycle of radioactive waste is represented graphically in Fig. 4. The figure is generic and can be applied to a variety of national programmes.

The duration of the waste stages and the duration of the repository life phases will depend on the decisions that will be made during the implementation of the geological facility, on the

design of the facility itself, and on the amount of waste to be emplaced in each particular nation.

As an example, the waste emplacement phase could last up to 100 years. At each decision point, various components of the decision will need to be discussed, e.g. ease of retrieval of waste packages; need for active control; changes affecting long term safety; monitoring; and costs.

REVERSIBILITY AND RETRIEVABILITY TRANSLATE INTO PRACTICE A PRECAUTIONARY APPROACH TO WASTE DISPOSAL DURING THE OPERATIONAL PHASE OF A GEOLOGICAL REPOSITORY. CONCERNING THE POST-CLOSURE PERIOD, WASTE RECOVERY IS FACILITATED BY THE CONFINEMENT AND CONTAINMENT DESIGN OF ANY GEOLOGICAL REPOSITORY. WASTE IS PRACTICALLY NEVER COMPLETELY IRRECOVERABLE, ALBEIT POSSIBLY AT GREAT EFFORT AND EXPENSE. RETRIEVABILITY IS NOT, HOWEVER, A PART OF THE LONG-TERM SAFETY CONCEPT OF GEOLOGICAL REPOSITORIES, AS THESE ARE LICENSED WITH THE UNDERSTANDING THAT SAFETY WILL RELY ON DESIGN FEATURES NOT REQUIRING FURTHER MAINTENANCE OR INTERVENTION. THE RETRIEVABILITY QUESTION IS ONE OF DEGREE RATHER THAN OF THE PRESENCE OR ABSENCE OF THE POSSIBILITY TO RECOVER THE WASTE. RESEARCH AND DEVELOPMENT MAY PROVIDE AVENUES FOR LESSENING THE DEGREE OF DIFFICULTY OF WASTE RECOVERY.

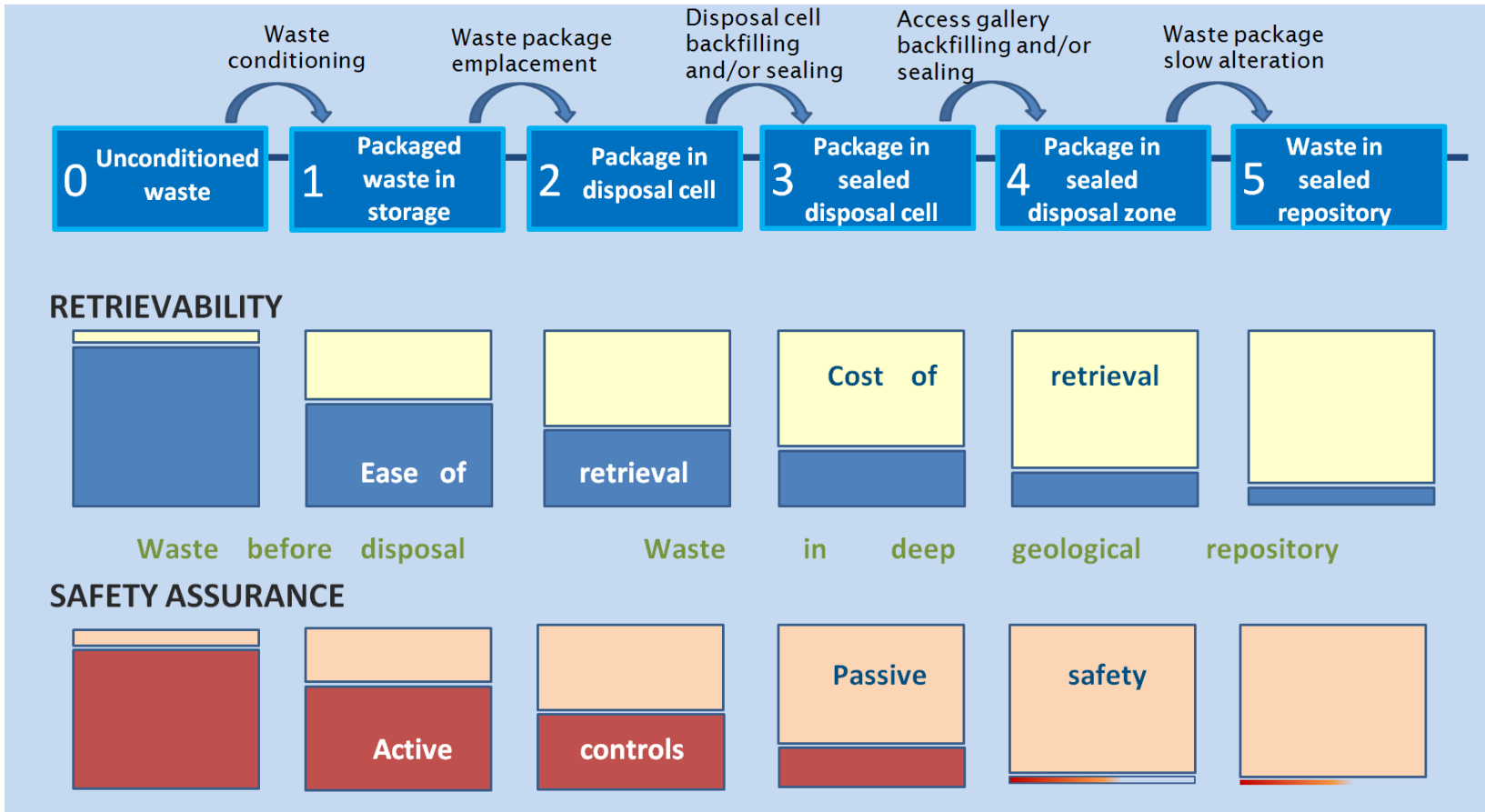


Fig.4: Lifecycle stages of the waste, retrievability, passive safety and active controls in a deep underground gallery-type repository