Reversibility and retrievability, a proposal for an international scale

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ABSTRACT

The concept of reversibility was introduced in France with the 1991 act. It was thoroughly considered through the Dossier 2005 reporting the results of the 15 years research performed in France, and then was again clearly mentioned as a specific request in the 28 June 2006 Planning Act. In the same time, reversibility and/or retrievability are being discussed in a number of countries, often considered in the the process towards reality for a geological disposal facility. Communication with stakeholders thus becomes a decisive part of the process. Andra suggests developing a Reversibility-Retrievability scale at international level, as a communication framework to describe various national approaches.

INTRODUCTION

Introduced from social demand, the issue of reversibility and retrievability of a geologic repository has been discussed at the international level for several years, in relation to stepwise decision making [1, 2, 3, 4, 5, 6, 7, 8]. It is strongly related to communication with stakeholders.
The terminology on reversibility and retrievability is not yet stabilized, as each organization involved in radioactive waste geologic disposal has to deal with its own national context. Various definitions are used, from which we use those proposed by the 2001 NEA report on Reversibility and Retrievability [6] in the present paper:

- Reversibility denotes the possibility of reversing one or a series of steps in repository planning at any stage of the program;
- Retrievability denotes the possibility of reversing the action of waste emplacement.

BACKGROUND AND PERSPECTIVE ON REVERSIBILITY & RETRIEVABILITY IN FRANCE

Historical Development

In 1991, the French Radioactive Waste Act requested the feasibility study of a deep geologic repository to include along with irreversibility consideration of a reversible approach.
During the siting phase of the French underground research laboratory (URL) in the 1992-1998 time-frame, reversibility appeared to be a significant issue for public acceptance and decision makers. At the government's request, the National Review Board (CNE) submitted a report on reversibility in June 1998. In December 1998, the French government reemphasized the need for the program to take into account reversibility.
In December 2005, Andra provided the French government with the "*Dossier 2005*" [9] that presents the results of the research work. This dossier concludes positively on the feasibility of geological deep disposal in the clay formation investigated in the Meuse / Haute-Marne underground research laboratory.
It proposes a technical response to the societal wish for reversibility, taking account of its possible motivations. A preliminary analysis of these motivations was conducted in order to propose possible suitable design features. It was emphasized that including the possibility of a reversible management does not aim at compensating in any way for potential doubts in the foundation of the safety case, which is a fundamental requirement: safety must be demonstrated prior to construction and operation. Reversibility may express ethical considerations, such as the precautionary principle, an attitude of

modesty with regard to long term time scales and relating uncertainties, and the wish to preserve the freedom of choice of later generations.

Reversibility includes in Andra's *Dossier 2005*:

- A staged disposal process that keeps the possibilities of choice open at each stage;
- The capability to manage the repository with flexibility, in particular with time;
- The retrievability of waste disposal packages (WDP), with procedures and technical means similar to emplacement in the first stages;
- The option of gradual staged closure allowing a gradual reduction of retrievability as one moves towards an increasingly passive configuration.

Design options enhancing reversibility are described in the dossier. They include:

- Modularity enabling construction in successive phases and flexible management of each repository module (Figure 1);
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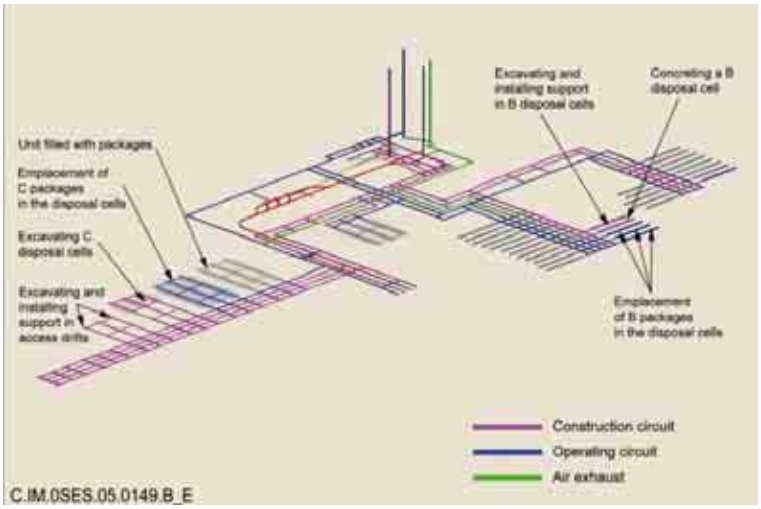

Fig.1. Modularity of the disposal process for HLW (C wastes) and ILW (B wastes) [10]

- Durable repository structures (access drifts, disposal cells, waste disposal canisters);
- Identification of successive stages for closure that can be decided with flexibility in time;
- Design options facilitating potential WDP retrieval (rock support, minimization of residual gaps around WDPs, no need for disposal cell backfilling after waste emplacement, etc.) (Figures 2 and 3);

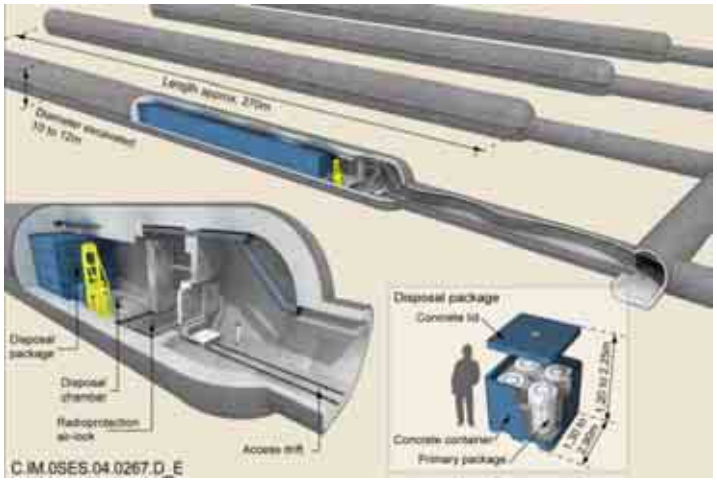

Fig.2. ILW disposal cell [10]

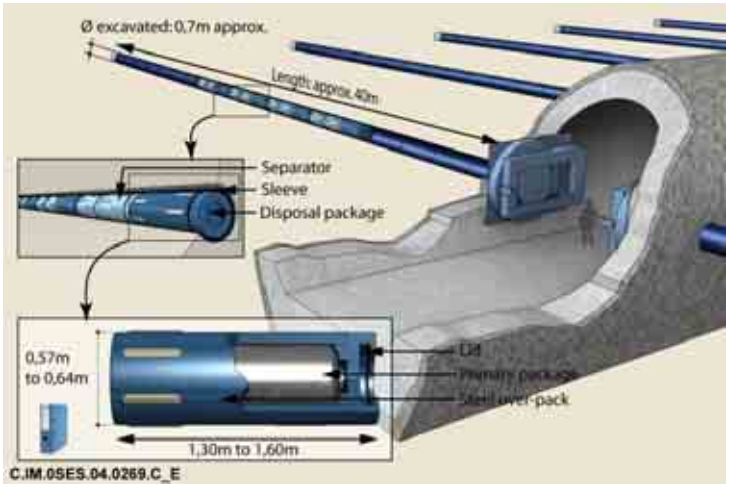

Fig.3. HLW disposal cell [1]

- Monitoring provisions to support ongoing management of the repository and the waste (representative structures monitored through the successive closure stages).

The scientific reviewers of the dossier did not contradict the reversibility objectives as presented by Andra. However, a reversibility period much higher than 100 years was judged to be not consistent with the state-of-the-art.
A national public debate on waste management was held in France in 2005-2006. It addressed reversibility among other issues. The final report issued by the Public Debate Commission indicated in particular that "Reactions and interveners questions on this subject within the framework of the public debate showed that the exchanges have to continue […], so as to share the possibilities offered by reversibility and to make this concept more concrete and accessible to the public" [11].

The new Radioactive Waste Management Planning Act, issued in 2006, imposes a reversibility approach to deep geological disposal. It states that:

- Reversibility of the repository will be provided for a period which cannot be less than 100 years.
- Interim storage and reversible geological repository are complementary.
- Andra will provide an application for the construction of a reversible repository so that it can be reviewed in 2015.
- Before a license for repository construction may be delivered, the French parliament will issue a law defining requirements regarding reversibility. This law will be issued after the license application has been reviewed by the National Review Board and the Safety Authority.
- During the licensing procedure, the government will check the consistency of the application with the future legal reversibility requirements.
- Another law will be issued prior to the final closure of the repository.

Few detailed requirements are defined by the Act as regards reversibility, and the future application for a reversible repository must be made before the French parliament has issued the new reversibility law. Thereby scientists and engineers are responsible for proposing to the nation from now to 2014 relevant options with respect to technical limits (safety, cost…).
It is also their responsibility to prepare the next phase so that, when the license is delivered, the design, building and testing of the repository may be conducted without delay before operating it in 2025. This schedule may seem far away in the future; but considering all the work to be done after the license is delivered, it is in fact relatively close. Therefore, intense dialogue with stakeholders has to be performed before application, to ensure that detailed designs will adapt easily to the final reversibility requirements, which will be specified by the future law.

The French National Program

To prepare options regarding reversibility, the main issues for the next years are to define a staged approach to the implementation of the repository with respect to cost and technical factors, to propose acceptable retrievability performances within the successive stages, and to define a decision-making process at each stage.

The work to be done as regards reversibility will be complementary to the work already done during the previous research phase. Therefore, the program from now to 2014 provides for a number of tasks relating to reversibility. Intermediate milestones were defined to help to manage the program in accordance with the National radioactive waste management plan [12].

Research, Development and Demonstration Planned

Research and development activities planned with regard to reversibility include a number of objectives to consolidate technical and scientific basis:

- Scientific data acquisition on repository material behaviour during the reversibility period;
- Field data acquisition on the host rock behavior with regard to processes occurring during the reversibility period: argillite creep, interaction between argillite and rock support, de-saturation, oxidization…
- Engineering developments to enhance the reversibility of the design options;
- Monitoring systems developments and field testing;
- Repository simulations during the reversibility period.

Reversibility related demonstration tests are also planned:

- Full scale waste handling tests above ground, made accessible to the public (normal and accidental situations; simulation of progressive aging of the structures…);
- Underground full or reduced scale tests of the construction and behaviour of repository structures.

Particular tasks are dedicated to collect and synthesize reversibility related data, to propose reversibility options and to assess reversibility performances. Safety assessment also takes the reversibility into account.

The work initiated before 2005 on the possible motivations of reversibility, in order to propose adequate solutions with respect to this social demand, will be continued and emphasized further. The objective is to understand this demand as well as possible, in order to balance it properly with technical and safety constraints. This means that studies will be carried out on social aspects, involving scientists from various fields of human sciences (sociology, economy, law science…).

A significant effort will also be dedicated to information exchange and dialogue with stakeholders. This work, focused on local public information and consultation, will obviously include discussions on reversibility.

Next Milestones of the Program

Reversibility will be part of the next milestones of the program:

- 2009: Andra will provide a first set of « reversibility options »; these options will be used as input data for the preliminary design of the repository;
- 2008-2012: Andra will have a dialogue with the local public for stepwise repository siting; reversibility will be an issue;
- 2012: Andra will provide reviewers with the scientific and technical basis of the future application; this includes preliminary designs with respect to reversibility;
- 2013: A public debate will be held on the repository project in Meuse/Haute-Marne. This will include broad discussions on reversibility options;
- 2014: Andra will include reversibility provisions in the application, taking into account feedback from public consultation; these provisions are a final proposal from the scientists to government and parliament of relevant options on staged implementation, retrievability performances, open decision-making processes, etc.

Need for a Supporting Framework

As mentioned above, Andra will have a dialogue from now to 2014 with various stakeholders to prepare socially acceptable options with respect to technical limits. In particular, the decision-making process will be an important issue.
This dialogue will be supported by the technical and scientific basis resulting from the program, and by planned demonstration tests. In addition, from the French experience of the last years, a simple framework is needed to support dialogue. It would enable a common understanding of the concepts to be discussed.

DRAFT PROPOSAL FOR A REVERSIBILITY-RETRIEVABILITY SCALE

A reversibility - retrievability scale would provide a suitable framework to support dialogue with stakeholders. Such a reversibility-retrievability scale should be easy to understand. Assessment of each level could be based on a mix of several criteria, based for example on indicators such as time to waste, availability of technology, etc.
A draft scale has been prepared. It is presented hereunder in order to show what it could be. As exchanges on this subject must continue, this project must not be considered as frozen and is submitted as a proposal for further discussion, improvement and re-formatting in order to comply with the requirements in the different countries.

Identification of Levels

In its initial version, the draft scale includes 7 levels, making it possible to analyze the whole waste management system. Therefore the proposed scale may cover interim storage stages as well as successive stages in the disposal process. The current naming of the levels hereunder aims at illustrating the evolution in the ease of return to raw waste:

- Level 7: waste is in its original state, without conditioning; return to the raw waste is obviously very easy;
- Level 6: waste is conditioned in a container, which may be a disposal or a storage container;
- Level 5: waste is in a disposal package which can be retrieved by similar means to the emplacement technology;
- Level 4: the emplacement cell is backfilled and/or sealed, but the access way to the cell remains open;
- Level 3: the access to emplacement cells is backfilled and/or sealed;
- Level 2: the repository is closed and monitored from the surface;
- Level 1: there is no longer monitoring. However, the data have been archived. Waste remains recoverable.

No level 0 is proposed, as even for a closed non-monitored repository, wastes may be recovered through mining technology.
Levels 5 to 1 are directly applicable to disposal. Levels 7 and 6 correspond to stages prior to the emplacement in the repository.
In France, the 2006 act states that interim stores and repositories play complementary roles in waste management. So it makes sense to include interim storage in the scale. In particular Level 5 would be a transient step between storage and disposal, and could be applied to both.

Characterization of the Levels

Attributes are to be defined to help to characterize each level of the proposed scale. For example, for levels 5 to 1, a potential attribute could be the time required to return to the disposed waste: at Level 5, it may take only days or weeks to get back to the disposed waste, whereas it may last years or even decades at Level 1. One can imagine complementary indicators such as the technical complexity, the availability of technology, the induced dose, the integrity of waste package, the effort to retrieve waste in a more general manner, etc.

Level assessment would result from the mix of the scores achieved for the various criteria. It can be noticed that the naming of the levels in present draft refers to the waste. Work has still to be done to express how the level of a repository is characterized, owing to the fact that various wastes can be positioned at different levels at the same time. It could be considered for example that the level for the repository is the lowest level of the disposed wastes, but it may also be considered useful to show the range of levels achieved for the wastes.

Consistency with Previous Work

The proposed scale is consistent with previous international work, but aims at being simpler, thus more adapted to dialogue with stakeholders. Table I shows the consistency with the time-zones defined in the EC Concerted Action on Retrievability[7] in 2000. These time zones were applicable to various national programs, which suggest that the new proposed scale would also be applicable at the international scale.

TABLE I. Consistency with the time-zones defined in the EC Concerted Action on Retrievability[7]

"Standard time zones"			**R Levels**
Zone N°.	**Description**	**Typical duration (years)**	
1	Interim storage at or near the surface	0-100	**5**
2	Design and construction of the repository and completion of the first disposal cells	10-20	
3	Period of filling one disposal cell with waste package(s)	< 5	
4	Period of keeping the package accessible before backfilling and sealing the disposal cell	0 -> 100	
5	Backfilling and sealing the disposal cell	< 1	**5 -> 4**
6	Period of keeping the backfilled and sealed disposal cell accessible before backfilling the depositing tunnel	0 -> 100	**4**
7	Backfilling the depositing tunnel	1 - 5	**4 -> 3**
8	Period of keeping the access tunnel open, after having backfilled the depositing tunnel	0 -> 100	**3**
9	Backfilling of the access tunnel	1 - 5	
10	Period of keeping the access shafts open, after having backfilled the access tunnel	0 -> 100	
11	Backfilling and sealing the shafts	1 - 5	**3 -> 2**
12	Post-closure phase with institutional control	0 - 500	**2**
13	Post-closure phase without institutional control	unlimited	**1**

POTENTIAL UTILIZATION OF THE SCALE

The potential utilization of the scale to support dialogue with stakeholders is illustrated hereunder. Three examples are described:

- The first one deals with the definition and characterization of reversibility versus retrievability;
- The second example shows the balance between reversibility-retrievability and implementation of passive components;
- The third one shows how a national program may be described by using the scale, allowing the presentation of the various decision points;

Characterization of Retrievability or Reversibility

The draft scale presented above shows various levels of retrievability of the waste packages, down to recoverability of the waste. It could be thus used as a retrievability scale, or as a retrievability-recoverability scale. At a given stage of waste management, the position of the system in the scale (levels for the various wastes) expresses the current retrievability or recoverability of wastes.
However, the scale can also help in representing the reversibility of a repository in a broader sense.
As can be noticed, the naming of the levels does not refer to time: the levels describe the state of the wastes at a given time, like a snapshot. However, describing the successive states of the repository, their duration, can be done by using the scale. Like a movie is made from a succession of pictures, reversibility may be described by the range of possible sequences of levels gone through the scale.
Along time, the duration of the successive levels allowed by design provides an indication of the reversibility of the waste management system.
The process for shifting from one level to the next is also part of reversibility: the decision-making process (who will make the decision, who will be involved, on which basis will the decision be made…) is an essential component of reversibility. For example, monitoring effort is generally not a criteria for the proposed draft scale (apart from level 2 vs 1), but as it can contribute to decision making to pass from one level to the next, it supports reversibility.
The balance at each stage and along time between (i) effort needed (technology, cost, impact) to maintain a level and (ii) effort needed to retrieve/recover a waste can also characterize the reversibility of the system.

Reversibility and Retrievability versus Passivity

Going from one stage of waste management to the next can correspond to the passage to a lower level of the proposed scale. For decision making, it will be valuable to explain the different issues of such a decision.
In particular it is important to show that passivity of waste management increases as retrievability decreases. Going through the steps of the disposal process complicates a potential return to the waste, but makes it possible to progressively implement passive components and passive safety functions, which is the final target of long term waste management. This is illustrated by Fig. 4.

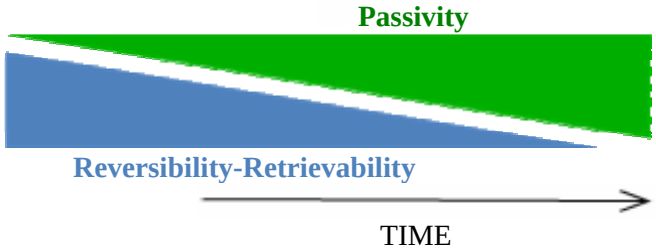

Fig.4. The balance between reversibility and passivity

Presentation of a National Program

Placing the proposed scale in a time-frame according to national program illustrates the progressivity of disposal. It is a suitable framework to discuss the decision- making process with stakeholders.
It allows one to plan decision points along with the staged approach of disposal. For each decision point, it may support the discussion needed to define responsibilities in decision making and to identify supporting information for the decision.
This supporting information can be, for example: the potential duration of the successive levels allowed by design, the confidence in repository behavior (accumulated data from monitoring…), the balance between effort needed to maintain a reversibility-retrievability level and effort needed to retrieve waste.

Fig 5 shows an example of application of this framework, for the French program. The decision-making process at two particular decision points is already clear: the licensing procedure on one hand and the final closure on the other hand, since the 2006 Act states that final closure of the repository would require a dedicated law. Work must be done now on the definition of intermediate decision points, and on the way the decisions would be made: who (Government, regulator, implementer...), on which basis, etc.

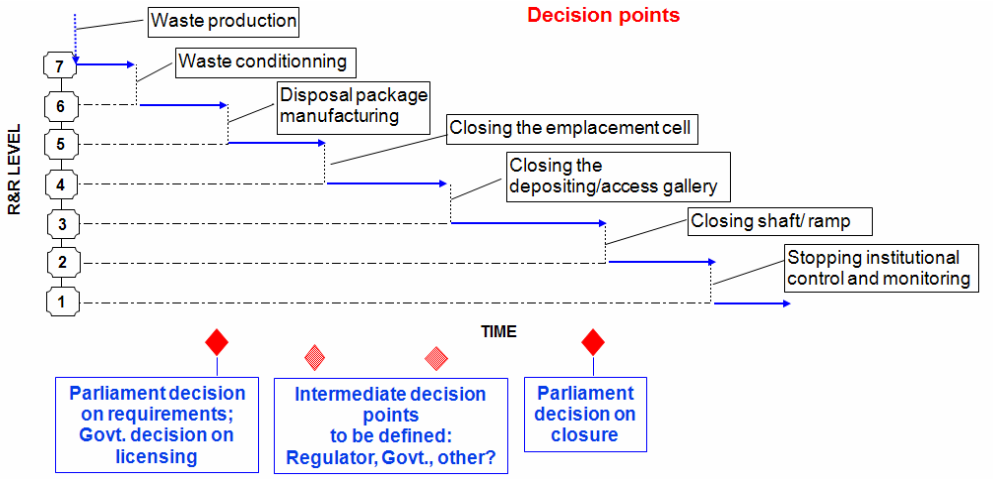

Fig. 5. Presentation of the stepwise approach using the draft scale, application to French program.

Fig 6 shows the possible disposal processes for two different wastes: the first waste to be disposed, where the process is very gradual, and a waste to be disposed later. In the second case, the steps may be crossed more quickly, taking benefit from the confidence acquired. The final closure step is the same for both wastes.

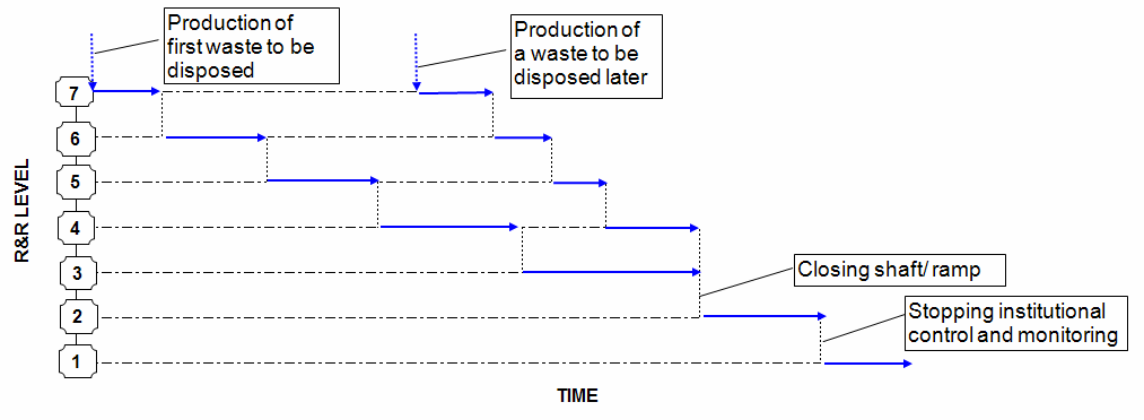

Fig.6. Presentation of disposal process for two different wastes.

CONCLUSIONS

As shown above, a reversibility-retrievability scale may support the dialogue with stakeholders. An internationally recognized scale would add value. It may help national programs to address reversibility/retrievability. In particular, it should enable consistent presentation of various national approaches.

Therefore, Andra already presented the draft project above to a few organizations from various countries. These preliminary exchanges indicated interest in such a framework and already led to improvements of the initial proposal.

A new initiative on reversibility and retrievability (R&R) was recently launched by the Radioactive Waste Management Committee (RWMC) of Nuclear Energy Agency [10]. Andra has proposed to develop this scale at the international level within this initiative.

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