

RESEARCH PROGRAM RELATED TO RETRIEVABILITY, REVERSIBILITY AND MONITORING OF GEOLOGICAL DISPOSAL IN FRANCE

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ABSTRACT

The *reversibility* for repositories is frequently quoted in the media, and opponents to nuclear energy or to waste burial often justify their opposition by the impossibility of reversibility in deep geological formations, as an echo to the supposed absence of reversibility in everything associated with nuclear energy in general.

Reversibility responds to *various motivations*: in case of error or of unpredicted events, it must be possible to intervene; inversely, it must also be possible to recycle certain materials many years after disposal; due to a potential lack of confidence, it must finally be possible to progress in a stepwise approach in order to ensure that every generation may orient the process.

That approach leads to a *wide definition of reversibility* no longer restricted to demonstrating that it is possible to remove a package technically (“retrievability”), but rather encompassing the possibility to modify the process at each step throughout the lifetime of the repository.

Confronted with this definition for reversibility, the preliminary design options of repositories selected for the Meuse/Haute-Marne site in France appear at this stage to be sufficiently flexible to allow further progress in the feasibility study of a reversible repository.

Four main areas of study need to be emphasised:

- It is necessary to further the knowledge concerning the evolution of a repository: What phenomena control the evolution of the repository? What characteristics of the different components do they affect?
- It is necessary to define *reversibility levels* and their specific characteristics while modulating them, if necessary, according to the different waste types;
- It is necessary to define a monitoring programme in close relationship with the phenomena modelling ensuring the representation of the repository evolution over time and the analysis of the safety conditions during each phase;
- Finally is it necessary to examine the effects of the different states of the repository on the implementation of technologies: for example, what characteristics or what state of the components may complicate package retrieval, in other words make the proposed technological means inadequate to intervene at each reversibility level?

BACKGROUND

The French Law of 30 December 1991 on the management of long-lived high-level radioactive waste prescribes three research areas:

- Partitioning and transmutation of long-lived radioactive elements;
- Long-term surface storage of radioactive waste;
- Possibilities of reversible or irreversible disposal in deep geological formations.

After reviewing the geological survey investigations conducted since the adoption of the 1991 Law in France, the French government confirmed, on 9 December 1998, the continuation of research on the possibilities of implementing a repository in deep geological formations, notably by authorising ANDRA to build an underground research laboratory on the Bure site straddling the Meuse and Haute-Marne departments in Eastern France. That site consists of a geological formation made of clay. Studies will also continue in granite.

The government confirmed that the studies must be conducted according to a reversibility rationale.

The Law prescribes 15 years of investigations (1991-2006) after which a report shall be submitted to the government and to parliament on the three research areas and the various associated solutions for the management of radioactive waste.

By the end of the 2006 legal deadline, the studies on the possibilities of a repository in deep geological formations should demonstrate the feasibility of such a repository. The objective for that date does not consist in coming up with a precise design for a repository, but in being able to propose disposal solutions that take into account the different waste types and the different research goals involved.

MOTIVATIONS TOWARDS REVERSIBILITY

Many motivations for reversibility have been expressed at both the national and international levels, including:

- *A principle of humility*: involving the possible correction of failures. Since human error is always possible, reversibility results from a modest attitude towards the reliability of the repository.
- *A spin-off of the precaution principle*: the principle itself has been invoked to legitimise reversibility.
- *An application of the recycling principle*: the retrieval of disposed waste may contribute to their recycling.
- *An extension of the ALARA principle to future generations*: waste retrieval must remain open in order to allow future generations to limit risks at the lowest possible level by implementing “the best techniques at a reasonable cost”.
- *A confidence factor*: to build the confidence of citizens in the safety of a repository and in a fair evaluation of its consequences on the environment and human beings involves the problem of being able to offer a sound demonstration over various and long timescales.

- *Respect for future generations*: the notion is already included in the French Law of 1991.

It is clear that none of those motivations is exclusive and, in fact, that the situation is much more diversified. That first typology must therefore be furthered and exploited in an effort to bring forward the first answers.

Due to that diversity, it is very unlikely that a single option may be proposed to meet reversibility requirements. Consequently, it appears necessary to propose a spectrum of solutions or, at the very least, an analysis of the foreseeable possibilities.

DEFINITION OF REVERSIBILITY

Based on the motivations described above, the meaning of “reversible repository” may be set schematically according to the two following different definitions:

- A technological definition, necessarily restrictive and based on package retrieval. Such a definition does not fulfil all the reversibility motivations formulated in the first paragraph;
- A wider definition consisting in maintaining the possibility to reconsider a previous decision in the disposal process.

In that context, the definition used by ANDRA in its feasibility studies for a reversible repository is:

- A “reversible repository” is a repository offering the possibility of choices at all times, as in the case of a storage facility, for waste-management purposes;
- A “reversible repository” must be robust over time in terms of the basic objectives set out to protect human beings and the environment (it may be shut down if that decision is taken).

In order to have a concrete definition, “reversible repository” must be defined with due account to technical, economic and scientific constraints relating to repository design.

PRELIMINARY CONCEPTS AND REVERSIBILITY

At the current stage of research, the feasibility study of a reversible repository does not consist in making final decisions in terms of the definition of architecture, package specifications or engineered barriers. It consists rather in selecting a series of concepts sufficiently flexible for study purposes. Those concepts must help to identify the factors that define a reversible repository. They must also contribute to analyse how it is possible to modulate those different factors in order to fulfil safety, monitoring and cost requirements.

Flexible design taking care of reversibility

With regard to the preliminary concepts currently studied by ANDRA, there are a certain number of hypotheses that meet criteria facilitating the reversibility of a repository and the reversibility study:

- From an architectural point of view, it is planned to dispose of the different waste types, notably those emitting heat or not, in separate areas, thus simplifying phenomenology and modelling.
- In the design of disposal cells, the preliminary concepts include several options for each waste type.
- In the phasing of repository implementation and operation, the construction of a repository extending over approximately a century has been selected as the study hypothesis. That hypothesis does not exclude other possibilities.
- Current temperature criteria for the design of heat-emitting waste-disposal cells prescribe a maximum varying between 100 and 150°C at the point of contact between the packages and the engineered barriers. Temperature limits help to understand the phenomenology.
- Preliminary concepts also cover waste overpackaging in order to facilitate handling, notably for radiation-protection purposes. Overpackaging includes overcontainers for C waste, containers for spent fuels or basket-packaging for B waste.

To design a reversible repository therefore means to analyse how different factors and different evolution processes of the repository lifetime may influence decisions on its management: for example, leaving the disposal cells open after fill-up requires maintenance that would be useless if they were sealed; inversely, leaving the cells open would facilitate their direct accessibility.

To study and design a reversible repository thus consist in defining which maintenance or monitoring activities should be associated with each of those choices.

Technological aspects

The design of a reversible repository also involves the design of technological means to ensure a return to a previous repository situation. For example, if for any reason it were decided to access the disposal cells once packages have been emplaced, the means to be used would be different from the ones used previously. In the case of heat-emitting waste, the interruption of ventilation and the installation of containment plugs increase the temperature. Consequently, operation (or “work-site”) conditions in the repository need to be designed to define which technologies are required and to assess the corresponding development effort.

At the stage of preliminary concepts, studies have particularly focused on package retrieval (“retrievability”). The intention was notably to demonstrate that package retrieval was technologically feasible in both vertical-cell designs and horizontal concepts. Design tests and studies of a retrieval system were conducted to show the feasibility of package retrieval, at least for B and C waste. For larger spent fuels, there is no certainty yet concerning the feasibility of a comparable system.

Preliminary studies have been undertaken on the retrieval of backfills or engineered barriers. They show that techniques are available and that there does not seem to be any real feasibility problem. Implementation conditions, notably in terms of temperature or radioactivity (gas) that actually determine their larger or smaller sophistication.

It is considered that the necessary technologies either for package retrieval or for drift clearing are more or less accessible whether the repository is reversible or not. In the framework of the

research on reversibility, the goal is therefore not to assess only their feasibility, but more precisely to assess how the conditions in which they would be implemented may define their larger or smaller sophistication.

WHICH ELEMENTS TO STUDY AND IMPLEMENT THE REVERSIBILITY OF A DISPOSAL?

The preliminary selection of designs for reversible geological repositories identifies the factors of reversibility related to the layouts of a repository, the methods of its implementation, the succession of the “time-phases” of the process of disposal. It identifies also the demand of knowledge needed to manage these different factors. These factors constitute elements of choice for managing the reversibility of a repository.

Therefore, four main areas of study need to be emphasised:

- It is necessary to further the knowledge concerning the evolution of a repository during all phases throughout its lifetime under reversibility conditions. What phenomena control the evolution of the repository? What characteristics of the different components do they affect?

One question is a time limit for reversibility.

Defining the extension of reversibility over time presents several difficulties:

- May setting out timescales exceeding several centuries (300 years, for example) actually contribute to provide a common meaning to reversibility? Historical or prehistorical data may serve as multiple references in terms of time and evolution of society. However, are they sufficient to establish appropriate timescales when it comes to future civilisations/generations, whether close or distant in time? May the knowledge of the past serve as a reference when determining time limits for the future where new situations may arise?
- Technically speaking, the search of a reference point for reversibility period is probably not simpler. It is resolved apparently by referring to the specific behaviour time of repository equipment and structures. The effort needed to retrieve packages from a repository then becomes a technical criterion of a reversible repository. That does not set out an actual reference point for the reversibility period, since package retrieval or recovery of the radioactive substances they contain may prove difficult, but technically “always” possible. Economic, social and environmental conditions will determine whether to retrieve packages or recover radioactive substances that may be potentially disseminated in the repository environment.

Hence, to limit *a priori* the reversibility period raises problems, since it would mean establishing an arbitrary limit without really knowing what it meant.

A solution would be to adopt a rationale involving reversibility levels that would allow for actual interventions on the evolution of the repository while maintaining the possibilities of options over time. The transition from one phase to the next does not appear as a definite choice anymore or as “turning the page” as the common expression goes. The choice would

then be made with a full awareness of the situation, in other words, with knowledge of the scientific, technical, economic and environmental parameters resulting from the transition to a new phase of the repository. The last reversibility level could be the final closure of the repository.

- Therefore, it is necessary to define the reversibility levels and their specific characteristics while modulating them, if necessary, according to the different waste types.

For example, for heat-emitting waste, the temperatures at the entrance of and inside the disposal cell vary greatly depending on the conceptual measures used. The way that ventilation in the drifts drains the heat from the cell depends on its power, the heat-transfer mode inside the cell (may convective phenomena be present?) and probably the definition of the operational plug at the cell entrance. Package accessibility, ventilation management, the decision to seal the cell all depend on those factors and define different *reversibility levels*, in relationship to thermal conditions. Beyond a certain temperature spectrum, it will be more difficult to intervene on the repository, and the reversibility level will therefore be lower.

- It is necessary to define a monitoring programme in close relationship with the phenomena modelling ensuring the representation of the repository evolution over time and the analysis of the safety conditions during each phase.

Monitoring the repository allows for a double use of the collected data:

- Verifying that the evolution of the repository does not deviate from the prescribed design. Based on criteria yet to be determined, it will serve as an alarm signal, if deviations were detected throughout that evolution;
- Refining the knowledge of the evolution of any component of the repository, thus helping to intervene with full awareness of the facts on the implementation and operation processes.

That implies that the modelling of the evolution of the different parts of the repository and, notably, of the disposal cells, has been established on a predictive basis. The scientific and technical problems encountered relate at that point to the definition of a measurement programme adapted to the phenomenology as well as to the definition, design and implementation of specific measuring tools. In that context, it may appear necessary to have disposal areas for testing or pilot-project purposes where the conditions of the subsequent phases may be anticipated in order to ensure that the decision to move on industrially to the next phase be taken with full knowledge of the situation.

The understanding acquired through the monitoring of the repository thus increases the confidence people have in it by explaining with simple words what actually goes on in a repository. It also contributes, in return, to gain more confidence in the long-term safety demonstration, if the choice were to be made then to continue activities according to the rationale involving the closure of the repository.

- Finally is it necessary to examine the effects of the different states of the repository on the implementation of technologies: for example, what characteristics or what state of the components may complicate package retrieval, in other words make the proposed technological means inadequate to intervene at each reversibility level?

Another point is an assessment of the cost, which could be associated specifically to reversibility. At the current research, it is premature to get an evaluation of the cost of the reversibility.

CONCLUSIONS

- In order to respond to various motivation of social and political demands, a wide definition of reversibility is suggested, no longer restricted to demonstrating that it is possible to remove a package technically ("retrievability"), but rather encompassing the possibility to modify the process at each step throughout the lifetime of the repository.
- Confronted with this definition for reversibility, the preliminary design options of repositories selected for the Meuse/Haute-Marne site in France appear at this stage to be sufficiently flexible to allow further progress in the feasibility study of a reversible repository.
- Four main areas of study need to be emphasized:
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 - It is necessary to define reversibility levels and their specific characteristics while modulating them, if necessary, according to the different waste types;
 - It is necessary to define a monitoring programme in close relationship with the phenomena modelling ensuring the representation of the repository evolution over time and the analysis of the safety conditions during each phase;
 - Finally is it necessary to examine the effects of the different states of the repository on the implementation of technologies.
- These studies identify the different factors, which constitute possible elements of choice for managing the reversibility of a repository.