4. NATIONAL POLICIES IN THE PLANNING OF PRE- AND POST-CLOSURE ACTIONS

4.1 Impact of an extended open period on post-closure safety

In their planning of repository construction, operation and closure, some programmes are considering concepts that include an extended "open period", in which the waste is kept readily retrievable and there is flexibility in the timing of any decision to backfill and seal the underground openings in which the waste is emplaced, which may be delayed perhaps for some hundreds of years (Appendix 4, observations from responses to Question 5.1b). Such concepts aim to combine, to some extent, the positive aspects of geological disposal, in terms of passive safety and security, and long-term storage, in terms of flexibility in decision-making.

Currently, national programmes vary considerably in the degree to which plans have been made for an extended open period. In Canada, NWMO has recommended Adaptive Phased Management, in which there is provision for retrievability of used fuel for a period lasting until such time as future society makes a decision on final closure, and on the appropriate form and duration of post-closure monitoring (NWMO, 2005). In the United Kingdom, a care and maintenance period of up to 300 years is currently foreseen, during which the facility would be open and the wastes monitored. In the United States, an open period of between 100 and 300 years is foreseen. In all these countries, the exact duration of such a period is regarded as being a decision for future generations. In planning how to implement an extended open period, including the time frame over which it will continue, the flexibility that this provides to future generations needs to be balanced against any detrimental effects that this period could have on long-term safety and the safety case.

For example, an unsealed repository would require active controls to guard against unauthorised access to the disposed materials. Furthermore, if left without backfilling, underground tunnels are likely to require continual monitoring and maintenance to guard against tunnel collapse, which, if it were to occur, could potentially make final backfilling difficult. The prospect of potential societal instability, which could lead to lapses in maintenance and security or even the neglect and premature abandonment of the disposal system, increases with time and may certainly be significant when considering safety over a time frame of centuries. To some extent, these concerns can be addressed by the design of the repository. For example, the concept of monitored long-term geological disposal considered in Switzerland for the disposal of spent fuel, vitrified high-level waste and long-lived intermediate-level waste involves an extended period of monitoring, during which retrieval of the waste is relatively easy, and the emplacement of a representative fraction of the waste in a pilot facility to test predictive models and to facilitate the early detection of any unexpected undesirable behaviour of the system should this occur. The pilot facility and its access routes are arranged in such a way that the facility can continue to be monitored for a long period after closure of the main facility. Both the main facility and the pilot facility should not represent a significant risk if, during a time of crisis, they should be abandoned without the access routes being closed according to plan (Nagra, 2002).

The safety case must take into account changes resulting from any open period on long-term performance (Appendix 4, observations from responses to Question 5.1a). The excavation, drainage and ventilation of underground openings, for example, inevitably perturb the geological environment of a repository. The engineered barrier system may also change, albeit only slightly in many cases, in the period between its emplacement and repository closure, and the processes bringing about these changes may be different to those operating post-closure. Some of the changes may be detrimental to long-term safety, or may at least complicate the safety case. The magnitude of the changes, and duration of transient perturbations, can sometimes increase with the duration of the open period. For example, in the case of a saturated host rock, drawdown of waters closer to the surface, up-coning of deep groundwaters, a reduction of the formation pore pressure at repository depth, and some de-saturation of the rock around the repository may all occur during the open period. These disturbances are likely to be reversible, but over timescales that may be greater for a prolonged pre-closure open phase than for a short one. A prolonged open period may also increase the probability that extraneous materials will be introduced into the repository and subsequently overlooked (e.g. oil spills)[17] and also increases the likelihood of accidents and unexpected events (e.g. rock falls) in general.

It is widely acknowledged that the disturbances caused by any open period on the safety-relevant characteristics of the system must be assessed as part of a safety case, although many can be excluded from detailed consideration, e.g. in safety assessment calculations, due to their limited impact or reversibility over short timescales.[18] In the case of the fractured hard rock at the Olkiluoto site in Finland, for example, the formation pore pressure at repository depth is expected to recover within a couple of years of backfilling and sealing the facility and the salinity distribution to recover within a few hundred years (Vieno *et al.*, 2003). A few perturbations may be irreversible or reversible over a longer timescale. In the case of the Callovo-Oxfordian clay being considered as a potential host rock in France, disturbances to the stress field of the site will eventually return to a state of equilibrium, but this is expected to take up to several hundred thousand years. Some irreversible or slowly reversible perturbations may need to be taken into account explicitly in the safety assessment calculations. An example is the formation of excavation-disturbed zones around underground excavations, which may have hydraulic conductivities that are orders of magnitude higher than the undisturbed rock and, in the case of many hard rocks (with the exception of salt), can persist with little change for very long times. The positive outcome of the recent peer review of the French Dossier 2005 Argile (Andra, 2005) also shows that safety cases have and can effectively address the potential effects on long-term safety of an open period.

Ensuring that there is no unacceptable long-term impact of the pre-closure phase on post-closure safety is widely seen as an objective in the planning of repository construction, operation and closure. The specific perturbations that need to be avoided can depend strongly on the specific barriers and safety functions provided by the system and the degree to which these are emphasised in the safety case. For example, if the diffusive transport barrier provided by a layer of plastic clay host rock is considered a key element of the safety case, then an important consideration is the avoidance of mechanical and chemical perturbations that could degrade this barrier. The repository may be designed to mitigate the potential impact of disturbances caused by any extended open period. For example, in the case of repositories for spent fuel and vitrified high-level waste in a saturated rock, steel canisters,

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17. Establishing a "safety culture" that seeks continual improvement and requires all potentially important process-influences of an introduced material, design change, or action to be analysed and documented, and applying quality assurance procedures during operation and any open period, are important in reducing this probability.

18. Although understanding of processes occurring in the pre-closure phase and safety assessment modelling of the impact of the pre-closure phase on post-closure safety may require more attention in some concepts, this is not widely seen as an area critical to the safety case (e.g. NEA, 2005).

if used, are designed with a corrosion allowance that takes account of uncertainties in the duration of the resaturation period, during which oxidising conditions may prevail and more rapid corrosion processes operate. A concern being addressed in most repository programmes involves the introduction of bacteria and their food sources during the construction and operational phases. This could lead for example to transient increases in corrosion rates. This type of uncertainty is also typically managed through the use of a robust container that can meet reliability targets even with a transient period of accelerated corrosion.

In view of the prospect of potential societal changes and of potentially detrimental perturbations occurring during or as a result of any open period, it may be prudent, from the point of view of safety, to work towards closure soon after completion of waste deposition. A shorter open period may also simplify the making of the safety case by reducing the time that the system is subjected to sometimes poorly understood transient processes, thus simplifying the analysis and description of repository evolution. These considerations have to be balanced against the ethical principle that future generations should be allowed flexibility in their decision-making, considerations of public perception and confidence, and programme-specific factors such as policies on retrievability and post-emplacement, pre-closure monitoring, which may require a more prolonged open period (see the discussion of ethical considerations in Chapter 2), or the views of the local community.

4.2 Monitoring and post-closure actions

The roles of both pre- and post-closure monitoring have been reviewed in NEA (2004c). There is a broad consensus that pre-closure monitoring of a wide range of parameters within and around a repository is an essential part of compiling a database for repository planning and for developing the safety case that supports decisions on implementation and closure. It may also support construction and operation, enabling any problems to be detected so that corrective actions can be taken. The extent and duration of the post-closure monitoring that will be undertaken is being discussed in many national programmes and internationally, and may in practice be decided as the licensing process proceeds.

In addition to monitoring, further passive and active measures may be required in the post-closure period.[19] Passive measures include for example record keeping, government ownership and land use restrictions, the construction of durable surface markers, and other measures of preserving knowledge about the location, design and contents of the disposal system. Active measures are those requiring continuous human oversight, such as conducting security patrols, or restricting access to a site (largely to satisfy security goals and IAEA safeguards requirements). The requirement for passive safety (Section 3.1.2) means that safety must not, in the long-term, depend on active measures, although they are not excluded.

With respect to timescales and the safety case, the main issues of concern are:

- How long should active measures, including monitoring, be maintained?
- What credit if any can be taken for both active and more passive measures in the safety case?

There are differences in the degree to which national regulations address these questions. In some cases, regulations indicate (i) the time frame over which monitoring, control and record keeping should be maintained, and/or (ii) the time frame over which human intrusion can be excluded in a safety case as a result of such actions. Examples are given in Table 4.2. In other cases, these time

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[19] Although such measures may operate after closure, they may be initiated (or plans drawn up) at earlier times.

frames are left to the implementer to determine and justify, and may then be formally decided in the course of the licensing process.

Table 4.2: **Examples of regulatory positions regarding the time frames for monitoring, control and record keeping (see Appendix 4, observations from responses to Question 5.2a)**

Issue	Regulations and regulatory guidelines	Time frame
Minimum period that active institutional control should be maintained (including monitoring of environmental conditions, e.g. concentrations of radioactive isotopes).	Hungarian regulations	0-50 years
Period beyond which no credit for active institutional control may be taken in a safety case	US EPA	100 years (the controls themselves must be maintained for more than 100 years if possible)
Period during which passive institutional controls are required, including monuments, markers and multiple record retention systems	US EPA and NRC	As long as achievable
Period of passive institutional control during which records can assumed to be preserved and probability of human intrusion is thus low	French regulatory guidance	0-500 years
Period during which inadvertent human intrusion can be excluded due information conservation	German Draft Criteria	0-500 years

The detection by monitoring of changes that could lead to decisions to intervene in the repository system in some manner is extremely unlikely, because of the nature of the expected processes and the ability to monitor changes in them. Post-closure monitoring may nevertheless be required by regulations as an element of confirming good engineering practice. Furthermore, there is a small but non-zero probability that detected changes could lead to decisions to intervene in the repository system in some manner, including removing material from it to process or dispose of elsewhere. Even if, as expected, monitoring shows that there are no significant deviations from the expected evolution of the system, this demonstration may be of value in allaying concerns of the local population regarding safety.

In the interests of providing defence in depth, as well as for public reassurance (see below), it seems reasonable that a target should be that post-closure controls and monitoring are maintained for as long as reasonably possible, taking into account the demands that this may place, for example, on funding and other resources. As long as post-closure controls are maintained, there is little possibility of inadvertent human intrusion into the repository. On the other hand, in order to take credit for these actions in a safety case, it must be argued that society will have the means and motivation to carry on with post-closure controls in the future. Given the prospect of societal changes and the possibility that the priorities of future generations, e.g. with respect to funding allocation, may be different to those of today, such credit cannot be taken indefinitely.

A cautious approach requires that active control of a site cannot be assumed in safety assessments or safety cases for more than about a hundred years at most (Appendix 4, observations from responses to Question 5.2b). It is reasonable to assume that records will be kept for longer than this, perhaps a few hundred years, and that this will also make inadvertent human intrusion less likely. For example, the 500 year period during which, according to Draft German Criteria, inadvertent human intrusion can be excluded due to information conservation is supported by the existence of mining archives of a similar age to this in Germany, which are still being used today (GRS-A-2990)[20]. As a further example, the French Academy, which was established in 1635 for the governance of French literary effort, grammar, orthography, and rhetoric, has succeeded in maintaining its institutions and in transmitting its entire legacy over the intervening 350 years. Historically, some systems of record keeping have been maintained for still longer periods. For example, the Domesday Book, which is a record of land and population in England created about 1 000 years ago, is still accessible today.

An example of current record keeping for a nuclear waste management facility is the preservation of records of the Centre de Stockage de la Manche, a near-surface repository in North West France managed by the French National Agency for Radioactive Waste Management (Andra). Detailed records are kept both at the site and in the French National Archives. Use of special media, such as archival paper, is expected to permits these records to be preserved for from three to five centuries. Duplication of the records at regular intervals may be considered, which could potentially extend the conservation period. Durable markers for geological repositories may remain for longer still (perhaps thousands of years). With increasing time, however, it becomes increasingly uncertain whether the messages that records or markers are designed to convey will be understood by humans. Thus, no credit is taken for such measures in averting or reducing the likelihood of human intrusion in safety assessment beyond around a few hundred years.

In many countries, the public is seen as favouring disposal systems that, although passive, would allow remedial actions to be taken if monitoring indicates unacceptable, anomalous evolution. The slow evolution of many key processes, however, sets limits on what can be observed through practical monitoring programmes. As pointed out in NEA (2004c), direct demonstration of repository functions or the detection of failures would require the development and testing of new technologies.

There is consensus that no monitoring or other post-closure actions should be undertaken that could jeopardise the primary objectives of geological disposal, i.e. the isolation of waste and the containment of radionuclides (Appendix 4, observations from responses to Question 5.2b). This is clearly not an issue for remote techniques, e.g. satellite surveillance, aerial photography, microseismic monitoring. However, where intrusive monitoring techniques are proposed (e.g. sampling groundwater for subsequent chemical analysis), a key consideration is that they should not interfere with the operation of the repository safety functions. For example, US regulations for geological disposal of long-lived waste require that monitoring may not "jeopardise the containment of waste" (EPA generic regulation 40 CFR Part 191, which is applied to the Waste Isolation Pilot Plant).

Any decision to carry out post-closure monitoring should not be seen as suggesting that the safety case is judged unreliable by either the implementer or regulator. Although monitoring could, in principle, allow remedial actions to be taken if desired, this possibility should not form part of the long-term safety case (Appendix 4, observations from responses to Question 5.2b). This is because, in order for a repository to receive the required licences, the long-term safety case should have

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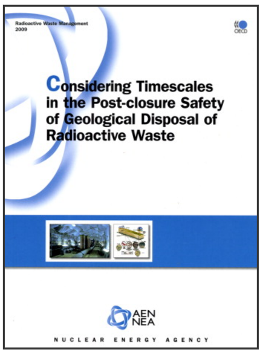
[20] www.rskonline.de/stellungnahmen/sicherheitskrit-endlager-rsk-ssk.pdf. (see p. 86)

demonstrated that there are no reasonably possible situations that would require post-closure remediation.

While the direct contributions from institutional controls to the safety case may be limited, and future enforcement mechanisms cannot be envisioned with certainty, requirements for such controls to continue for long periods are seen as a possible means not only of averting human intrusion, but also of improving societal acceptance and confidence in the disposal system. US regulations, for example, require active controls to be maintained "for as long a period of time as is practicable after disposal" and for monitoring to continue "until there are no significant concerns to be addressed" (Sections 14a and 14b of the EPA regulation, 40 CFR Part 191, applied for the Waste Isolation Pilot Plant – WIPP). The fact that the implementer must take concrete actions in the immediate future – including plans for passive controls, and establishing funding mechanisms – may provide some reassurance to the public of a commitment to ongoing stewardship at the site. This is analogous to requirements for nuclear safeguards, which require controls that are not time limited.



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