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THE CONCEPT OF OVERSIGHT OF A GEOLOGICAL DISPOSAL FACILITY ADOPTED BY ICRP - IMPLICATION FOR INTERNATIONAL AND NATIONAL GUIDANCE?

Discussion paper for the RF meeting of March 2013

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THE CONCEPT OF OVERSIGHT OF A GEOLOGICAL DISPOSAL FACILITY ADOPTED BY ICRP - IMPLICATION FOR INTERNATIONAL AND NATIONAL GUIDANCE ?

DISCUSSION PAPER FOR THE RF MEETING OF MARCH 2013

Executive summary and organization of this report

The hazard of some radioactive waste extends to periods of time that are comparable to the geological timescales. For these long time periods, one must still minimise potential exposures and ensure protection of man and the environment. Protection for long time scales is achieved by the practice of geological disposal. For fulfilling its safety mission, geological disposal relies on a system of protective measures that become increasingly passive with the passage of time.

Oversight or "watchful care" is the reference concept in the new publication of the International Commission on Radiological Protection (ICRP) related to geological disposal of long-lived solid radioactive waste [1]. The concept was revisited and applied in the R&R project [2] of the NEA. Oversight of a radiological source refers to what man can accomplish in order to limit exposure through his actions. The radioactive source can be either the waste or the repository once it is filled with the waste. Oversight can be direct, as in the case of inspections concerning the conditions of waste emplacement and review of the results of a direct monitoring programme, or indirect, as it is the case when parts or the whole repository are sealed. The involvement of society is an additional element of oversight. Control is another important concept and is a complementary concept to oversight. Control can be active, as in the case of inspections – and it is then part of oversight –, or passive, through the intrinsic safety features built into the repository design (Fig. 1).

The ICRP text observes that, from a radiological viewpoint, in addition to passive controls, "the crucial factor that influences the application of the protection system over the different phases in the lifetime of a disposal facility is the level of oversight or 'watchful care' that is present. The level of oversight affects the capability to control the source and to avoid or reduce exposures." Three periods and levels of oversight of the waste are expected over the lifetime of a repository. (Fig. 2) When the repository is being built and operated, direct oversight of the waste may be exercised through active control if disposal cells and repository galleries are not yet sealed; when the waste is no longer accessible, which is the case when parts or the whole repository are sealed, only indirect forms of oversight may be available which, depending on the time period, may include remote monitoring or institutional arrangements such as surface monitoring or maintaining records and memory. If memory of the disposal facility is lost, there is absence of oversight. Absence of oversight is not planned for, but the potential for loss of oversight needs to be addressed when considering long-term safety and it is taken into account in designing and licensing the repository.

Oversight requires the presence of man and is a complementary form of control to the built-in passive controls of the facility, which are independent on human presence. The importance of considering oversight is also related to the increased demands by society. These demands for provisions of oversight by the public may be motivated by unfamiliarity with (or lack of confidence in the maturity of) the disposal technology, or by discomfort with the concept of purely passive safety without any means of oversight or active control. There may also be a desire to avoid making decisions today that may preclude different actions in the future and therefore avoiding irreversible steps or even of preserving the ability to participate

in future decision making. These provisions are not safety requirements but are part of what could be called the "safety story", i.e., provisions that increase confidence in safety. In order to find an optimal oversight approach it is important to harmonise social and technical demands from the beginning.

This paper is provided to the Regulators' Forum (RF) of the RWMC in order to start discussion on the impact of the new concept and of the ICRP-122 recommendations on national and international regulatory policy and guidance.

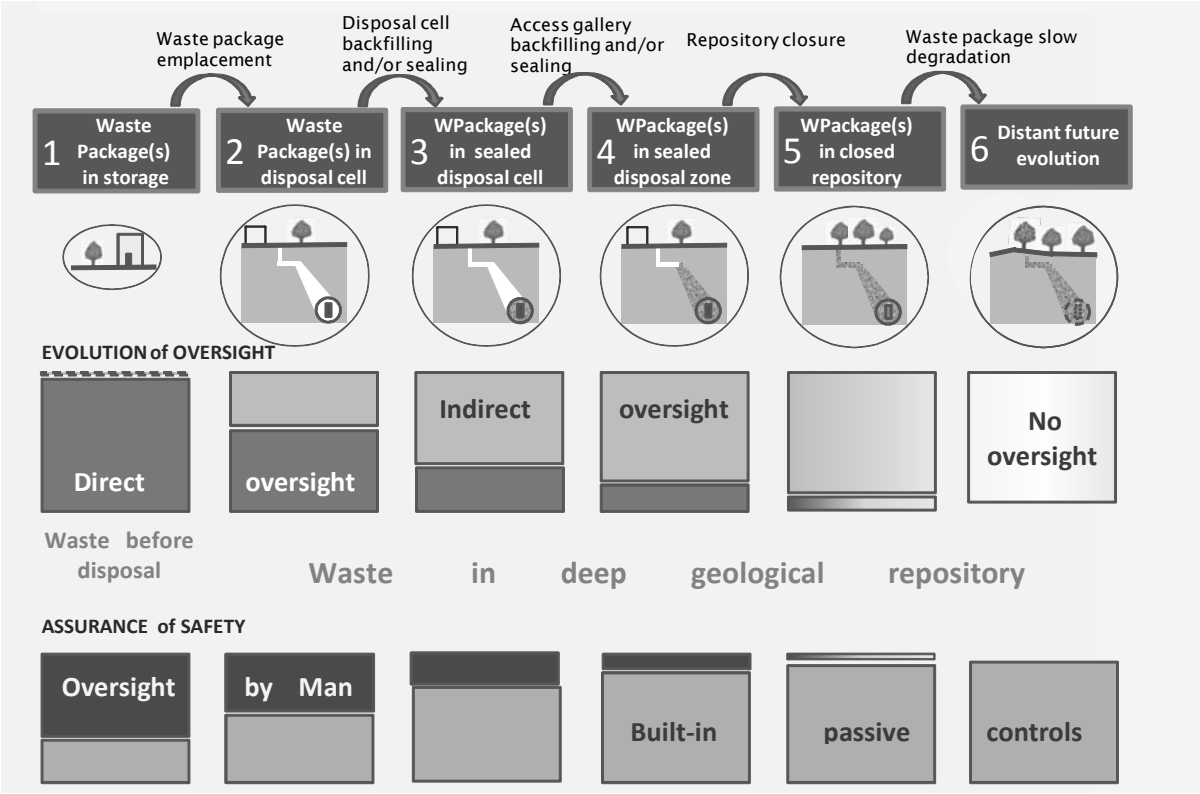

Figure 1. *Evolution of oversight and means of assuring of safety over the repository lifetime. The transition to a no oversight period is hypothetical, but it cannot be excluded, and a repository is specifically designed and licensed so that its safety does not rely on the presence of man. This is why passive controls are gradually built into the facility until its closure.*

The introduction of the concepts of "oversight" and "level of oversight" in a regulatory type of document may have important implications for the international and national regulatory guidance. The 1st RWMC/RF workshop (Tokyo-2009) organized by the OECD/NEA acknowledged, for instance, the difficulties involved with the duration of institutional control and stated that "the issue of maintenance of control[1] was a challenge to regulators, as well as to implementers and policy makers" [3]. This issue is closely connected to the issues of transfer of responsibilities, information and memory preservation as well as to the meaning of safety, which is often presented as being related to maintaining control.

[1] "oversight" in the current vocabulary

This document discusses the potential impacts.

The first chapter introduces the subject.

Chapter 2 defines in detail the difference between control and oversight. Active control and oversight mean the same thing only during the period of direct access to the waste or when parts of the repository are actively managed; afterwards, control and oversight separate. After closure, control is mainly exercised through means no longer involving man; oversight will be exercised through means involving man.

Chapter 3 explains the reasons for the evolution from control to oversight and draws a distinction between human oversight activities and the passive safety features of a repository. Human oversight activities may involve a wider group of stakeholders other than just regulators and implementers. Also, the level of oversight has an impact on the applicable radiological criteria.

Chapter 4 presents how oversight may be exercised during the operational and post-closure phases. It depends on the status of the disposal facility. Oversight includes active measures such as monitoring, inspections and land use restrictions. It includes as well passive measures such as keeping records and relying on markers.

Chapter 5 addresses the duration of indirect oversight. The intention is not to lose memory of the existence of the disposal facility. There may be a different duration for active and passive oversight. As time progresses the degree of oversight may change, corresponding, for example, to less frequent inspections. The responsibility of oversight will switch from institutional regulators to societal decision-makers such as local and national political authorities. The decisions to reduce the level of active controls would be based to some extent on the degree of confidence in the behavior of the facility, and other societal and economic factors and will be discussed with the stakeholders concerned.

Chapter 6 deals with the respective responsibilities of operators, regulators and society for exercising and maintaining oversight. The sharing of responsibilities should be well established. The role of local communities is likely to remain important in time.

Chapter 7 deals with the planning for oversight in the different stages of development of the disposal facility. Before the operational phase, the implementer prepares a monitoring and surveillance programme which is reviewed by the regulator and other stakeholders and is periodically updated on the basis of the experience feedback from operations. The regulator will need to be satisfied with the implementer's plans before granting a licence to proceed with the next step. Stakeholders are most likely to be involved on environmental monitoring aspects. Plans for indirect oversight on extended time frames are evaluated and needs for financial reserves and institutional management arrangements are also identified.

Chapter 8 considers the societal expectation and challenges associated with oversight. The extent to which these demands are made and the priorities of local communities depend on the country and the stage of the geological disposal programme. Societal concerns in the operational phase are likely to include environmental monitoring requirements and monitoring of socio-economic impacts. Tools for the local community to maintain memory are country specific and range from land registers and markers, to oral history, regular dissemination and developing the culture of memory in institutions and territories.

Chapter 9 gives the status of national guidance with respect to implementing the oversight concept. All have realized the importance of keeping memory after closure and considered passive measures in this respect. A few countries have made plans for active controls after closure. Other programmes have not yet made explicit the extent and duration of post closure monitoring.

Chapter 10 delivers the main messages for developing international and national guidance on the subject.

1 - Introduction

The goal of a geological disposal facility for high-level and long-lived radioactive waste is to isolate and contain this waste in order to protect humans and the environment for periods that may be comparable with geological time scales. The international position is that, once closed, the repository will continue to perform its safety mission in a manner that does not require continued care by man. Repositories are thus designed to be robust to a large spectrum of events and with built-in passive safety features.

However, as indicated by the ICRP, geological disposal of radioactive waste is a planned activity and even *"If oversight ceases to exist in the post-closure period, the disposal system is still a functioning facility".* Therefore loss of oversight should not be planned for. Demands to keep records, memory and oversight exist through laws, regulations, and others for, e.g.:

- an institutional protection period and measures against human intrusion or for facilitating retrieval, e.g., land-use exclusion;
- land withdrawal;
- containers meant to last for a certain number of centuries;
- monitoring of local environment;
- maintenance of records and even provisions of "permanent" markers; and
- oversight in general for a specified period of time, during which human intrusion is not a concern.

These provisions are not safety requirements but are part of what could be called the "safety story", i.e., provisions that increase confidence in safety.

In "Learning and Adapting to Societal Requirements for Radioactive Waste Management" (NEA 5296), published in 2004 [4], it is outlined that "Enhanced oversight by local authorities, fully visible to stakeholders, builds public confidence in the decision making process". The report: "Regulating the Long Term Safety of Geological Disposal" (NEA 6182), published in 2007 [5], acknowledges that "special considerations need to be given to the role of post-closure institutional control to establish confidence".

Following this evolution, the new IAEA Standards for disposal of radioactive waste (SSR-5, 2011) [6] recognize that "it is likely that 'passive institutional controls'[2], such as the use of markers and control on land use, will be implemented and maintained, at least for a certain period immediately after closure. Active institutional controls such as monitoring may also be applied for a period after closure of a geological disposal facility, for example, to address public concerns and licensing requirements or as protection against human intrusion". Implementers are exploring what is possible; this requirement is clearly stated in the regulatory framework for the WIPP repository [7].

In a similar vein, the Euratom Directive 2011/70 of 19 July 2011, Article 12 (e) [8], implies obligations on EU countries in terms of controls after closure at least for a certain period of time and the keeping of records without time limits, hence, again forms of continued interest in the fate of facility and oversight.

[2]The expression « passive institutional controls » although used in the past, e. g. in the US regulation as in 40 CFR Part 191 subparts B and C for the compliance recertification application for the waste isolation pilot plant (WIPP) may be misleading since institutional controls is about the role of institutions and therefore corresponds to active engagement and measures.

The 1st RWMC/RF workshop (Tokyo-2009) [3] acknowledged the difficulties involved with the duration of institutional control and stated that "the issue of the duration of control, the types of events that may lead to loss of control, and the types of controls that may be relied upon over different timescales need to be better understood and addressed. The issue of maintenance of control is a challenge to regulators, as well as to implementers and policy makers. This issue is closely connected to the issues of transfer of responsibilities, information and memory preservation as well as to the meaning of safety, which is often presented as being related to maintaining control."

The new ICRP guidance on radiation protection in geological disposal underlines that a crucial factor that influences the application of the protection system over the different phases during the lifetime of a geological disposal facility, is the level of oversight that is present. It states that: "The long term safety of a geological disposal facility relies on a passive system not depending on the presence and intervention of man for fulfilling its safety goals. Nevertheless the level of oversight directly affects the capability to reduce or avoid some exposures." The participation of stakeholders is put forward, since the guidance also states: "The different decisions to be made relating to the evolution of the oversight should be discussed with stakeholders". This first-time introduction of oversight and "level of oversight" in an international guidance is likely to have important implications for the international and national guidance. These potential impacts are described in this document.

2 – Definition of oversight

The concept of "oversight", as distinct and complementary to "control", in the context of repository development, was introduced first within the Reversibility and Retrievability (R&R) project [1], an NEA/RWMC initiative that took place in 2007-2011. The R&R report states that "controls include measures that do not necessarily rely on man. Thus, passive controls may be exercised by the components of the repository system itself, including measures introduced for instance to reduce risks of human intrusion. In the opposite, active controls are always performed by human beings. In the case of regulatory control, they are performed by regulatory authorities in the form of inspections, verification of records, verification of quality assurance procedure, verification of safeguards, etc. The term institutional control is more general and may be applied by organizations that do not meet the definition of a regulatory body, and may apply in situations which do not fall within the scope of regulated facilities and activities (i.e. regulatory control may be thought of as a special form of institutional control). Some forms of institutional control may be considered more likely to endure further into the future than regulatory control."

The R&R report sets out as well that "oversight refers to regulators or society 'keeping watchful care' of the disposal system and the actual implementation of plans and requirements. It includes regulatory supervision and control, preservation of records and societal memory of the presence of the facility." The report distinguishes "direct oversight which refers to active control measures during the operational phase of the facility e.g. inspections and monitoring" from "indirect oversight which refers to measures that are used once the facility is closed."

These definitions are taken up and completed in the body of the ICRP publication [2] and in the glossary of the same document. However there are a few inconsistencies between the glossary and the body of the document. In the glossary, it is written that indirect oversight is characterized by waste packages being no longer visible, which may imply that these waste packages are visible when there is direct oversight. Actually, most waste packages will not be visible as soon as they will be emplaced in disposal cavities. "Visible" may in fact mean "easily accessible".

From the definition given in the body of the ICRP publication completed by the R&R report we propose the following understanding for oversight:

Oversight refers to society 'keeping watchful care' of the disposal system and the actual implementation of plans and requirements. In that sense, it provides a useful framework to view technical monitoring activities and societal engagement as parts of a unified whole. It includes regulatory supervision and

control, preservation of societal records and societal memory of the presence of the facility. Oversight is related to active control and covers activities that may extend beyond regulatory or institutional control and society at large may be involved. Oversight can be exercised by implementers, regulators, institutions depending on central government but also by local government, NGOs and the general public.

Direct oversight refers to monitoring measures and inspections performed during the operational phase of the facility consistent with the controls performed at other nuclear licensed facilities that handle similar radioactive materials. Indirect oversight refers to measures that are used when parts of the facility have been sealed or once the facility is closed and there is no longer access to the underground facilities e.g. a period of continued regulatory control, land use restrictions, preservation of land use records, monitoring by society to check that the environmental conditions are not degrading.

From a radiological point of view, as stated in the ICRP publication, the protection system is strongly influenced by the level of oversight. For the time period following closure, when the presence or the role of the regulator is not assured in the longer term, it is suggested that the more general term of "institutional oversight" rather than of "institutional control" be recommended, reflecting the fact that the regulation enforcing aspects after closure may be weaker than in the earlier period. Eventually, there may be a time when society will no longer keep a watchful eye on the facility and memory of the presence of the disposal facility will be lost (in other words a time when there is no oversight of the disposal facility).

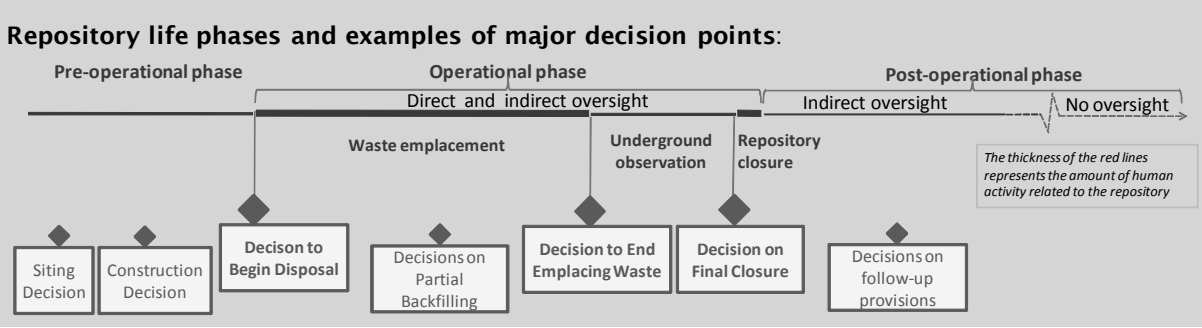

Figure 2: Repository lifecycle phases and examples of associated decisions. The transition between the various forms of oversight is gradual and the actual duration of each time period will vary project by project.

3- Reasons for distinguishing control from oversight

The main reason for distinguishing control from oversight was to draw the distinction between man-based and non-man-based activities. Control can take place through measures that do not necessarily rely on man. For instance, the barriers that constitute a nuclear waste repository continue to exercise some types of control functions long after closure of the repository: they control the access of groundwater, the temperature of the near field, the release of radionuclides, etc. These are passive controls that do not depend on further action by man. Active controls require instead the presence of a regulator or other organisation, *e.g.*, in the form of inspections, verification of records, verification of quality assurance procedure, verification of safeguards, etc. Active controls are important until closure of the disposal galleries after which most active controls may no longer be possible. After a repository is sealed, we move away from active control to a period where man can, at most, only monitor the repository indirectly.

In this context, the term oversight applies equally well to the pre-closure and post-closure phases. The level of oversight – what is possible and what may be done – will vary with time; the pre-closure phase being one of mostly direct oversight and the post-closure phase, of indirect oversight. The level or type of oversight depends on whether humans have access to the waste or not and this affects the capability to manage the source and to avoid or reduce some exposures.

The radiological criteria of the ICRP recognise and take account of the fact that the level or type of oversight will change with time depending on the degree of sealing of the facility. For instance, oversight helps reduce the potential for *inadvertent* human intrusion. It is important to note that the ICRP requires continuity of oversight as long as practicable. Continuity of oversight suggests that the waste is never "cleared" from regulatory control, which justifies the ICRP's 0.3 mSv/yr dose constraint for repository performance (if the waste was "cleared" from regulatory control, the reference dose constraint would be 10 μSv/yr). To this effect, the ICRP makes also the point that a repository has to be considered as a functioning nuclear facility at all times, including after the potential loss of oversight. Monitoring, if used by regulators to check whether regulations are being met, can be seen as an active control measure; if it used by society to check that the environmental conditions are not degrading, it is an active control measure but under an oversight rather than a regulatory regime. In this sense, we may refer to it as an "active oversight" measure.

As explained above, oversight is the more general term that refers to society 'keeping a watchful care' of the disposal system and the actual implementation of plans and decisions. It is now accepted that the different decisions to be made relating to the evolution of the oversight should be discussed with stakeholders. Society may also participate in oversight through a number of activities, which at this stage are not fully investigated.

The importance of considering oversight is related to the increased demands from society to be involved in decision-making, for example, as outlined in the ICRP guidance. These demands for provisions for oversight by the public may be motivated by unfamiliarity with (or lack of confidence in the maturity of) the disposal technology, or by discomfort with the concept of purely passive safety without any means of oversight or active control. There may also be a desire to avoid making decisions today that may preclude different actions in the future and therefore avoiding irreversible steps or even of preserving the ability to participate in future decision making. Significant social demands can also arise from concerns about the ability to access materials that may become valuable at a future time and the ability to continue to directly monitor conditions in the repository. An extended period of active control may increase familiarity with the concept of passive/intrinsic safety.

Societal demands may be based partly on a perceived need for further confirmation that the repository is operating as planned, and partly on a concept of safety which includes oversight as an essential component. In this view, the assurance of safety depends not only on predictive demonstrations, but also on continued oversight and monitoring. According to this approach, while post-closure safety assessments are required to demonstrate safety even in the absence of oversight and monitoring, the overall safety provisions would nevertheless include plans for continued institutional oversight, monitoring, and possibly retrievability for a period of time following closure and sealing of the repository. Such plans may allow further building of confidence in safety and respond to a societal need not to forget the facility.

The concept of oversight is in accordance with the clarification of roles and better understanding of the systemic nature of safety and the definition of the regulatory system. Regulatory control of nuclear facilities involves not just one institution but a range of bodies associated with their development and delivery which may be described as oversight activities. The decision making process in radioactive waste management and disposal today is viewed in the context of a well structured dialogue/interaction between implementer, nuclear safety authority, political decision-maker and the general public and decisions for planning oversight and implementation of oversight is part of that process [9].

4 – Different forms of oversight

Three levels of oversight have to be considered for the purpose of radiological protection:

- direct oversight when the disposal facility is being implemented and is under active supervision;

- indirect oversight when parts of or the whole disposal facility are sealed and oversight is being exercised by regulators or special administrative bodies or society at large to provide confirmation of performance and protection before closure or continued confidence of protection thereafter;

- no oversight, as there is no guarantee that the memory of the repository will persist in the distant future.

Oversight during the operational phase
During the operational phase the waste is emplaced, followed by a period of observation prior to closure. For a period during this phase, some galleries may be filled and sealed and having reached their final configuration, while others may still be open and being filled. Part of the facility will therefore be monitored by the operator and under direct oversight of regulatory safety authorities in cooperation with other relevant stakeholders, the other part will be under indirect oversight. This phase may be divided into three relevant time periods:

- The emplacement period: A licence is granted that authorizes the transfer and emplacement of waste packages into pre-excavated galleries, rooms, and/or boreholes. The environmental conditions are continuously monitored and compared with the baseline data. Research and development continues. The operator implements the monitoring programme, the regulator performs regular inspections of the underground operations. The long-term safety case is regularly updated by the operator and reviewed by the regulator. In this phase, some waste packages will be held in storage and will be visible; others will have been emplaced in disposal galleries, tunnels or boreholes and may no longer be visible. New underground disposal galleries may be being built and partial backfilling and/or sealing of galleries and disposal facility areas may also take place. Filled or part filled disposal galleries may be monitored by remote sensors; this may be considered as indirect oversight at close range. As disposal galleries are backfilled and sealed, the level of oversight will gradually change from direct to indirect oversight in the different parts of the underground facility.

- The observation period: After all waste packages are emplaced it might be decided to monitor (parts of) the disposal facility and to keep some accessibility to at least part of the waste while additional performance evaluation and demonstration takes place. Direct oversight will only concern a small part of the facility.

- The closure period: A license to close is granted. Backfilling and sealing are performed according to design. Access from the surface to the underground facility is terminated. Surface facilities may be dismantled or parts of them may remain operational to maintain, for example, site security.

- All relevant information is to be preserved in an archive and society may be involved regularly in the oversight of the disposal. All underground parts of the disposal facility become under indirect oversight.

Oversight during the post-operational phase
During this phase, the presence of man is no longer required to directly manage the facility. This phase is the longest one, and is divided into two relevant time periods:

- The period of indirect oversight: After closure, safety is assured totally through the intrinsic, built-in provisions of the design of the disposal facility. Nevertheless, it is expected that monitoring of the baseline environmental conditions will continue for a period of time. Regulatory or societal oversight may also continue for a period of time. Archives of technical information and data will be kept

including, for example, configuration of waste packages and design of the disposal facility. The use of warning signs or markers to remind of the existence of the repository may apply. Inadvertent human intrusion in the disposal facility is highly unlikely. Future generations may implement relevant international safeguards and controls.

- The period of no oversight: It is not possible to foresee the point at which indirect oversight might terminate. The end of indirect oversight must still be considered in the design and planning stage as there is no guarantee that the memory of the site will persist into the distant future to ensure that oversight will be maintained. Eventually, loss of memory and consequently loss of oversight may take place, either progressively or following major unpredictable events, such as catastrophic natural events, societal breakdown including war, or loss of records. Inadvertent human intrusion into the disposal facility cannot be ruled out during this time period. The intrinsic hazard of the waste will decrease with time but it may continue to pose a significant hazard for a considerable time. The loss of oversight would not result in a change in the intrinsic, passive protective capability of the disposal facility.

Oversight measures before closure

These include monitoring and preservation of records and memory:

- Monitoring:

  Before the operational phase, the implementer prepares a monitoring and surveillance programme which is periodically updated on the basis of the experience feedback from operations. The programme should meet, at least, the following general objectives:

  - demonstration that the disposal system is functioning as expected. This means that the components fulfil their functions as specified in the safety case and that actual conditions are consistent with the assumptions made for assessing post-closure safety;
  - strengthen the understanding of aspects of system behaviour used in developing the safety case and allow further testing of models used to predict them;
  - accumulate a database that contains characteristics of the disposal facility site and its surroundings that may be used in future decision making, as part of a step-by-step process of disposal facility construction, operation and closure.

  At the start of the operational period, the operator's monitoring and surveillance programme, both within the disposal facility and elsewhere on and off site, will need to be brought up to date including extension to include radiation monitoring and environmental sampling for radioactive substances. Parts of the monitoring and surveillance programme will be to demonstrate compliance with licence conditions (for example, with respect to any limits on radioactive discharges to water or air) and assurance of radiological protection for facility workers, members of the public and the environment.

  The monitoring and surveillance programme will need to be agreed as appropriate with the regulator and other stakeholders. Monitoring of the host rock and groundwater to identify physical and chemical perturbations during operation will be needed. Such monitoring will enable assessment of the effects of construction and operation on the characteristics of the site and demonstration that any such effects do not unacceptably compromise the safety case. Where specific provision is made for possible waste retrieval, monitoring during the operational period is likely to be needed to contribute to decisions as to whether to retrieve waste or to move towards closure.

During the operational period, the operator will need to develop the programme for monitoring while closure of the disposal facility is taking place. The programme for environmental and performance monitoring after closure will also need to be developed during this phase. The operator would need to substantiate the anticipated timescale over which such a programme would continue.

- Record keeping system:

  The objective is to ensure that key information, data and their provenance are recorded and preserved. Evidence of quality audits will form part of long-term information management and record especially in respect of data, evolution of the safety assessment and of important decisions. The implementer should provide information showing that the provisions (legal, financial, technical) for institutional control including a description of the organization that will carry out post-closure activities (monitoring, security, potential actions to be implemented, periodic assessment of the institutional control arrangements) will be adequate for subsequent phases. This information should address, at least:
  - long-term information management and record-keeping procedures and provisions for maintaining institutional memory of the disposal facility (site, radioactive, inventory, ...);
  - a description of the safety and security provisions (safeguards, ...) including those to minimise the potential for human intrusion;
  - the organization and provisions for institutional control arrangements.

The operator's programme of measures to be implemented before closure should be agreed with the regulator and relevant stakeholders. As part of regulatory oversight, its implementation should be overseen by the regulator, possibly through inspections. To meet societal demands, there may also be a need for implementation to be verified by additional independent reviews.

Oversight measures during the post-closure phase

Indirect oversight refers to measures that are used once the facility is closed e.g. a period of continued institutional control, preservation of land use records, and possibly monitoring to check that the environmental conditions are not degrading; such measures might be implemented by societal stakeholders other than the operator or regulator. It consists of those actions, mechanisms and/or arrangements implemented in order to check that the environmental conditions are not degrading and to maintain knowledge of the repository facility after closure in order to inform current and future generations of hazards and risks.

Typically, controls may be classified as structural controls which include features and physical devices constructed to control access and non-structural controls which rely on legal and administrative initiatives.

Maintaining indirect oversight on the repository site can be achieved by records, knowledge and memory (RK&M project [9]) or through more active means:

- Maintaining records and memory that are designed to warn and inform future generations about the nature and location of site hazards without significant institutional intervention include :
  - Records keeping: local, national, international ;
  - Land use records ;
  - Development of centers of interest ;

- Knowledge mothballing for later revival ;
- Markers and monuments.

- Additional means of indirect oversight include for example:
  - Maintaining a protection zone with control of site access to prevent deep drillings in the surroundings of the repository ;
  - Land use restriction ;
  - Monitoring under various local, national, international arrangements.

Monitoring and surveillance may change in nature but they are likely to be maintained as long as appropriate institutions exist and that future generations are convinced that these measures are beneficial for safety (or to keep the retrievability option open). Any post-closure monitoring decided by future generations would need to be designed in such way that no significant negative impacts on the performance of the containment barriers and therefore on the long term safety of the repository would occur; this would require a sound knowledge of the facility.

Due consideration must be given to reach a balance between what is expected of monitoring and what is technologically feasible. It may possible to obtain *in situ* data even after closure but such monitoring may be constrained by limits on the amount and duration of data collection. Surface-based techniques providing data on the macroscopic evolution of the closed repository and ongoing-monitoring in deep boreholes could also be implemented as such activities are not technically influenced by the process of closure. Safeguards controls may continue to apply.

Different means of indirect oversight may be required by the regulator, national institutions or future generations. They will be implemented, successively or in parallel, by regulatory control, by interest of local people and by memory keeping at the local, national or international level. As far as is feasible, the approach to indirect oversight will need to be planned in advance and proposals presented in the application for a construction licence, particularly where they may impact the design of the geological disposal facility. Presenting proposals at this early stage may contribute to building confidence in the safety of geological disposal facility and also to its acceptance.

5 – Duration of post-closure oversight

The intention is not to lose memory of the existence of the disposal facility. The post-closure period is likely to begin with a period of formal institutional indirect oversight. It is reasonable to expect that monitoring and surveillance would be maintained for as long as society considers it beneficial, even though it is a characteristic of geological disposal – and part of the basis for the closure licence granted by the regulator – that safety does not depend on post-closure monitoring. The duration of active and passive controls will be different. The use of passive controls, such as the preservation of information, the use of markers and archives, including international archives, is likely to help reduce the risk of intrusion into a disposal facility over a much longer timescale than active controls.

During the time of indirect oversight, there might be some presence of people/staff/operator at the site. Knowledge is maintained, monitoring may continue to occur and some corrective actions could be made if needed. However, in most cases, options to address radiological protection will be indirect. As time progresses the degree of oversight may change, corresponding, for example, to less frequent inspections. The decisions to reduce the level of oversight would be based to some extent on the degree of confidence in the behavior of the facility, and other societal and economic factors. Decisions related to the organization and evolution of the oversight should be discussed with the stakeholders concerned.

6 – Responsibilities for oversight

The safety of the geological disposal facility is first and foremost the responsibility of its implementer and operator under the supervision of an independent regulatory body. Society at large is expected to play an influential role in choosing major options that affect safety, such as the location of the facility and, possibly, how the facility is to be managed over time.

During the time of direct oversight, the operator, overseen by the regulator and in interaction with the concerned stakeholders, will be able to actively manage the protection of workers, the public and the environment through direct and indirect actions. We may distinguish the role of the operator, regulator and stakeholders during the pre-operational and operational phases, and the post-closure phase.

During the pre-operational and operational phases:

- The role of the operator is to prepare, implement and regularly update a monitoring and surveillance programme during the operational phase. Where specific provision is made for possible waste retrieval, monitoring during the operational period will be needed to contribute to decisions as to whether to retrieve waste or to move towards the closure phase.

- The role of the regulator is to approve this programme (if appropriate) and control its implementation by inspections and possible independent measurements and, if necessary, decide on corrective actions to be implemented by the operator. This part may be called regulatory oversight.

- This regulatory oversight will be performed in cooperation with relevant stakeholders.

During the post-closure phase there is a shared responsibility of regulators and stakeholders:

- After closure, a period of indirect regulatory oversight may be planned in the operational license. Following this period, maintaining indirect oversight and memory of the facility is likely to become a societal responsibility, possibly discharged through national or local government. One might expect that society would maintain forms of indirect oversight and memory as long as possible. However, there is no guarantee on their existence in the distant future.

- Responsibilities for “who does what” after closure have not been defined yet. However, technical studies to this effect are being carried out by radioactive waste management agencies in consultation with other stakeholders, e.g., the RK&M project [10].

One type of control that might continue after active indirect oversight has ceased is the preservation of memory or records of the presence of a geological disposal facility. Other measures, such as restrictions on land use, decided by the authorities in interaction with the different stakeholders, might also apply. Measures to preserve the memory of a facility might help reduce the probability of inadvertent human intrusion and may assist the justification and planning for any deliberate maintenance action or retrieval operation of waste should this be required in the future. At some point in the distant future, the memory of the presence of the disposal facility may be lost. The choice of location of the geological disposal facility and its technical design will constitute the remaining "built-in control” against inadvertent intrusion into the facility.

Some national approaches plan emplacement and backfilling strategies that would result in direct oversight of the site lasting for several tens of years after the start of operations. It is not possible to know the criteria that may be used by the people making decisions at that time. The different decisions to be made relating to the evolution of the oversight should be discussed with stakeholders.

7 – Planning for oversight

Planning for oversight during the operational period

The basis for planning for oversight should take into account the following statement from the ICRP :
"During the operational period, the operator, overseen by the regulator, in interaction with the concerned stakeholders, will be able to actively manage the protection of workers, the public and the environment through a variety of actions. During this timeframe both direct and indirect oversight will take place as parts of the disposal facility will be under direct oversight, and at the same time others will be under indirect oversight."

Before the operational phase, the implementer prepares a monitoring and surveillance programme (oversight programme) which is periodically updated on the basis of the experience feedback from operations. All monitoring is conducted to inform the decision process, either indirectly, e.g. by enhancing the science basis used to develop predictive models, or directly, e.g. by verifying in-situ evolutions do not exceed certain trigger values. The programme should meet, at least, the following general objectives [11]:

- demonstrate that, so far, the disposal system is functioning as expected. This means that the components fulfil their functions as specified in the safety case and that actual conditions are consistent with the assumptions made for assessing post-closure safety;

- strengthen the understanding of aspects of system behaviour used in developing the safety case and allow further testing of models used to predict them.

As part of regulatory oversight, this programme should be approved by the regulator and presented to the concerned stakeholders to take their suggestions into account. Its implementation is controlled by the regulator through inspections and may be verified by independent measurements.

This was acknowledged in the IAEA TECDOC on monitoring from 2001 which states that : "*monitoring plans will be revised periodically in response to technical developments and modifications to the repository design and changing societal demands for information*" [12]. Dialogue and its documentation become a means to assure transfer of knowledge, awareness and ultimately, helps develop higher confidence in safety.

An important role of the monitoring programme will be to provide information and data to inform an assessment of the options available to further conduct the disposal process prior to closure. Some national contexts have identified legal provisions governing the process of authorizing closure, which would include review by safety authorities and possibly call for a dedicated law for repository closure. There seems to be, at present, only limited guidance or understanding available on how decision points between granting of a license and closing the repository would be addressed, e.g. if, when and how stakeholders including safety authorities would be involved. In particular, there is no clear understanding on the relative weight monitoring data would carry to informing these decisions. It may be assumed that monitoring results obtained in-situ or from associated long term science activities will provide a significant basis for decisions on further disposal process management.

A certain number of limitations of monitoring can be recognized. These are primarily due to five considerations:

- Monitoring is limited in time, and even in a very favourable monitoring environment that allows in-situ data to be collected over a century scale time period, some natural processes, which operate on substantially longer timescales, will not be detectable;

- Monitoring is limited in space, as practical considerations of disposal process management may constrain monitoring activities to limit any undue interference with waste emplacement operations and closure of filled parts of a repository;

- Monitoring is constrained by the requirement to preserve favourable properties for long term safety and monitoring activities cannot reduce the expected performances of the natural environment or of the engineered barriers;

- Monitoring is constrained by local environmental conditions and monitoring systems must be designed for durable operations under possibly harsh conditions, e.g. saline groundwater or elevated temperatures within the waste disposal units;

- Monitoring is constrained by available technology and certain specific parameters may not be directly accessible for in-situ monitoring.

For all of these, it is important to achieve a balance between the added value monitoring can bring to a transparent and informed management of the disposal process, and the potential risk to operational activities and to long term safety.

Planning for oversight during the post-operational period

During the operational phase, the operator will develop an application to close and seal the facility. The confirmation of the basis used to evaluate long term safety is a prerequisite to obtaining authorization to move to post-closure. Therefore, performance monitoring to obtain information and data relevant to long term safety is likely to be conducted prior to closure of the repository. It is not clear at this stage whether additional monitoring may be called for after closure but, during the operational phase, the operator will need to prepare a draft plan for post-closure institutional oversight. The corresponding financial provisions and organizational arrangements should also be planned.

Two arguments can be provided to suggest that this cannot reasonably be developed to a great level of detail at the present stage. First, the decision on closing a repository is on the order of a century away. It would be presumptuous to guess at what type of further monitoring requirements, if any, might be expressed at that time. Second, the decision to definitely close a repository – at least from today's perspective – is preceded by (i) a century of experience with disposing of waste, managing a repository and obtaining information from in-situ monitoring and from a parallel long term science and technology programme, (ii) confirmation and re-evaluation of the safety case prior to closure. It might then be argued that, should any residual questions remain concerning the long term safety of the repository, then the decision to close the repository would need to be postponed. Conversely, if stakeholders agree on having confidence in the long term safety, it would be difficult to associate this view with a request for further monitoring.

An exception may be the case when repository closure would call for a near- or far-field response that can be monitored over reasonable time scales, and that was not already seen subsequent to partial closure of, say, disposal drifts. For instance, the hydrogeological response to closure in crystalline rock might deserve special attention. In that case, ongoing monitoring from distant boreholes may provide useful information over a time span beginning prior to construction, throughout operation and until the early post-closure phase.

The above does not apply to surface based post-closure monitoring, as may be warranted during an institutional control period, for the purposes of, for example, intrusion prevention and nuclear safeguards surveillance.

At the start of the post-closure phase, the operator will need to present a firm plan for institutional controls and continuing monitoring and surveillance. The regulator, likely in interaction with local political

decision-makers and concerned stakeholders, will need to agree what controls, monitoring and surveillance are required and for how long.

8 – Societal expectation and challenges

The MoDeRn project [13] outlines that many countries have set up initiatives for lay stakeholder engagement in radioactive waste management, including oversight of geological disposal facilities, in one way or another. In some cases such initiatives have a relatively long history, in others they are of a more recent nature. Differences exist between the level at which these interactions take (or have taken) place: at the national level, in view of general policy decisions (such as the choice for geological disposal as the preferred final solution); or at the local and/or regional level in view of siting a disposal facility. Furthermore, in several countries different engagement initiatives were undertaken, following different approaches, for different types of options, facilities and/or waste categories. This may be a basis to envisage how lay stakeholder inputs might affect the development of national monitoring programmes in the future.

Thus far, relatively few countries have engaged with lay stakeholders specifically on the subject of monitoring. This is mainly because national disposal programmes are at a relatively early stage of implementation. A range of initiatives to engage with lay stakeholders on broader issues of radioactive waste management in different countries have nevertheless identified some key views and expectations that may influence decisions on repository monitoring:

- Monitoring to provide assurance: i.e. to demonstrate good practice and to verify the adequacy of the basis for the long-term safety case;
- Monitoring to aid decision making in a stepwise process and to provide transparency; and through this :
- Potential for sharing knowledge and make (to some extent) visible what is happening below the surface and thus, almost literally, opening the ’black box’ to stakeholder scrutiny.
- Raise the potential for independent oversight: Availability of data creates opportunity for checks and balances and for independent expert judgement.

Lay stakeholder expectations of monitoring have mainly been expressed indirectly and at quite a high level to-date. Such expectations could be factored into the development of monitoring objectives and strategies. However, it is unlikely that current understanding of lay stakeholder opinions could be used to guide the selection of specific monitoring parameters, or the development of a monitoring programme, because available information is not sufficiently detailed.

The importance of developing a better understanding of lay stakeholder expectations is recognized by the MoDeRn project. Often, expert stakeholders’, and, in particular, the implementer’s, perceptions of such expectations is currently based on written evidence from engagement activities involving lay stakeholders. Engagement events provide the opportunity for expert stakeholder to elicit lay stakeholder views directly, and to learn about their concerns. The enhanced understanding and experience gained by those experts involved in lay stakeholder engagement can be applied in subsequent discussions, and further contribute to clarifying how monitoring may contribute to confidence and acceptability of the disposal process. The degree to which such input is informed by direct engagement may vary, and opinions should be supported, where possible, by written evidence. Nevertheless, experts’ perceptions of lay stakeholder expectations provide a valuable tool for informing others and sharing information, which can help to avoid reinventing the wheel in future planning and engagement activities.

At this stage, the understanding of the impact of lay stakeholder views on the development of monitoring programmes requires further development. The extent of lay stakeholder engagement to-date on the subject

of monitoring suggests that definitive conclusions should not be drawn without more extensive consultation and debate.

According to an ongoing NEA survey [14], local communities seem to demand specific monitoring developments mainly in the pre-operational and operational phases. The extent to which these demands are made and the priorities of local communities depend on the country and the stage of the geological disposal programme. Societal concerns in the operational phase refer in the first place to environmental monitoring and secondly to monitoring of socio-economic impacts.

In the UK, "monitoring and testing performance" are issues of concern to the local authorities, and they can be crucial as the national approach is to seek "suitable" (i.e., not necessarily "best") geology and the repository designed to site circumstances [15]. In Sweden, demands on monitoring and preservation of RK&M have emerged at the local level and will be an issue to be looked at by both SKB and the Swedish Council for Nuclear Waste. In Canada indigenous people have been very explicit about the need to monitor both the environment and the nuclear waste management system. They recommended the setting up of a special Aboriginal Nuclear Waste Monitoring Agency to be active as long as possible. In France, the FSC workshop in Bar-le-Duc in 2009 showed that the CLIS was particularly concerned about public health and that epidemiological monitoring is a key issue [16]. Overall, local communities can contribute to monitoring. Partnerships can also enable the local community to undertake some of the monitoring tasks, including monitoring other institutions performance [17].

From the ongoing NEA survey, requests for monitoring in the post-operational phase are not so clearly expressed by local communities, compared to monitoring during the pre-operational and operational phases. When monitoring is requested, environmental monitoring is the main concern. Nevertheless, it is clear that there is an emerging role for local communities in local stewardship, which involves oversight basically in perpetuity [18]. There is a high debate in France on the contribution of local people to preserve memory; Sweden seems to be still entering this field and discussing which would be the best way to pass knowledge on to future generations. Tools for the local community to maintain memory are country specific and range from land registers and markers, to oral history, regular dissemination and developing the culture of memory in institutions and territories [19].

9 – Status of national guidance

When looking at the legal and regulatory frameworks described in the national context overviews, the levels of detail in which monitoring requirements and approaches are specified vary considerably. Even though some of these national frameworks provide a basis for what needs to be included in a monitoring programme, this tends to be described in relatively general terms, without too much (if any) specification on how the act of monitoring is defined. Mention may be made of a stepwise implementation process, but no details are available on how decisions at each step should be taken. Some regulations may include specific requirements for implementation strategies, e.g. the Swiss regulator calls for monitoring to be conducted in a pilot facility.

The French guidelines also address monitoring to inform reversible disposal management, especially as related to structural integrity of waste disposal packages and disposal cell conditions over time to retain flexibility for potential waste retrieval.

A special case is post-closure monitoring. Several regulations or guidelines make explicit mention of this, but do not specify whether that should be a form of environmental surface monitoring, or a form of below surface repository monitoring. It is also unclear whether the expectations are about monitoring construction, possible migration of radionuclides from the facility, access control for nuclear safeguards (e.g. no unauthorised excavations), or to check for large scale evolutions such as indicated by surface subsidence.

It appears that safety authorities and other expert stakeholders such as national review boards are gradually placing greater emphasis on monitoring. At this stage, it does not appear, however, that detailed

expectations are expressed. A number of general considerations can be identified, e.g. related to the longevity of some of the possible monitoring and thus the need to address related technological difficulties, and related to the preservation of safety functions in a monitored repository. There seems to be agreement that in-situ monitoring offers some added value and possibly reassurance for the long

The duration of post-closure monitoring will vary nation by nation. For example, in Switzerland it will continue "… as long as it is thought beneficial to society". For the US WIPP facility: the programme will last until "…no more meaningful data are being collected". Other programmes have not yet made explicit the extent and duration of post closure monitoring.

Reasons for post-closure monitoring can be diverse. The ongoing NEA study has compiled the following expressed reasons, so far:

- Safeguards (Belgium, Canada, Germany, Netherlands, Spain, Sweden, Switzerland).
- To understand the evolution of the near-field (Netherlands, Sweden).
- To determine the post-closure evolution of the geosphere (WIPP, Belgium, Canada, Netherlands, Russia).
- To evaluate the impacts of the repository on the surface (Canada, Netherlands).
- To confirm performance assessment assumptions (WIPP, Yucca Mountain, Canada, Finland, Spain).
- As an aid to decision-making - retrieval the waste or ending the institutional control phase (Belgium, France, Japan, Netherlands).
- To gain public acceptability and public confidence (Belgium, Canada, Germany, Japan, Sweden, Switzerland).
- To assure legal requirement (the Netherlands, WIPP, Yucca Mountain, Hungary).

10 – Key messages for developing international and national guidance

The above study indicates that the following conclusions can be drawn at this stage :

- Even though the long term safety of a geological disposal facility relies ultimately on safety provisions and passive controls built into the disposal facility there should be no intent to terminate oversight of the disposal facility. The disposal facility is a functioning facility at all times and oversight must be maintained as long as memory is preserved.
- Oversight or "watchful care" is the reference concept in the new recommendations of the International Commission on Radiological Protection (ICRP) related to geological disposal of long-lived solid radioactive waste. The concept of control was previously used implying the specific role of a regulatory body. Oversight is complementary to control in the sense that it relates to activities of society at large. It includes regulatory supervision and control, preservation of societal records and societal memory of the presence of the facility. It is more appropriate than control which may also refer to passive provisions built into the repository system.

- Three levels of oversight of the waste are expected over the lifetime of a repository. When the repository is being built and operated, direct oversight of the waste may be exercised through active control if repository galleries are not yet sealed; when the waste is no longer accessible, which is the case when parts or the whole repository are sealed, only indirect forms of oversight may be available which, depending on the time period, may include such institutional arrangements as surface monitoring or maintaining records and memory. If memory of the disposal facility is lost, there is absence of oversight.
- The level of oversight is a crucial factor that influences the application of the protection system over the different phases during the lifetime of a geological disposal facility. It affects the capability to manage the source and to avoid or reduce some exposures.
- Regulatory oversight may be exercised during the operational phase and at the beginning of the post-closure phase. In order to increase confidence in the safety of the disposal facility it is important that oversight by society at large, in the sense of 'watchful care', be exercised from the beginning of the project which means that the different decisions to be made relating to the evolution of the oversight should be discussed with stakeholders. Moreover, societal oversight may be considered more likely to endure further into the future than regulatory control and could reduce the likelihood of inadvertent human intrusion in the medium term.
- Before the operational phase, the implementer prepares a monitoring and surveillance programme (oversight programme) which is periodically updated on the basis of the experience feedback from operations. As part of regulatory oversight, this programme should be approved by the regulator and presented to the concerned stakeholders to take their suggestions into account. Its implementation is controlled by the regulator through inspections and may be verified by independent measurements.
- Post-closure oversight can be exercised through monitoring of technical parameters such as groundwater, geotechnical and environmental parameters and through technical analyses of those data; oversight can also be exercised through monitoring institutional provisions meant to be protective of the repository, e.g., land withdrawal provisions established by law; oversight can also be exercised, in a broader sense, through monitoring agreements made with the local hosts. Implementers, regulators, policy makers, local communities may be variously engaged in these oversight/monitoring activities. From this point of view it must be born in mind that monitoring serves the purpose of oversight and is part of the latter. At the same time oversight serves the purpose of preservation of records, knowledge and memory of the facility. In order to find an optimal oversight approach it is important to harmonise social and technical demands from the beginning.
- It should be noted that any post-closure monitoring decided by future generations should be designed in such a way that no significant negative impacts on the performance of the containment barriers and therefore on the long term safety of the repository would occur. Due consideration must therefore be given to reach a balance between what is expected of monitoring and what is technologically feasible.

- As time progresses the degree of oversight may change, corresponding, for example, to less frequent inspections. The decisions to reduce the level of oversight would be based to some extent on the degree of confidence in the behavior of the facility, and other societal and economic factors. Decisions related to the organization and evolution of the oversight will need to be discussed with the stakeholders concerned.

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