Perspectives on Radioactive Waste Repository Monitoring

Confirmation, Compliance, Confidence Building, and Societal Vigilance

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Monitoring is now widely seen as a necessary part of programmes for the geological disposal of radioactive waste. However, we find different perspectives on the nature and role of monitoring. Among technical experts it is viewed firstly as a matter of performance confirmation, a tool for validating the safety case underlying repository construction. Among concerned citizens we find a view of monitoring as enabling the critical scrutiny of safety, an instrument for acknowledging uncertainties and detecting emergent problems in a repository. After outlining differing views on questions of whether, why, what, where and for how long to monitor we discuss monitoring in light of constant vigilance as a technical and moral principle of nuclear safety. We suggest that "how much monitoring" and "how should it be organised" are societal questions and as such need to be broadly discussed.

1 Introduction

Geological disposal of higher activity radioactive waste presents many technical and societal challenges, not least because of the timescales involved. Research on geological disposal has been carried out in different countries for about half a century, but only in the past decade or so monitoring has become a specific focus of political, policy, and research & development activity. Monitoring can refer to a range of different activities and arrangements, which raises questions of what is meant by monitoring and what is its purpose. Drawing on research conducted as part of an international project, MoDeRn, we explore the views of professional experts in the field of radioactive waste management and of community stakeholders on the nature and role of monitoring in geological disposal.[1] We find that monitoring has different meanings for different people, and that expectations of monitoring differ between groups in society. We point to a tension between two perspectives on how to assess monitoring. The first we find among technical experts, who tend to view monitoring in terms of performance confirmation; that is, as a tool for validating the repository design concept and its construction. The second view we find among lay stakeholders, many of whom see monitoring in terms of the critical assessment of safety; that is, as a form of surveillance that acknowledges uncertainties and can detect unanticipated problems in a repository. We outline the different views that we have identified, structured as a series of questions about whether, why, what, how/where and for how long to monitor. We conclude by considering the role of monitoring in the governance of geological disposal and in particular in relation to the exercise of societal vigilance.

2 Empirical Data

The findings summarised here are based on several data sources: interviews with 18 specialists in European radioactive waste management organisations; observation of technical workshops on repository monitoring; workshops involving volunteers from communities which host existing nuclear facilities who have had varying degrees of engagement with radioactive waste management projects in Belgium, Sweden and the United Kingdom; a visit to two underground research laboratories (URLs) in Switzerland with a subset of these volunteers; and an analysis of strategic and technical documents on repository monitoring. Where possible, interviews and group discussions were recorded and fully transcribed to facilitate analysis. Interpretation of the results was supported by reference to relevant research literature. The analysis cannot claim to provide a representative categorisation of views on monitoring in relation to geological disposal but can provide insight into the understandings, concerns and reasoning of experts and affected citizens.

3 Whether and Why to Monitor

One thing on which all of our respondents agreed was that monitoring should be an integral part of repository development and design.[2] Waste management experts referred to two reports as being decisive in the way their community looks at monitoring today. The first of these is an International Atomic Energy Agency (IAEA) Technical Document on monitoring of geological repositories for high-level radioactive waste (IAEA 2001). In this report we find the first explicit definition of monitoring for geological disposal.[3] The second is the report of a European Thematic Network (ETN) on the role of monitoring in a phased approach to the geological disposal of radioactive waste (EC 2004). The structural integration of monitoring activities into the geological disposal process is therefore a relatively recent development. This has been marked by the inclusion of requirements relating to repository monitoring strategies in an IAEA Safety Standards document (IAEA 2006). This document states that safety should be ensured "by passive means inherent in the characteristics of the site and the facility and those of the waste packages" (IAEA 2006, p. 4), and should not depend upon monitoring and active management. The IAEA nevertheless envisages a contributory role for monitoring to support progress to the goal of passive safety.

The IAEA and the ETN reports give multiple reasons for monitoring a geological repository. These can be summarised as: (a) monitoring can enhance understanding of the behaviour of the repository system and its environment, (b) offer confirmation of the disposal concept, and thus (c) provide information on the repository system for purposes of decision-making now and in the future, thereby supporting a stepwise implementation of geological disposal. The IAEA Safety Standards document also refers to its role in confirming the conditions for operational and post-closure safety, thereby supplying an evidence base for decision-making at each stage (IAEA 2006). In addition, it is explicitly assumed that monitoring can support "public confidence" (IAEA 2001; EC 2004) or social or public "acceptance" (e.g. IAEA 2006)[4]. Providing assurance was explicitly mentioned by all of the technical specialists interviewed as one of the main drivers for monitoring, with distinctions being drawn between three different ways in which this is done:

- monitoring as a tool for performance assessment and quality assurance for the designer, modeller, implementer – providing data to verify both the repository system and the modelling behind it;
- monitoring as a way of demonstrating that the repository programme has successfully incorporated specific societal expectations by being compliant with regulatory requirements, thereby providing assurance to regulators, particularly in relation to operational safety and environmental impact assessment;
- monitoring as a means to build public confidence both by responding to (potentially changing) public demands for transparency and oversight of repository development and staged closure.

The potential role of monitoring in public confidence building was echoed in the workshops with local stakeholders in Belgium, Sweden and the United Kingdom (UK). The Belgian group, for example, came to the conclusion that confidence building and "keeping guard" over the safety of the facility were the main reasons for monitoring.[5] The UK group also identified stakeholder confidence in the safety of the repository as one of three reasons to monitor, the others being verification of compliance with regulations or standards, and "quality control" to support continuous improvement.[6] Informing both the Belgian view on keeping guard and UK views on verification of continued safety is a notion of maintaining watch over the repository, something to which we return below. Confidence building through compliance monitoring and quality control thus seems to be the key reasons for monitoring put forward by implementers, regulators and citizens. However, some subtle but significant differences can be detected between the viewpoints of these different actors.

One important difference is the emphasis put by regulators and implementers and their monitoring experts on performance *confirmation,* while citizens tended to emphasise quality control and *checking* expected behaviour. This difference is particularly evident where the question of long-term safety is concerned.

During a workshop with implementers and regulators,[7] it was stressed several times that the focus should be on performance *confirmation*, and not on *checking* performance (see Harvey/White 2011). Because these actors rely heavily on the safety case as the principal method for demonstrating confidence in the safety of the disposal system, they consider the checks on whether or not the system provides adequate safety to come from the development of the repository design, and from the site selection and site characterisation activities. Obtaining a licence for constructing and operating a repository, they argued, is proof of a high degree of confidence in the safe performance of a repository, and hence "there would not be reliance on monitoring as a basis for *ensuring* safety" (recorded in Harvey/White 2011, p. 18, *emphasis added*). In other words, monitoring must be dedicated to progressively reducing the need to repeatedly check on safety, to verifying the needlessness of continuing to look.

From accounts of the relationship between stakeholders and monitoring activities in the nuclear field published by the Nuclear Energy Agency and others, however, it seems clear that in many situations stakeholders expect a more critical assessment of safety, reflecting social science research on risk and trust (e.g. Giddens 1991; Simmons/Wynne 1993; Irwin 2008). They require not only operator and expert assurance of safety, but also the assurance of (independent) monitoring for any evidence of exposure to harmful releases. They may not expect monitoring to contribute to the safety of a facility, but do expect it to check that safety is ensured.

The only "lay" participant in the workshop referred to above observed that the focus on confirmation, rather than on checking, of expected behaviour appeared "rather arrogant, since the system might not perform as expected", pointing out that "implementers should not assume that monitoring will only confirm their expectations" (cited in Harvey/White 2011, p. 18). Similar arguments were made by participants in the Belgian, Swedish and UK workshops with community stakeholders. When the term ‚performance confirmation' was used in a presentation by a waste management organisation representative it was questioned by the Belgian group, as participants considered it inappropriate to take as a starting point the assumption that no problems can occur in future. They pointed out that in geological disposal one will never be completely certain that all will go well in future before starting implementation.[8] Monitoring was thus considered necessary to remain on guard, but was only seen as effective if accompanied by a response plan or what UK stakeholders referred to as a "Plan B" should anything unexpected be detected.[9] This raised the concern that designing monitoring programmes for performance confirmation is likely to lead to implementers prioritizing different measures to those which might be most appropriate for registering less likely or unexpected events.

4 What, Where and How to Monitor?

The IAEA and ETN documents identify a number of different types of monitoring, relating to: occupational health and safety during the operational phase; protection of the surrounding environment; performance confirmation and staged decision-making; and prevention of nuclear proliferation (EC 2004; IAEA 2001; IAEA 2006). From an implementer's perspective, monitoring the behaviour of the repository system from within the repository itself, for the purpose of verifying design elements supporting the long-term safety of the facility, is especially desirable during the phase of construction and operation, when changes in the design remain possible. It does, however, present two important challenges.

The first challenge is to identify processes that can be measured in the relatively short period before closure and which would conclusively confirm the basis for predictions of (very) long-term system behaviour. Although discussion continues about which parameters should be measured, the following aspects can be noted. The position taken by the technical specialists interviewed was that it will be possible to identify measurable parameters that would enable them to validate (and if need be calibrate) the models on which they build their safety cases. But for both technical and financial reasons the parameters selected are likely to be few in number.

The second challenge is how to organise such monitoring without compromising fundamental safety barriers. This is an issue during the stages before closure but is seen as particularly problematic after (partial) closure of the facility. Hence, they are investigating options for non-intrusive techniques, such as wireless sensor networks and wireless through-the-earth data transmission, fibre-optic technologies and geophysical techniques, monitoring of groundwater chemistry, geotechnical monitoring, and aerial or satellite-based monitoring. Although some of these techniques look promising, several require much further research to adapt them to the requirements of repository monitoring (White et al. 2010).

From our interviews, it seems that there is a widely held perception in the expert community that public and stakeholder expectations were likely to focus on environmental monitoring to protect against human health impacts. A review of literature on citizen and stakeholder engagement with monitoring seems to corroborate this perception, as most of the activities reported involved some sort of environmental monitoring. In several cases monitoring was commissioned or conducted by local institutional stakeholders, particularly local government, including in some cases monitoring of the socioeconomic environment (e.g. Conway et al. 2009). Dissatisfaction with or distrust of institutions also led members of some communities to demand or initiate participatory environmental monitoring, involving citizens in data collection (e.g. Vári/Ferencz 2007; NEA 2009). In the field of radioactive waste and other nuclear industry facilities, there is considerable evidence of stakeholder and citizen involvement in facility monitoring activities (e.g. NEA 2003; NEA 2010). This demonstrates the desire of citizens and communities in many different contexts for active engagement with facility monitoring programmes.

From our own engagement exercises, we learned that local citizens were generally less concerned about which parameters or at which exact location to monitor. What they insisted upon was that a monitoring programme for geological disposal should be as comprehensive as possible, including both near-field and far-field monitoring, as well as the socioeconomic environment. Both the Belgian and UK groups acknowledged a tension between potentially intrusive near-field monitoring and the integrity of barriers and seals. It was also considered important, notably by the Belgian group, to continue searching for alternative techniques or parameters for repository processes that would be difficult to monitor with current technology, and to consider laboratory simulations as substitutes for near-field monitoring (e.g. in a post-closure situation).[10] On the other hand, this question of monitoring processes in underground laboratories or pilot facilities during repository development to reduce the need for directly monitoring the repository during implementation also raised some concerns about the need "to know what happens in reality" and was questioned in the Swedish discussions. [11]

5 How Long to Monitor?

On the question of how long to monitor, technical specialists and concerned citizens again tended to differ. Post-closure monitoring was considered by experts to be technically unnecessary, as they did not expect anything to be detected once closure had ensured passive safety. For them, monitoring is dedicated to confirming that the conditions outlined in the regulatory safety case have been achieved and to supporting repository closure. Post-closure near-field monitoring in particular was said by many of them to be unrealistic and even potentially counterproductive insofar as the techniques used might contribute to compromising barrier integrity. Nevertheless, many experts interviewed accepted that there could be value in post-closure monitoring if it served to reassure others, such as local communities – a position also expressed in technical guidance documents (e.g. IAEA 2006). It was noted by some of our interviewees that although there may be currently little evidence of statutory requirements for post-closure monitoring for reasons of radiological protection, it seemed likely that they would be introduced in some countries in the future in response to societal demands.

Evidence from the Belgian, Swedish and UK workshops confirmed that many engaged citizens do have expectations and concerns regarding post-closure monitoring, and are unlikely to let the issue be ignored. Less clear was the type of monitoring (near-field, far-field or surface environment) they would expect in the post-closure period. In the Swedish workshop it was pointed out that even if post-closure monitoring is considered desirable, the necessary technological innovation is unlikely to happen without the purposeful allocation of funds to research and development. Community stakeholders were therefore concerned about post-closure safety but, unlike the technical experts, tended to see continued monitoring of some sort as necessary not merely to confirm that the evolution of the repository system conforms to technical expectations but to ensure that it continues to do so and is not affected by unanticipated events or evolutions, a concern to which we return in our final section.

6 Monitoring and (Risk) Governance

What is the role of monitoring in (risk) governance of geological repositories? One of the key principles informing the management and regulation of nuclear safety is that of constant surveillance. This is firstly a political and moral principle, and it expresses what societies interpret nuclear safety to mean. Monitoring programmes are therefore ways of putting the moral principle of tireless vigilance into technical practice. This is particularly the case for nuclear installations such as power plants, reprocessing plants and storage facilities, as pointed out by nuclear scientist Alvin Weinberg when he referred to the unusual degree of vigilance which had to be exercised over programmes of nuclear power generation during the entire course of their development in order to guarantee safety (Weinberg 1972). Geological repositories, incorporating the technical – and moral – principle of passive safety, can be understood as a way to renegotiate the need for unremitting vigilance by delegating responsibility for safety to an engineered geological disposal system. Weinberg believed that effective geological disposal reduced the need for vigilance to a minimum, in line with current expert thinking that all that will be needed of society to ensure safety is surveillance to avoid intentional or unintentional human intrusion into the repository system.[12] However, our exploratory engagement with community stakeholders from three European countries suggests that more is expected by many citizens.

These are, as Weinberg reminds us, societal questions that cannot be answered from a technical-expert perspective alone (Weinberg 1972). Society will have to decide what kind of human vigilance is needed and for how long it should continue. Nevertheless, to relinquish direct control of the wastes will require societal confidence in the repository system and trust in those responsible for designing, implementing, overseeing and regulating it. It may therefore be easier for national and local decision-makers – and the communities they represent – to commit to taking successive steps in repository siting, development, licensing, construction and operation if the contingent nature of their trust and commitment[13] at each and every stage is acknowledged and the opportunity to re-evaluate or even veto plans is upheld.

In addition to providing confirmation of the models upon which the safety case is based, therefore, there is another way in which monitoring can support public confidence. This is by helping to demonstrate that the implementer of a disposal programme recognises that there are systemic uncertainties and is taking a precautionary approach,[14] although this potential role of monitoring was not emphasised explicitly in our workshops. Such open acknowledgement of uncertainty is not without its risks, in that it may appear to bring into question the premise of passive safety as the technological solution to the socio-technical problem of guaranteeing unflagging vigilance over long-lived high-level radioactive waste. By introducing the notion of retrievability or reversibility into law, however, countries such as Switzerland and France are already moving towards an adapted socio-technical solution one still directed towards achieving passive safety, but which recognises that this end point may be further away than initially envisaged, subject to a longer chain of socio-technical decision-making, and may not be final.[15] This reminds us that we may inevitably pass the burden of decision about final closure to subsequent generations. Acknowledging this demands that we think specifically about the type of information, knowledge and skills that need to be passed on to future generations, and the role that monitoring might play in meeting the needs of future operators, regulators, decision-makers and affected citizens.

Notes

1) A full description of the project and copies of published reports cited here can be found at: http://www.modern-fp7.eu/home/.
2) There are nevertheless evident national differences in the attention given to monitoring by radioactive waste management organisations and regulators, a point to which we return further on in this paper. This is often associated with different disposal

concepts: in France, for example, where reversibility has become a policy requirement, monitoring has been the focus of research and development, whereas in Sweden, where the proposed concept does not envisage retrievability of wastes, monitoring is not viewed as the same challenge.

3) Monitoring is defined here as "...continuous or periodic observations and measurements of engineering, environmental or radiological parameters, to help evaluate the behaviour of components of the repository system, or the impacts of the repository and its operation on the environment". (IAEA 2001, p. 1)
4) In this last document, the role of monitoring for social or public acceptability is particularly linked to the question of post-closure safety.
5) MoDeRn Exploratory Engagement Exercise, Mol, Belgium, December 15, 2011.
6) MoDeRn Exploratory Engagement Exercise, Birmingham, UK, April 19, 2012.
7) MoDeRn Expert Stakeholder Workshop, Oxford, UK, May 4–5, 2011.
8) MoDeRn Exploratory Engagement Exercise, Mol, Belgium, February 2, 2012.
9) MoDeRn Exploratory Engagement Exercise, Mol, Belgium, December 15, 2011; Birmingham, UK, April 19, 2012.
10) MoDeRn Exploratory Engagement Exercise, Mol, Belgium, May 24, 2012.
11) MoDeRn Exploratory Engagement Exercise, Östhammar, Sweden, March 16, 2012.
12) International guidelines require external safeguards monitoring of human access in order to prevent the proliferation of nuclear materials (IAEA 2001).
13) On the provisional nature of social trust see, for example, Lewis/Weigert 1985; Giddens 1991; Jones/George 1998.
14) On uncertainty, precaution and the governance of technology see, for example, Stirling 2006.
15) For a discussion of the adoption of the principle of reversibility in French radioactive waste policy see Barthe 2009.

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Monitoring im Endlager: notwendig für die Akzeptanz?

Anmerkungen aus Sicht eines Betreibers von Zwischenlagern

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Das Monitoring eines Endlagers kann im Sinne der Internationalen Atomenergie-Organisation (IAEA) als vertrauensbildende Maßnahme verstanden werden, die in einem definierten Zeitraum während und nach der Betriebsphase durchgeführt wird. Erste Erfahrungen mit Monitoring wurden in Deutschland bereits bei den bestehenden Zwischenlagern gemacht. Basierend auf diesen Erfahrungen werden hier aus Sicht eines Nukleardienstleisters Randbedingungen und Möglichkeiten des Monitorings eines Endlagers aufgezeigt und der mögliche Beitrag von Monitoring zur gesellschaftlichen Akzeptanz eines Endlagers diskutiert.

1 Einführung

Die zentrale Aufgabe eines Endlagers für radioaktive Abfälle in tiefen geologischen Formationen ist es, Radionuklide dauerhaft von den Stoffkreisläufen zu isolieren. Den nachfolgenden Generationen sollen dabei keine Lasten aufgebürdet werden, d. h. das Endlager soll wartungs- und überwachungsfrei funktionieren. Ein Endlagersystem für hochradioaktive Abfälle ist nur dann genehmigungsfähig, wenn in einem Langzeitsicherheitsnachweis gezeigt werden kann, dass diese Ziele mindestens für den regulatorisch geforderten Nachweiszeitraum erreicht werden. In Deutschland sind das eine Million Jahre, also ein weitaus längerer Zeitraum als der, der seit der letzten Eiszeit vergangen ist. Ob sich das Endlagersystem bzw. die einzelnen Komponenten des Systems in der erwarteten Weise entwickeln, kann durch ein Monitoring geprüft werden. Die Internationale Atomenergie-Organisation (IAEA) definiert Monitoring als „continuous or periodic observations and measurements of environmental, engineering, or radiological parameters to