A Socio-Technical Perspective on Repository Monitoring - 12229

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ABSTRACT

Monitoring geological repositories for high-activity radioactive wastes has both technical and social dimensions, which are closely interrelated. To investigate the implications of this for geological disposal, data on experts' expectations of repository monitoring and the functions that it is expected to serve were analysed. The analysis drew on strategic and technical documents on monitoring produced by national agencies and by international organisations or projects; interviews with specialists in radioactive waste management organisations on monitoring and on their perceptions of societal concerns and expectations; and observations from technical workshops on repository monitoring. Three main rationales for monitoring were found: performance confirmation; decision support in a step-wise process; and public and stakeholder confidence building. The expectation that monitoring will enhance public confidence is then examined from a social scientific perspective and the potential for and challenges to using monitoring in this way are reviewed. In conclusion, implications for stakeholder engagement in the development of monitoring objectives and strategies are discussed.

INTRODUCTION

Monitoring geological repositories for high-activity radioactive wastes has both technical and social dimensions. These two dimensions are closely interrelated, to the extent that one may more properly characterise monitoring as a *socio-technical* activity. In order to understand more fully the implications of this for the development of effective monitoring programmes, the perspectives and expectations of technical experts and other specialists within waste management agencies and associated research organisations on repository monitoring and the functions that it is expected to serve were sought and analysed. The research was carried out as part of a multidisciplinary international research project on Monitoring Developments for Safe Repository Operation and Staged Closure (MoDeRn).[1] Data were drawn from: strategic and technical documents on monitoring produced by international organisations and projects, as well as by national agencies; interviews with 18 specialists in European radioactive waste management organisations which covered their views on monitoring and their perceptions of societal concerns and expectations; and observation of technical workshops on repository monitoring. Where possible, interviews were recorded and fully transcribed to facilitate analysis, which consisted of thematic content analysis. Interpretation of the results was supported by reference to the research literature in the field of social studies of science and technology. The main findings are summarised in the next section, followed by a discussion that relates them to the social-theoretical and social research literature, and the final section considers the implications for the use of monitoring as a means of enhancing public and stakeholder confidence in geological disposal.

[1] A full description of the project can be found at: http://www.modern-fp7.eu/home/.

EXPERT VIEWS ON MONITORING

The structural integration of monitoring activities into the geological disposal process is a relatively recent development. This has been marked at international level by an International Atomic Energy Agency report, published in 2001, on monitoring of geological repositories for high level radioactive waste, and the inclusion of safety requirements relating to monitoring strategies in its Safety Standards document published in 2006 [1, 2]. The 2004 report of the European Thematic Network on the role of monitoring in a phased approach to the geological disposal of radioactive waste was also cited as an important point of reference [3]. These documents identify a number of different types of monitoring: monitoring related to occupational health and safety during the operational phase; monitoring the surrounding environment for environmental protection; monitoring repository processes for a variety of technical reasons and to support staged decision making; and safeguard monitoring to prevent nuclear proliferation. In addition, these and other documents state that monitoring can support public confidence.

In the MoDeRn project the focus is on strategies for measuring the behaviour of the repository system. For the experts interviewed, monitoring is therefore about seeking confirmation that the repository performs as required and that their science-based expectations about the evolution of the repository system, on which the safety case is based, are correct. More broadly, monitoring was also seen as being about providing information on the repository system for purposes of decision-making. The issue of (re)assurance and confidence building was explicitly and repeatedly mentioned by all respondents as one of the main drivers for monitoring. Three dimensions to this role of monitoring were emphasized:

1. Monitoring as a means of assurance for the designer, modeller, implementer
    - Monitoring was understood as a tool for verifying both the repository system and the modelling behind it.
    - Monitoring was seen as especially advantageous during the phase of construction and operation when changes in the design remain possible.
    - Post-closure monitoring tended to be seen as unnecessary and even unrealistic - and even potentially counterproductive if it were to compromise barrier functions - but it was also noted that it may be of value to reassure non-expert stakeholders.

2. Monitoring to assure the regulator
    - Monitoring for compliance and to assure the regulator was particularly mentioned in the context of meeting regulatory requirements relating to operational safety and environmental impact assessment.
    - Monitoring to assure the regulator of repository performance was also seen as important, not least because of the intermediate position the regulator holds between the implementer and the public.
    - It was also noted that although there may be 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.

3. Monitoring to reassure the public: building public confidence in the repository
    - Based on the impressions of lay-stakeholder concerns that our interviewees expressed, it seems that there is a widely held perception that public and stakeholder expectations are likely to focus on environmental monitoring, both in terms of the operational management of the facility and of long-term post-closure safety, in order to protect against environmental and therefore human health impacts.

- Finally, and importantly, from the documents examined and the interviews conducted there appeared to be a general consensus within the expert community that monitoring has a major role to play in building public confidence in geological disposal, although the social process by which it might produce this effect was not identified.

One possible interpretation of this last point in light of expert views of the purposes of monitoring is that the production of monitoring data which corroborate models will provide evidence to support claims to long-term safety.[2]

When asked about stakeholder expectations of monitoring most experts said that they had not yet explicitly discussed monitoring strategies with local stakeholders. Many experts therefore found it difficult to anticipate what lay stakeholder expectations might be and whether it would be feasible to address them. One recurrently expressed view was that local and public stakeholders would be more interested in environmental monitoring than in near field monitoring, of the repository itself. Similarly several interviewees felt that post-closure monitoring was likely to be more a focus of public interest and concern than operational monitoring. These experts saw post-closure monitoring with the aim of providing assurance of long-term safety as a major challenge, particularly if this were to involve near field monitoring. Developing a post-closure repository monitoring strategy, if that were to be necessary, was considered by many of our respondents as still more of a question of R&D, than simply one of engineering and implementation.

This touches on two important questions. The first is how any requirement to monitor *within* the repository *after* closure would need to be reconciled with the principle of ensuring passive safety. The second is whether or not there are processes that can be measured in the relatively short period *before* closure which would conclusively validate the accuracy of predictions of system behaviour for a very long time after closure. But apart from finding solutions for monitoring without compromising the safety barriers (i.e. answering the question of *how* to monitor), there is continuing discussion about what exactly should be measured, about which parameters are important (i.e. the answers to the question of *what* to monitor) and can provide sufficient basis to validate (and if need be adjust) the models on which regulatory safety cases are built.

However, what, how and for how long to monitor remains not only a question of science and technology, but also of societal requirements. Over the operational life of a repository these requirements may change. Monitoring programmes will therefore need to possess sufficent flexibility to be able to respond to changing social and regulatory expectations that may be placed upon them.

[2]Social scientific research on relations between experts and citizens suggests that although this might be a necessary condition for public confidence, it is not in itself likely to be a *sufficient* condition to ensure confidence.

MONITORING: A COMBINED TECHNICAL AND SOCIAL ACTIVITY

To say that monitoring involves both technical and social purposes may seem perhaps to be self-evident because, as is clear from the preceding section, the expert community recognises this to be the case. Thus, while there are strong technical reasons for monitoring a geological repository (e.g. monitoring of disturbances in the host rock during excavation; or monitoring the lining of entrance galleries in the period before closure in repositories in salt or saturated clay), questions of evidence, confidence and decision-making always have, to a greater or lesser extent, a social component.

The prevailing paradigm for geological disposal today is not one of institutional forgetting, but one of actively remembering and continuous vigilance. This is by and large a matter of social preference: a result of how society today interprets nuclear safety. The technical act of monitoring and the way its results are given meaning then become an important instrument in the pursuit of vigilance.

Monitoring and Vigilance

The idea of vigilance as a leading principle for nuclear safety is not new, and has long had advocates within the nuclear expert community. A famous principled vision, outlining the challenge of the safe disposal of radioactive waste and how it should be addressed, was provided by the nuclear scientist Alvin Weinberg [4]. What was distinctive about the type of vigilance he had in mind, was its constant and tireless nature, as well as the exceptional longevity of vigilance required to guarantee safety.

This is particularly the case for nuclear installations such as power plants, fuel production or reprocessing plants, and storage facilities. Deep geological repositories may in that respect be of a particular nature, as their inherent reliance on passive safety can be understood as a way of trying to renegotiate the need for ‘eternal’ vigilance. For Weinberg the relative advantage of geological disposal was indeed the progressive relaxation of monitoring demands it appears to allow for as a more complete isolation of the waste from the biosphere is secured. However, he still saw a residual amount of surveillance being required ‘almost in perpetuity’ even with geological disposal.

The question is then how to interpret this need for surveillance: How much vigilance is enough and how should it be organised? This is a societal question that cannot be answered from a technical-expert perspective alone, something that Weinberg acknowledged.

Particularly with regard to monitoring for long-term safety in a pre- and post-closure phase, the appreciation of what monitoring can and should contribute is likely to vary considerably between experts and lay-stakeholders, inspired by fundamentally different views on what it means to stay vigilant and for how long.

- From an *expert* point of view the focus of monitoring for long-term safety during the operational, and more generally pre-closure, phase is on *confirming safety*, rather thaen questioning safety. Monitoring in a post-closure phase was viewed typically in terms of observing changes in the repository environment and considering possible effects these may cause on the repository function. This view seems to accept the impossibility to foresee and plan for all contingencies, but is focused on contingencies extraneous to the system. Preparedness for registering things previously unthought-of in terms of the repository system and its safety case, seems less evident when experts consider the post-closure phase.

- *Lay stakeholders* on the other hand are more likely to place the emphasis on ensuring that the repository will not have any effect, at any time, on its natural and human environment; and on maintaining preparedness in case the unexpected does happen, both pre- and post-closure. This view would be more in line with a use of monitoring *to question,* that is to *critically assess,* safety.

This difference in view stems from the fact that society at large may not be as confident as the expert community that with today's knowledge experts can fully understand and control long term repository behaviour. These doubts have many origins, but are at least partially based on evidence from known cases of expert or institutional failure, whether in the nuclear field or elsewhere, and of what has been labelled the 'atrophy of vigilance' [5, 6]. But it is not only risks due to negligence that give rise to public discomfort. What also worries people, is that there remain risks due to the impossibility of foreseeing all contingencies [7]. Expert statements on repository safety that do not recognise these uncertainties, may not be perceived as trustworthy.

Putting Trust in the Monitoring System

The concept of trust is important in understanding the underlying mechanisms by which monitoring may or may not contribute to building confidence in geological disposal. Given the very nature of radiation as a threat that is only visible through technical tools and scientific judgement, on issues of safety and feeling safe, citizens typically find themselves reliant upon - and therefore being expected to trust - experts and expert systems [8].

Trust is in essence about not worrying and not asking questions, but with regard to radioactive waste and its management, people do worry and are therefore not very eager to commit to putting a bet on the future contingent actions of the waste managers and the robustness of their long-term management systems. Furthermore, although attitude surveys have found that in many European countries scientists are the most trusted source of information on radioactive waste management, albeit by only 40% of those surveyed across all Member States, other survey research reveals public ambivalence and even significant levels of distrust towards scientists and experts, and towards the institutions that employ them, particularly when faced with controversial issues [9, 10].

Cultivating good personal relationships can contribute to establishing and maintaining a degree of trust between individuals who interact regularly but this has limitations when considering whole institutions and large groups of stakeholders. What then can substitute for interpersonal trust? One answer lies in establishing mechanisms that underwrite trust in the (impersonal) activities of organisations and institutions [11]; in the case of a radioactive waste repository this may include giving specific consideration to roles and responsibilities with regard to monitoring, to creating (arenas for) transparency and to enhancing its role in maintaining and demonstrating vigilance. For example:

- One element might be to make more explicit and binding, through legal or regulatory provisions, the role of monitoring as a tool for ensuring transparency, effective oversight and fully informed societal decision making.

- Another is to avoid a situation of potential self-regulation by making sure the implementer is not the only party who has monitoring responsibilities, and that there are different parties involved in the development, installation, operation of monitoring devices and the analysis of their results.

- The role of an independent regulator is in that regard an important one. The regulator by definition plays the role of intermediary between the implementer and society, and can make an important contribution to achieving public confidence. In an ideal world, there would be strong and competent regulators, working independently from the implementer, and guaranteeing to defend the overall good of society at all times. In the real world, this may not always be the case (e.g. due to limited state resources, too close links between those responsible for policy making and those regulating and supervising it, etc.), or it may, at least, not necessarily be perceived as such by stakeholder groups and citizens.

- In addition to the regulator, therefore, consideration might be given, in those contexts where additional assurances are needed, to complementary mechanisms that could contribute to rendering the monitoring system, viewed as a socio-technical system, more stable, traceable and transparent. These could for example consist of: introducing other independent oversight bodies; providing concerned stakeholders with the resources to commission their own independent reviews of monitoring activity and results; engaging concerned stakeholders to some extent in monitoring activity; and so forth.

When society comes to decide how intensively and for how long vigilance should be maintained, it will also be deciding what level of trust it is willing to place in the repository system (or in the people implementing and inspecting it). This will be easier to do if during the progressive stages of conceptualisation, siting, licensing, construction and operation, there is the possibility to evaluate the evidence on which to base this trust and to consider any uncertainties and limitations to which it may be subject . The implementation of a credible and responsive monitoring strategy may be seen to demonstrate that the operator of the disposal programme is aware that there are still uncertainties and is taking appropriate precautions by maintaining vigilance until society can satisfied that it is no longer required.

This contains the risk of putting into question the premise of passive safety as the technical solution that in principle obviates the need for extended societal vigilance - or at least may delay its immediate implementation. By introducing the notion of reversibility into law, France and Switzerland are already moving towards an adapted technical solution: one that eventually still relies on passive safety, but that puts this end point potentially much further out than initially planned. Such evolutions confront us more directly with the fact that we will inevitably pass burdens on to next generations (e.g. the decision to close – or not to close – a repository). Acknowledging this focuses attention on the types of information, knowledge and skills that need to be passed on to future generations in order to support them in this decision. Continued monitoring, it would seem, could play an important role in providing future facility operators, regulators, decision-makers and other concerned parties with the necessary resources.

CONCLUSIONS

This has raised a number of issues for consideration when planning for engagement with stakeholders on the subject of repository monitoring, which is the focus of the subsequent phase of the socio-technical component of the MoDeRn research project. This final section therefore reviews the implications of these findings for engaging different types of stakeholders, in particular non-specialist or ‘lay’ stakeholders, in defining monitoring objectives and strategies.

One thing upon which, from the evidence that we have examined, the expert community appears to agree is that issues of (re)assurance and confidence building are among the main

drivers for monitoring. The vital question then becomes how to organise monitoring in such a way that it responds to different stakeholders' expectations, thus contributing to raising their confidence in a repository performing to the promised standards of safety.

A first, perhaps self-evident, observation is that monitoring is not an end in itself; rather it is a means to support, in a number of ways, the implementation of geological disposal, and it is the safety of geological disposal that is the main focus of stakeholder concern. One implication of this would be that, given the potential mediating role that monitoring may play in supporting stakeholder confidence in geological disposal, any engagement on monitoring would most usefully be set in the context of the citizen and stakeholder engagement processes on the overall development and implementation of geological disposal.[3], This may be applicable both at a national level, in relation to general policy questions of whether or not to opt for geological disposal and to more specific questions such as that of reversibility and retrievability, and also at the regional or community level, to supporting local decision making and as a continuing source of assurance of safety.

A second observation deriving from the research so far is that the way in which experts view monitoring and what they expect to obtain from it differs according to (among other things) the way they view the concept of geological disposal and long-term safety. On the one hand, some have great confidence in the multi-barrier design providing multiple safety functions to ensure long-term safety, seeing monitoring primarily as a means of confirming the models on which they have based the repository design and which are used to evaluate long term safety after closure, but as having no active safety role in the post-closure phase. Others, on the other hand, see post-closure monitoring for unexpected evolutions of the repository, at least for a period of time, as a precaution that might be considered necessary, if only by societal decision makers. This is not simply a matter of a difference between expert and 'lay' perceptions. The data that were collected showed that there is more than one way of interpreting passive safety as a viable alternative to perpetual, active vigilance. Where underlying assumptions about geological disposal and about safety are not made explicit, their influence on interpretations and expectations as regards to monitoring will not be clear. When engaging with different types of stakeholders, therefore, those responsible for developing and implementing repository monitoring strategies as part of national HLW repository programmes will not only need to take into account the existence of different conceptualisations of these issues but will also need to focus their interactions with stakeholders on making explicit what lies behind different actors' views on monitoring, including their own.

Third, and related to this, is the observation that monitoring could be part of the answer to the societal expectation that vigilance should be maintaineds. Like it or not, some burdens will inevitably be passed on to future generations. First, because in most programmes it seems unlikely that geological repositories will be closed by the same generation who build them. Second, because certainty and safety can never be unconditionally guaranteed. By broadening the debate on monitoring objectives to include how to register things previously unthought-of and thus considering not only the 'known unknowns', but also the potential for 'unknown unknowns', experts can show humility and recognition of the impossibility to plan for or foresee all contingencies in advance of their occurrence.[4] This would also mean showing preparedness to discuss monitoring issues not only with a view to preparing for closure (the main purpose for monitoring from an expert perspective), but also with regard to a post-closure phase, or as an extension of monitoring during the operational phase in the case of a societal decision to

[3] Notwithstanding the exploratory research being conducted as part of the MoDeRn project.
[4] A principle that has been advocated for more general application in relation to expertise and policy [12].

postpone final closure. The adoption in some countries of pre-closure management options of retrievability or reversibility could be viewed as indication of such humility and of a technical preparedness to respond should future socio-technical decision making lead to actions other than immediate closure.
What seems important is that monitoring programmes are designed – and are seen to be so designed - to remain sufficiently flexible to adapt to changing social and regulatory expectations that may be placed upon them. To maintain confidence over time, both the process and outputs of monitoring will have to continue meeting different stakeholders' expectations, while staying within the limits of what is scientifically sound, technically and financially feasible, and safe. When developing and maintaining monitoring programmes, interaction with different types of stakeholders would seem to be essential, in order to get these elements in balance. The weighing of these elements against each other is something that concerns society as a whole, and not therefore something an implementer should do on its own; nor to be left solely to technical regulatory decisions.

A fourth observation is that, in order to contribute to confidence building, the process of monitoring needs to be transparent and open to public and expert scrutiny. This is not done merely by producing data and presenting them as evidence to corroborate experts' models and validate their claims. What is as important (if not more so) is to produce these data in such a way that others have access to them and are able to verify how they came about. This would require an appropriately designed and functioning institutional context in which roles and responsibilities for long-term radioactive waste management are organised. Important components of such a context are:

- A monitoring reference framework that recognises the role of monitoring as a tool for achieving transparency;
- An independent regulator which has the means to perform its role appropriately, has an excellent track record, and is itself open and transparent towards the public;
- A system for 'monitoring the monitor' involving appropriate parties in the development, installation, and operation of monitoring devices and the analysis of their results. In some countries this may be a role performed by the regulator, but may also involve...
- An independent oversight body at the central level;
- Empowerment measures to enable concerned stakeholders at the local level to engage with monitoring activity, either through direct active involvement (for example, in environmental monitoring), or through the involvement of external experts of their choosing.

Existing social science research suggests that an institutional context with these characteristics, promoting transparency and scrutiny, is likely to contribute significantly to building and maintaining societal confidence.

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