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Sound science in geological disposal in the United Kingdom

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ABSTRACT

The safe implementation of geological disposal must be underpinned by sound science. This paper describes the approaches taken by the Nuclear Decommissioning Authority Radioactive Waste Management Directorate, the implementing body for geological disposal in the UK, to build an evidence base of scientific data and understanding which is robust to scrutiny and so provides confidence in the safety of geological disposal.

KEYWORDS: scientific basis, safety case, quality, evaluation.

Introduction

GEOLOGICAL disposal is the UK Government's policy for higher activity radioactive wastes (Department for Environment Fisheries and Rural Affairs *et al.*, 2008). The principle of geological disposal is to isolate the waste deep inside a suitable rock formation to ensure that no harmful quantities of radioactivity reach the surface environment. To achieve this, the waste will be placed in an engineered underground containment facility, the geological disposal facility (GDF). The facility will be designed so that natural and man-made barriers work together to minimize the escape of radioactivity. The Nuclear Decommissioning Authority (NDA) has responsibility for the implementation of geological disposal in the UK. The NDA has set up the Radioactive Waste Management Directorate (RWMD) to develop an effective delivery organization to implement a safe, sustainable and publicly acceptable geological disposal programme. The RWMD has developed a multi-barrier concept for geological disposal of higher activity radioactive wastes. These wastes include high-level waste (HLW), spent nuclear fuel, intermediate-level (ILW) and certain low-level (LLW) radioactive wastes. A schematic representation of a multiple barrier system is provided in Fig. 1. More specific examples are presented in the generic disposal system safety case (DSSC) (Nuclear Decommissioning Authority, 2010*a*).

The range of geological settings that could be suitable for hosting a geological disposal facility for higher activity radioactive wastes in the UK is wide and diverse. The UK Government policy is that the siting process for a geological disposal facility will be based upon voluntarism and partnership. This means that any geological settings available for the disposal facility will depend on the locations of sites identified through discussions with local communities involved in the process. Therefore, in the early stages of planning, a range of generic geological settings, including the associated variants on rock formations that might overlie the GDF host rock, is considered (Nuclear Decommissioning Authority, 2010*b*).

The science base to support geological disposal

In order to build confidence that the scientific basis for the safety of geological disposal is robust, it is necessary to document the evidence

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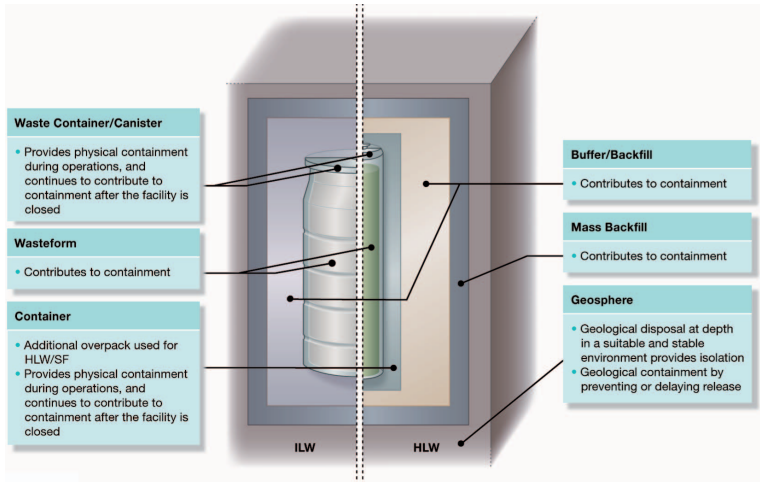

FIG. 1. Schematic representation of a multiple barrier system. Figure published with the permission of the NDA.

and subject it to scrutiny. The status of the science underpinning geological disposal in the UK has been documented recently in a series of status reports which form part of the generic DSSC. The DSSC presents a collection of safety arguments and evidence to demonstrate that the disposal system will be safe to operate, will remain safe after it is closed and will meet all applicable regulatory safety requirements. It is a suite of 'live' documents, and is updated regularly as the evidence base is expanded and improved. The DSSC document suite includes volumes covering the safety of the transport of the waste to a GDF (Nuclear Decommissioning Authority, 2010*c*), the construction and operation of the facility (Nuclear Decommissioning Authority, 2010*d*), and the long-term safety after it is closed (Nuclear Decommissioning Authority, 2010*e*). As illustrated in Fig. 2, each status report presents RWMD's view of the scientific evidence to support the safety arguments presented in the generic transport, operations and post-closure safety cases, and draws on more than twenty years of research in the field carried out in the UK and overseas. The set of status reports was structured to relate to key research topics relevant to multi-barrier concepts for geological disposal, as shown in Fig. 3:

(1) reports on package evolution (Nuclear Decommissioning Authority, 2010*f*), near-field evolution (Nuclear Decommissioning Authority, 2010*g*), and geosphere (Nuclear

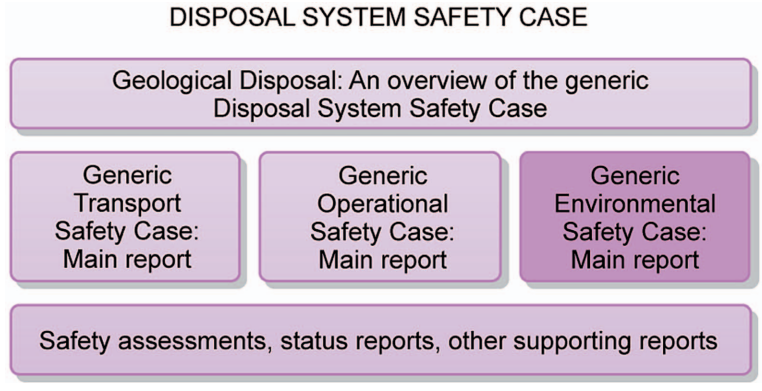

FIG. 2. Structure of the disposal system safety case (DSSC). Figure published with the permission of the NDA.

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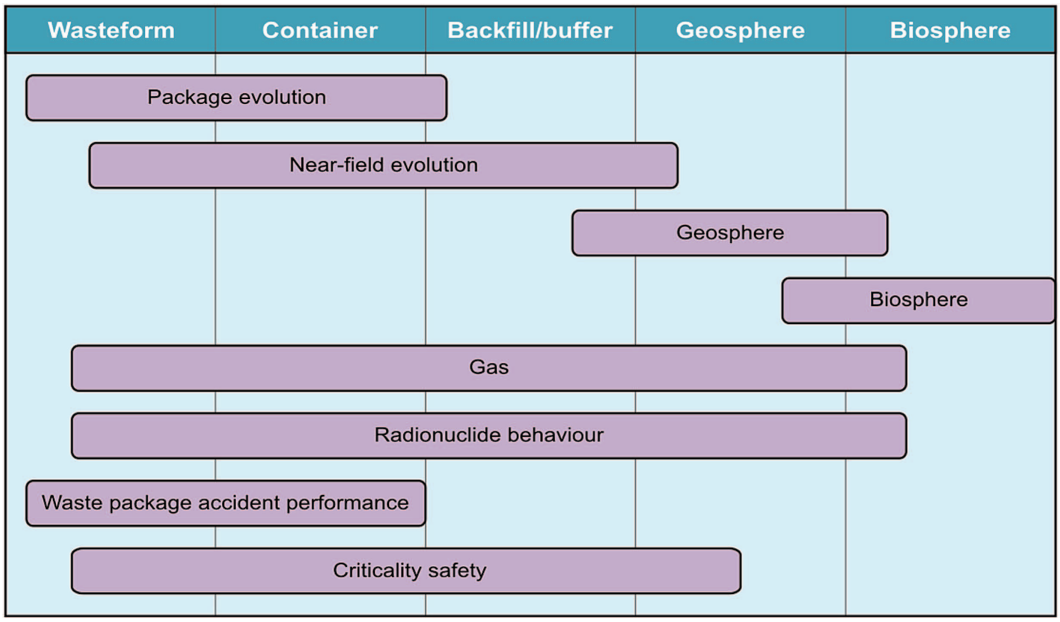

FIG. 3. Status report interfaces. Figure published with the permission of the NDA.

Decommissioning Authority, 2010*h*), describing the understanding of the role of, and evolution of, the barriers;

(2) reports on radionuclide behaviour (Nuclear Decommissioning Authority, 2010*i*), and gas generation and migration (Nuclear Decommissioning Authority, 2010*j*) describing the release and movement of materials through the multi-barrier system;

(3) reports on criticality safety and waste package accident performance (Nuclear Decommissioning Authority, 2010*k*) addressing the control of these events and their outcome; and

(4) a report on biosphere describing what a future biosphere may look like and how radionuclide uptake might be expected to take place (Nuclear Decommissioning Authority, 2010*l*).

Confidence in the science presented in the status reports was established through independent peer review by a team of around twenty internationally recognized subject experts, drawn from the radioactive waste sector and from academia.

The main conclusion from the DSSC was that there was a good understanding of the key features of the various barriers in the multi-barrier system and of the ways in which they interact. This gives confidence that, once a preferred site (or sites) and disposal concept(s) have been selected, it will be possible to develop an optimized design of a GDF which will meet all environmental safety requirements (Nuclear Decommissioning Authority, 2010*a*). This finding for the UK programme is in line with international consensus. For example, a recent report prepared for the European Commission states that "There is a worldwide scientific consensus that safe geological disposal is technically feasible" (Falck and Nillson, 2009).

Although confidence in geological disposal is now well established, it is acknowledged that significant research and development will be necessary for a number of years into the future. Another important role of the status reports was to identify gaps or 'information needs' in the scientific evidence base and so provide the foundation on which to build the future research and development (R&D) programme. The information needs identified in the status reports have been compiled in a document which describes the R&D programme for the preparatory studies phase of implementation of geological disposal (Nuclear Decommissioning Authority, 2011). The R&D programme document is a 'live' document and is updated periodically, to incorporate the additional knowledge from completed R&D.

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Delivering quality in R&D

Once the current status of the science has been established and gaps in the evidence base identified, the next step in building the science base is to carry out R&D to build the knowledge base. The RWMD does not carry out its own R&D. Instead, R&D services are commissioned from organizations with expertise in relevant fields. The role of RWMD is to be the 'intelligent customer' for the R&D it has commissioned, which means it has to have a sufficient understanding to be able to purchase appropriate R&D and to understand the implications of the R&D outputs for the programme. The steps in the delivery of R&D services are described in the RWMD's R&D Strategy (Nuclear Decommissioning Authority, 2009) and presented in Fig. 4. A number of processes have been embedded to ensure that the R&D delivered through this process is of a high quality. In order to ensure quality in the suppliers of R&D, potential suppliers with suitable capabilities were appointed through a competitive framework tender process, which sought to ensure that the teams delivering R&D were suitably qualified and experienced and also had access to the required laboratory and analytical facilities. Framework contracts for R&D were awarded to several consortia led by specialist technical consultants. All of these consortia have the freedom to recruit additional expertise through the use of subcontracts, which may be for the duration of the framework or to provide specialist support in the delivery of a specific task.

In order to ensure quality in the individual task, framework consortia are provided with a definition and purpose of the particular task of the specific R&D and invited to submit a proposal for a programme of work that meets the objective set out in the specification. Through this approach, researchers are free to propose their approach and the format of the deliverables and thus the approach makes maximum use of the supply chain's capabilities for delivery of innovation and value. Proposals are assessed by tender review panels which evaluate bids against the specific criteria defined in the contract technical specification and select winning suppliers. The assessment criteria include consideration of the quality of the proposed approach and of the skills and experience of the proposed team.

In order to ensure quality in delivery, a proactive approach is taken to contract management with a particular focus on technical quality. Regular progress meetings are held throughout the contract duration and these frequently involve independent experts who in turn contribute to the direction of the ongoing R&D.

In order to ensure quality in outputs, deliverables reporting on the outcomes of commissioned R&D tasks are required to be in the form of contractor-approved reports. This means that they will have been subjected to the supplier's own internal review and approval processes, as specified in their organization's quality procedures, before they are submitted as final deliverables. In addition, work is reviewed by the RWMD to check that the work meets the requirements specified in the invitation to tender and to ensure that the work is of an acceptable scientific quality. Where appropriate, external subject experts are commissioned to provide independent peer reviews of R&D outputs. Individuals are selected who have a high technical standing in their particular field, which is recognized at a national and/or international level. Attempts are made to ensure that the field of reviewers utilized is as broad as practicable and to include overseas experts as well as UK experts.

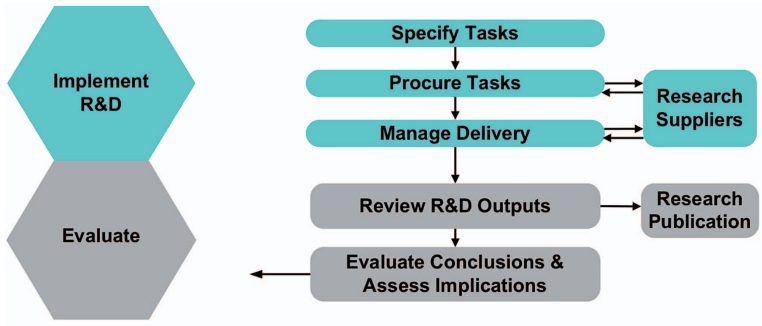

FIG. 4. Steps in the delivery of research and development. Figure published with the permission of the NDA.

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Thus the review processes used for R&D commissioned by the RWMD are in line with those generally accepted as good practice in the wider scientific community. Increasing priority is being placed on the publication of research results from the RWMD programme in the scientific peer-reviewed literature as this will again increase confidence in the quality of the science.

In order to demonstrate quality in management and in the 'intelligent client' capability, the RWMD requires that its Research Managers hold PhDs in a relevant discipline and undertake a continued programme of professional development in their specialist field. The RWMD has recently become the first employer to have its professional development scheme approved as part of the Science Council's pilot employer Continuing Personal or Professional Development (CPD) approval scheme.

Further confidence in the RWMD R&D programme is provided by oversight arrangements. Oversight of the R&D programme is provided by the RWMD's R&D advisory panel with a membership of five independent university professors. The panel meets three times a year and provides input on the scientific content and delivery of the programme. The panel may also access other independent subject matter experts as required. As noted in section 3, the panel were involved in advising on the scientific evidence set out in the status reports and in the subsequent development of the R&D programme and reviewed a draft of the document. Scrutiny of the R&D programme is also provided by the Committee on Radioactive Waste Management (CoRWM). The CoRWM was involved in discussions about the developing R&D programme document and provided informal review comments on a draft document.

The R&D programme is also subject to voluntary regulation by the appropriate regulators. As part of a process of early engagement on key issues, an early draft of the R&D programme document was discussed with regulators. At key milestones, the programme is also subjected to independent programme-wide reviews, by bodies with national or international standing, such as the Royal Society or the Nuclear Energy Agency (NEA).

Evaluating new knowledge

Evaluation of R&D outputs is an important step in R&D process as this is the stage where the implications of R&D outputs for the geological disposal project are assessed. Evaluations of individual tasks are carried out on task completion. The evaluations assess: (1) the extent to which the research objective has been met; (2) the implications of the R&D for the specification, design or assessment; (3) the requirement for any follow-on R&D; and (4) other benefits gained from the R&D. The findings of the peer review form an important input to the evaluation process.

Evaluation of R&D outputs is an important component of the role of an RWMD research manager as part of the 'intelligent customer' role. However, frequently, external experts from technical specialist organizations, academia and overseas waste management organizations are invited to contribute to the evaluation, in order to ensure that the evaluation is balanced. This new knowledge and its implications are recorded in the status reports and become part of the scientific evidence base underpinning geological disposal. In addition, periodic evaluations are carried out of specific topic areas and of the whole R&D programme. These wider reviews ensure that the evidence from R&D by third parties, particularly the academic community and work in support of overseas geological disposal programmes is captured and evaluated in the context of the UK programme.

Wider initiatives

The RWMD builds further confidence in the science by supporting development of the wider science base in the area of geological disposal. For example, it has recently worked with the Engineering and Physical Sciences Research Council (EPSRC), under the auspices of the Research Councils Energy Programme (RCEP), to joint-fund relevant research challenges associated with the implementation of a geological waste facility. As a result, a joint workshop of subject experts from academia and industry was held, broadly focussed in the area of geological disposal of nuclear waste. This workshop provided attendees the opportunity to jointly investigate the issues relating to geological disposal of nuclear waste, identify areas for research and to develop outline proposals and possible 'consortia' to address them. Outlines developed here were assessed by a joint panel and appropriate ones invited to prepare full proposals for consideration through a subsequent managed call. Approximately $\leqslant 4$ m ($\leqslant 2$ m from EPSRC/

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$\leqslant$2 m from RWMD) of funding has been awarded as a result of this call. A similar joint initiative with Natural Environment Research Council (NERC) is currently being planned with the aim of launching a call for proposals in the autumn of 2012. Collaborative awards in science and engineering (CASE) studentships relevant to radioactive waste disposal, where the RWMD provides a contribution towards funding a specific piece of work, are another example of support of the wider scientific understanding in the field. In addition to the co-funded activities, the RWMD often provides 'in-kind' support to academic research projects, for example by offering the input from its technical staff on steering committees for project consortia. The way in which the evidence base is built upon these broader scientific initiatives is illustrated schematically in Fig. 5.

In addition to strengthening a broader science base, these joint initiatives with academic institutions play a very important role in the development of the skills base for geological disposal. Although it is considered that the skills and resources are adequate for the current preparatory phase of the geological disposal programme, it is acknowledged that the requirement for resources will increase significantly once the programme reaches a state of development where site-based work can be initiated. The exact timescale for this change will depend on the progress with voluntarism but, for planning purposes, this is assumed to be in approximately 2017.

The RWMD also contributes to a number of international initiatives in the field of radioactive waste disposal. It participates in a number of European Commission projects and other collaborative projects with sister organizations overseas. It is an executive member of the International Geological Disposal Technology Platform (IGD-TP) (Palmu *et al.*, 2012) and an active participant in a number of activities organized by the Nuclear Energy Agency of the Organisation of Economic Cooperation and Development (OECD) and of the International Atomic Energy Authority (IAEA).

Summary

This paper presents a summary of the approaches adopted by the RWMD to ensure the quality of the science underpinning the implementation of geological disposal in the UK. It describes:

(1) a structured approach to present the evidence base and determine the information needs, supported by rigorous peer review;

(2) selection of high-quality research approaches to meet the information needs through a competitive 'solution-based' approach implemented by well qualified and equipped teams; and

(3) critical evaluation of new knowledge in the context of geological disposal.

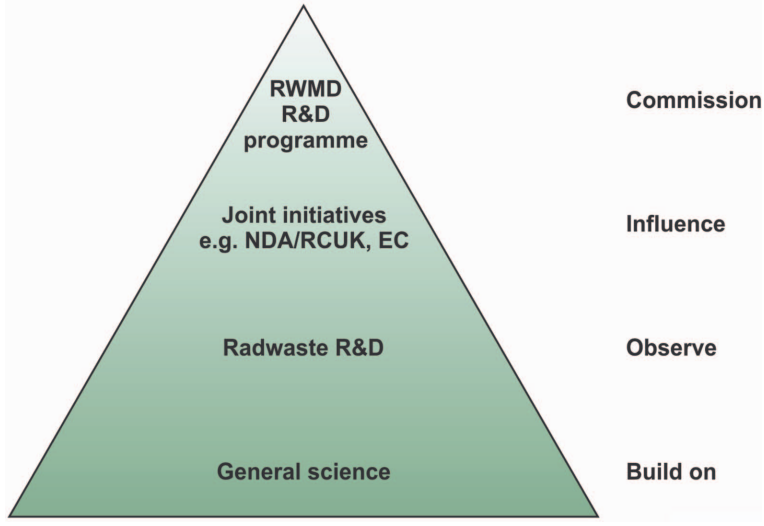

FIG. 5. The science base for geological disposal in the UK. Figure published with the permission of the NDA.

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In addition, the RWMD participates in a number of broader initiatives in the field of radioactive waste disposal, such as those led by the research councils and international programmes which build further confidence in the approaches.

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