Radioactive Waste Immobilisation Network
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RWIN IX Meeting – Geological Disposal
April 23rd 2009
University of Sheffield

Abstracts

NDA RWMD Research Development and Strategy
Neil Smart
NDA

With the publication of the Managing Radioactive Waste Safely (MRWS) White Paper in June 2008, a major milestone was achieved in determining future UK Government arrangements for the long term management of higher activity radioactive waste.

The MRWS programme led to publication of the White Paper. This included the work undertaken by the independent Committee on Radioactive Waste Management (CoRWM) to assess the available options and the consultation undertaken to establish a framework for implementing geological disposal which, together with safe and secure interim storage, was identified as the best approach.

The higher activity wastes to be managed in the long-term through geological disposal comprise of all radioactive material that has no further use and that cannot be managed under the "Policy for the Long-term Management of Solid Low Level Radioactive Waste in the United Kingdom" through for example, emplacement in the low-level waste repository (LLWR) near Drigg. These higher activity wastes include:

High-level waste (HLW) – a liquid by-product from the reprocessing of spent nuclear fuel, which is made passively safe by converting it to a solid glass wasteform through a process known as vitrification.

Intermediate-level waste (ILW) – arising mainly from the reprocessing of spent fuel and from general operations and maintenance at nuclear sites, and including metal items such as fuel cladding and reactor components, and sludges from the treatment of radioactive liquid effluents.

A small fraction of *low-level waste (LLW)* – that is unsuitable for near-surface disposal at the LLWR.

In addition to existing wastes, there are some radioactive materials that are not currently classified as waste but that may, if it were decided at some point that they had no further use, need to be managed through geological disposal. They include: Spent fuel (SF), Plutonium and Uranium - UK Government will decide whether or not these materials should be declared as waste in the future. In the meantime, we factor the possible inclusion of these materials into the design and development of a geological disposal facility.

This presentation will outline the underpinning research activities required to support implementation of this project in the UK

R&D for Geological Disposal: Role & Expectations of the Environment Agency Doug Ilett Environment Agency

Abstract: In this presentation we will outline briefly the role of the Environment Agency in R&D activities for a Geological Disposal Facility (GDF). We will describe our own programme of R&D, aimed at informing our future regulatory activities of a GDF. Finally, we will explain our broad expectations for R&D activities to underpin a GDF environmental safety case.

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Doug Ilett
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Deep borehole disposal: an alternative to the mined & engineered repository for high-level wastes.
Fergus Gibb
University of Sheffield

Modern concepts for deep borehole disposal (DBD) – sometimes called very deep disposal (VDD) – are of two types; low temperature and high temperature. In low temperature disposals the near field temperatures generated by the decay of the waste are well below those required to melt the host rock while in high temperature variants the heat output of the waste packages are designed to be sufficient to cause partial melting. DBD involves sinking large diameter boreholes 4 to 6 km down into the basement of the continental crust and deploying the waste packages over the lowermost 1 to 2 km. We have been developing different versions of low temperature VDD tailored to specific high-level waste types. Version 1 is for vitrified reprocessing waste; 2a for spent UO_2 fuel; 2b for spent MOX and 3 for Pu. There are important technical differences between these variants, which can not be gone into in any detail in the time available, but copies of relevant publications can be supplied. The basic principles of DBD are illustrated with reference to the version for vitrified reprocessing waste and nine reasons are identified why DBD is potentially a better option for the geological disposal of this and other high-level wastes than a mined repository. Four of the more significant are safety, cost-effectiveness, potential availability of geologically suitable sites and the possibility of early implementation. These, including an outline safety case, are discussed in more detail before arriving at a tenth potential advantage of DBD – improved acceptability.

An alternative to a deep mined repository : disposal in large diameter boreholes
John Beswick

As part of the Government's programme for managing radioactive waste, a White Paper was published entitled '*A framework for implementing geological disposal*'. The preferred concept is for a deep mined repository, but other options are to be considered and the Government recognises the need to take account of developments in storage and disposal options, as well as new technologies and solutions.

One option for consideration is the use of deep boreholes for the disposal of certain radioactive waste products. This concept was first reviewed in the early 1980s by the US Department of Energy, Office of Nuclear Waste Isolation (ONWI). At that time, the ONWI report rejected deep borehole disposal (DBD) of radioactive waste on the basis that the necessary sizes and depths were not achievable. Since the 1980s, the technology for drilling and supporting deep boreholes has advanced dramatically such that this may no longer be true.

The history and background to deep borehole disposal and the technical issues of the deep borehole concept are presented highlighting the current status of the technology and the requirements for development together with a guide to likely times for implementation and costs.

The deep borehole concept may at first appear to be less favourable than a deep mined repository, but the current focus on repositories in old geologies may not provide sufficient comfort for the Safety Case to be approved by the regulatory authorities as geological and hydrogeological prediction in complex geologies is very difficult to demonstrate to the level needed. The question is, does the deep borehole concept offer a more assured and potentially cheaper solution for radioactive wastes that can be accommodated in a deep borehole?

Design Options for the UK Geological Disposal Facility for HLW and Spent Fuel
Neil Chapman
MCM Consulting/University of Sheffield

At least two different disposal concept designs will be required to accommodate the UK's HLW/SF and, separately, ILW. The geological environment that might eventually emerge as the preferred location is not known and the siting process may require evaluation of several different geological environments. The NDA is thus looking at conceptual designs that could be appropriate for a wide range of host rock and geological environment possibilities. A recent project has evaluated the range of geological disposal facility design options available worldwide for the disposal of HLW and spent fuel and established a set of 12 generic options that would cater for any geological environment likely to arise. The appropriateness of each option in a set of five generic geological environments was assessed. The findings provide communities and other stakeholders with illustrative material on what a geological disposal facility might look like in specific situations and a starting point for matching sites to relevant designs, so that safety studies and design/packaging optimisation work can commence as potential sites emerge.

Interaction of glasses with a GDF environment
Russell J Hand
University of Sheffield,

Recently possible co-disposal of cementitious and vitrified wasteforms has gained increasing attention in the UK. This type of disposal system means that the vitrified HLW will be placed in a highly alkaline environment; in particular the Nirex reference backfill for cementitious repositories is designed to maintain a high pH. Silicate and borosilicate glasses in general display low durabilities under highly alkaline conditions and thus, for example, special glass compositions have had to be developed for the reinforcement of cement and concrete in construction applications. Although pH excursions are seen in conventional high *SA*/*V* durability tests on glasses, the effect of these excursions is limited by silica saturation of the attacking solution and the development of protective gel layers on the glass surface giving the so-called "final rate" kinetics. It cannot be assumed that similarly low final rates will apply when the attacking solution is highly alkaline. In this presentation I will briefly review the current state of knowledge concerning the durability of silicate and borosilicate glasses under highly alkaline conditions.

Current BGS research on radioactive waste disposal
Richard Shaw
British Geological Society

The BGS is currently funding three projects in the radioactive waste disposal field. They are:

Geosphere Containment - studying fluid and gas flow in low permeability materials, both natural clays and manufactured bentonite blocks.

Palaeohydrogeology - extending the understanding developed under the EC funded EQUIP and PADAMOT projects with a current focus on organic geochemistry for the determination of past climatic conditions.

Bio-Tran - lab based column experiments to enhance understanding of the microbiological processes that may influence the transport properties of the rack mass in enhancing or retarding radionuclide migration.

BGS undertakes a range of commissioned projects for a number of clients. These include the Large Scale Gas Injection Test (LASGIT) in the Aspo URL where a fully completed full size disposal borehole is undergoing long term hydration of bentonite backfill and gas injection.

BGS is co-ordinator for the recently started 4 year FP7 FORGE (Fate of Repository Gases) project that is designed to significantly improve understanding of the processes of gas migration in a repository context for both clay and 'granite' hosted settings.

Matching the Modelling Approach to the Geological Environment
Sarah Watson
Quintessa

England and Wales offer a wide range of geological environments that are potentially suitable to host a GDF, and which have a wide range of different groundwater flow characteristics. Groundwater flow and transport modelling will be a vital component of the work to develop the GDF, and there is a wide range of different modelling approaches that could be applied. The modelling approach must be matched to the characteristics of the system being modelled and the objectives of the study. This presentation will use recent work carried out for NDA RWMD to illustrate the range of approaches that are available and the types of environment they might appropriately be applied to.

Rock engineering for deep geological disposal
John Harrison
Imperial College London

Geological disposal of waste is being actively pursued at a number of sites worldwide, and thus there is now a wealth of rock engineering experience from many sites worldwide regarding this endeavour. However, the intrinsic properties of all natural rock masses means that engineering within them poses a complex set of challenges, many of which continue to represent key research questions. Here, we will cover some of the key issues in rock engineering for geological disposal, outlining the approaches being adopted and highlighting areas of research importance.

Biogeochemical processes impacting geological disposal of radioactive waste
Vernon Phoenix
University of Glasgow

Microorganisms are capable of utilizing a diverse range of energy sources and can exist in an equally diverse range of environments. Consequently, they have potential to mediate corrosion and impact radionuclide mobility at numerous locations within the disposal system. Microbially driven immobilization mechanisms include reduction of radionuclides to less soluble forms, adsorption of radionuclides onto cell surfaces and immobilization into biogenic minerals such as iron-oxides. Mobilization mechanisms include microbial production of organic complexing agents, acid synthesis via oxidation of sulphides & ammonia and oxidation of organic waste matrices. The microorganisms ability to utilize and mediate redox within the disposal system plays a key role in controlling radionuclide mobilization and fate. However, these biogeochemical processes are dependent on the presence of water, nutrients and a sufficient density of functioning organisms. Immediately adjacent to HLW, high radiation doses, high temperatures and corresponding desiccation is expected to make microbial activity negligible. Thus corrosion resistant waste matrices and canister materials are unlikely to experience any microbial degradation unless the system is compromised. If compromised, oxidizing conditions provide greatest potential for microbially induced corrosion. Once the waste has cooled, access of microorganisms to HLW is restricted providing HLW is enclosed within a very low permeability, self sealing backfill; bentonite being the most effective backfill for preventing microbial ingress. Cement based disposal systems for ILW/LLW generate high pH (pH ~ 12) which will inhibit activity of microorganisms except for those which are alkalophilic. However, oxidizing environments (which stimulate acid producing microbes) have potential to promote microbial degradation of this material. ILW/LLW waste matrices composed of organics such as cellulosic material are readily degraded by bacteria and can generate significant gas production, both under aerobic and anaerobic conditions. Microbial communities also have the potential to impact advective transport of radionuclides via biofilm formation and consequent permeability clogging. In the far field, important biogeochemical processes include consumption of gasses generated in the near field, metabolic breakdown of organic complexes transporting radionuclides, radionuclide immobilization via reduction and radionuclide immobilization onto biogenic metal oxides.

Immobilisation and Disposal Options for the Management of Separated Uranium
Joe Small,
National Nuclear Laboratory

The UK has significant quantities of materials containing uranium. These comprise mainly; uranium hexafluoride (UF_6) resulting from isotopic enrichment of oxide fuels, and uranium trioxide (UO_3) product from the reprocessing of used nuclear fuels. In addition, there are smaller quantities of separated uranium in other chemical forms. The Nuclear Decommissioning Authority (NDA) has identified a range of options for the management of its stocks of these uranic materials, including, interim storage prior to conditioning for direct disposal; indefinite storage; and reuse. The National Nuclear Laboratory (NNL) are undertaking research to underpin the NDA strategy.

This presentation concerns the disposal option and the conditioning required in order that the current chemical forms (UF_6, UO_3) can be converted into stable materials suitable for geological disposal. The chemical stability and compatibility of uranium wasteforms with geological disposal concepts will be discussed and the radiological and volume impacts considered. A range of immobilisation technologies and geological disposal concepts will be discussed.

Colloids and Complexants in a Geological Disposal Environment
Peter Warwick
Loughborough University

Intermediate level and long-lived low-level wastes are heterogeneous mixtures of radionuclides and materials which together form the “source term” for the far-field (Geosphere) of a nuclear waste repository. Radionuclides may form water soluble complexes which may be transported into the far-field by the movement of groundwater. The complexes will be subjected to physical and chemical gradients e.g. pH, cation and anion concentrations, radiolysis and temperature as they move from the near-field, through the disturbed zone (the interface between the near-field and far-field of the repository), and then into the far-field. In addition to these gradients, complexes may be subjected to microbial interactions. In the far-field, transport will depend on the hydrogeology and the solubility and stability of the complexes. In addition to radionuclide transport by complex formation, colloids may also play a significant part in transporting radionuclides. An essential requirement for predicting radiological risk to the public from the repository is therefore to be able to predict the transport of radionuclides from the near-field, through the far-field and into the Biosphere. The key issue is therefore “how do you represent the impact of organic complexants and colloids in Performance Assessment when considering a diverse range of radionuclides and, chemical gradients evolving over space and time?” There are several approaches to answering this question and one of them – “the story board” approach, which was developed to drive research and identify those complexant types to be included in PAs, will be discussed during this talk.

Research In Support Of An Environmental Safety Case For A Geological Disposal Facility
Andy Baker
Independent consultant

The attributes of a well-designed and managed repository research programme are discussed. The approach to developing such a programme may include the following:

- The Environmental Safety Case should be fundamental basis for identifying a programme of research.
- The definition of the research programme should be systematic and transparent;
- Developer, regulators and other stakeholders need to develop a common view of what a proportionate research programme looks like.
- Good forward planning tis necessary, taking account of government and regulatory decision points.
- For a programme lasting many years, a good approach to information management needs to be developed.
- Post-job evaluation and peer review are important.