Review of research on geological disposal of radioactive waste proposed by the UK Nuclear Decommissioning Agency

MRWS West Cumbria Document 146 March 2011 V1.4

Professor Stuart Haszeldine FRSE C.Geol.
School of GeoSciences, University of Edinburgh

Abstract

The NDA has summarized UK research work achieved, and future research work needed, on the pathway towards choosing sites for a radioactive waste Repository. This produces a listing of 203 research Areas, intended as the definite statement of generic needs before the next phase moving towards site choices. None of the work is specific to West Cumbria, although most of the proposed work could be applied to West Cumbria. The compilation is written in accessible language and gives a good indication of the size of the problem. Next steps for the NDA are summarized for each Area, and some methods of undertaking the work are suggested. The volume and detail of categorisation makes the report complex to overview, and so results have been re-cast as graphs and a summary Table. That enables ranking and comparison internally, and comparison with research listings from other organizations. Analyses of these summaries shows that: i) Most Areas are categorized as “Urgent” or “Medium”; more discrimination to prioritise between research Areas would be helpful; ii) Most research Areas are agreed between several types of organization; iii) The importance placed on different Areas varies greatly. iv) At least 52 Areas need to be resolved before any Sites can be chosen. Omissions by NDA include: a) a lack of time estimation for the work, b) a lack of costs to achieve the work; c) omission of lessons learned from previous UK site investigation; d) under-recognition of future work needed to limit leakage of radioactive gas, and dispose of MOX fuel and plutonium; e) under-recognition of below-ground laboratory work needed to understand geology. There is demonstrable benefit in enabling critique from outside the NDA so that larger, arms length, funding for technical challenges needs to be given to Regulators and Communities to ensure that the MRWS process is capable of being both scientific and balanced.

Aims

The aim of this document is to assess the proposals released in February 2011 by the Nuclear Decommissioning Authority (NDA) for a programme of UK research relating to radioactive waste collection, processing, and long-term geological storage (NDA/RWMD/073). The approach taken is to examine the following topics:

- understanding the categorization and scope of work achieved and still to do
- identifying research responses proposed by NDA
- understanding the NDA prorities
- identifying research needs for storage proposed by other organizations
- determining a match or mismatch between these two
- identifying omissions.

This work is funded by MRWS West Cumbria, so local issues are highlighted.

Context within MRWS and RWMD

The report does not provide a self-contained overview of its context within the RWMD waste disposal programme. This “preparatory studies phase” is stated by NDA (2010) to be 5 years maximum duration and part of MRWS (2008) Stages 1 to 4 of the site selection process. The UK waste default inventory includes ILW plus HLW,

spent nuclear fuel, and separated plutonium, and waste from new-build nuclear power plant

Purpose of Report

This report states it is to move on from "identifying drivers", ie needs, to working out which Topics and Areas need research work undertaken. According to this report, "at a later stage" the budget will be allocated, tasks defined and procured from research suppliers, results received reviewed and published. These will lead to MRWS Stage 5, ie investigations on specific site(s). That stage 5 may use geophysical surveying, or boreholes from the surface, for example. At this stage because no sites (or regions) have been identified, the NDA research has to be generic. The scope of the report deliberately keeps all options open for all types of setting of Repository, with all types of engineered design for a Repository being considered. That results in many of the statements being generic, with rider clauses stating that more detailed and site specific research will be needed, or undertaken, when a specific site is identified. Consequently, none of this research is intended to be specific to West Cumbria, although most of it would be relevant, should sites be investigated in West Cumbria.

Benchmarking against other nations programmes

In the European Union 143 nuclear power plants are in use: Belgium (7), Bulgaria (2), Czech Republic (6), Finland (4), France (58), Germany (17), Hungary (4), Netherlands (1), Romania (2), Slovakia (4), Slovenia (1), Spain (8), Sweden (10), and UK (19). Italy and Poland plan to build nuclear plants, and the UK plans to renew its nuclear plants.

Several nations are ahead of the UK in siting a subsurface repository. Finland plans to have its repository operational in 2020, Sweden in 2023, France in 2025. In Germany a licence has been granted to operate the deep disposal facility at Konrad for "non-heat emitting wastes". The WIPP in New Mexico USA is operational to receive long lived transuranic wastes in USA. Japan has started a siting process (OECD 2008).

Context of UK radioactive waste storage

The UK first commenced work on radioactive waste storage in 1970's. The British Geological Survey used generic hydrogeological settings to identify 537 sites across the whole UK, and PIEDA in 1988 - 89 worked with Nirex through several cycles of technical sieving to produce a short list of 11 in 1988, which included Sellafield A – in anyhydrite beneath the Sellafield site. The Sellafield B site at Longlands Farm was then introduced during the sieving of 9 specific onshore sites plus 2 generic offshore sites, to make a total of 12 sites. Boreholes were drilled at Dounreay and Sellafield in 1989-91, and the second borehole at Sellafield proved Borrowdale Volcanics at depth, which could be investigated to form a Repository (Nirex 2005).
When an application was made by Nirex to develop access shafts into a deep underground Rock Characterisation Facility, a public Planning Inquiry ensued which was, at the time, the UK's longest. This found against Nirex, with the Planning Inspector concluding "*the Assessor's advice is that two principles of over-riding value can be derived from his review of the geological, geomorphological & hydrogeological criteria. One principle is that: The location should be in a region of low hydraulic gradients, so that there should be slow-moving & long groundwater pathways. And the other is that: The geology & hydrogeology of the site and its district should be sufficiently uncomplicated as to be readily characterisable & predictable."* (McDonald 1997, para. 6A.60).

The current process to search for and develop a repository 'Managing Radioactive Waste Safely' (MRWS) was launched by Government in 2001, and is founded on open-ness, transparency and public engagement. Radioactive waste is currently stored at 34 surface locations around the UK.

Method of NDA work for this report

The report is very long (150 pages), because it is intended to be a comprehensive exposition and listing of all the Topics and Areas related to geological disposal of ILW higher activity wastes, spent fuel and separated plutonium both for wastes now and for future wastes. It is apparent that an extremely wide range of current, and recent, research and project work has been summarized in this report. That includes work undertaken by UK Nirex and predecessors, work undertaken by international collaborative radwaste projects, and a very large number of reviews of published work undertaken by, or funded by, the NDA. This review and listing includes most known Topics affecting the general nature of geological disposal of radioactive waste in the UK. The review work has a commendably wide scope, and includes additional surface based aspects such as: geochemical information and databases suitable for prediction and simulations; assessments of packaging suitable for transport to a common temporary store; and also softer skills such as the need for public engagement and site assessment methods. The aim of this NDA document is to compile all known Topics, subdivide these to Areas, and to examine the state of knowledge, and NDA capability, in each.

West Cumbria: This document does not attempt to assess whether West Cumbria, or any particular site, is amenable to analysis with these concepts, tools and techniques. There is no attempt to consider the assemblage of tools and techniques available or applicable to any individual West Cumbria setting.

By contrast, the types of self-inquiry asked by the NDA of itself in this report can be paraphrased as: Is this a Topic of impact (importance); Is enough known about this? How urgent is it to do some work on this relative to the phase of investigation the process is at? Does NDA have a need to continue capability in this – by undertaking more reviews, or buying in to international projects run overseas? Does NDA need to commission its own work, focused on a UK waste mix or storage setting?

NDA research Topics, scope, and analysis

Fifteen Topics are identified by the NDA to organize research on radioactive waste. These encompass the range of technical issues from diverse wastes in their different types of packaging, through different types of waste containment, to site investigation techniques, public understanding and finally designing the approach to integrated site performance assessment.

The report is written in conventional English, and uses accessible language. The detailed overview provides an introduction to each topic, then summarises the types of research and achievement gained in the UK or globally. This gives a very good "feel" for the size of the problems already tackled, and the large problems which remain to be solved. There are cross-references between sections which demonstrate that multiple inter-dependencies in attempting to understand the totality of a complex system. Specific research and development is briefly suggested in each topic, sometimes with suggestions about the method to take that forward - for example collaboration on any European or international project, new experimental or

measurement work commissioned from a contractor, a consultancy report, or an internal review by NDA.

Method: The 15 Topics are sub-divided into 203 Areas, each of which is analysed and described. This provides a very thorough coverage of known issues, and enables clear conceptual boundaries to be placed around discrete areas of work. However that disaggregation inevitably makes the report difficult to use and to re-combine into a total overview of the Repository as a disposal system. For each Topic the NDA used internal expertise and external advice to split into a suite of Sub-topics, and then into Areas. These have then been considered in terms of significance and impact on safety or delivery of the Repository. These Areas were each rated by the NDA as High, Medium or Low, by using a series of seven structured questions, focused around the technical and commercial "drivers" which would utilise the knowledge gained. This is a sensible and very logically structured type of approach, which should draw attention to many diverse aspects of research needs (or lack of needs) in each Area. However the final matrix for decisions is reduced to just three criteria: Impact, Gap in knowledge, Urgency. Each of these criteria is ranked simply as High Medium or Low (p21). This is easy to understand, but complex to use.

		Area 1.1.1
	Sub-topic 1.1	Area 1.1.2
		Area 1.1.3
Topic 1	Sub-topic 1.2	Area 1.2.1
		Area 1.2.2
	Sub-topic 1.3	Area 1.3.1
		Area 1.3.2
		Area 1.3.3

Driver	Impact	Knowledge Gap	Urgency
Supports the identification and development of GDF concepts	M	M	L
Supports the Disposal System Safety Case	H	M	M

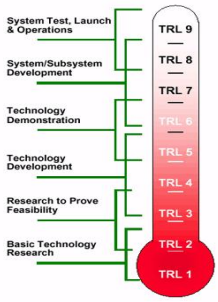


Fig. 1 (left) NDA division of research Topics into Sub-Areas and Areas
Fig 2 NDA analysis of each Area linked to several "drivers" and 3 fold ranking
Fig 3 Technology Readiness Levels to describe the Operational ability of an Area

Critique of methods: The process, of course, relies upon all factors being considered at the start. It is not clear how the fifteen topics were elicited – that is described in previous reports – and the implication is that these were drawn from NDA internal perception and work in related radwaste agencies internationally. However, there is no clear audit trail, nor is there a clear explanation how any external perceptions were considered. The method of "scoring" or coming to a final assessment is obscure, and presumably relies on expert judgement by a corporate personality. The work has been reviewed by internal NDA managers, but there is no mention of external peer review of this process to elicit and rank research priorities, or to discuss the criteria used. Consequently, this process must be subject to the possibility of unintended institutional bias, where a group of people, experts or non-experts, become convinced by discussion that a problem is "solved" or "not solved".

The summary statements in the Area analyses are sometimes supported by refering to external reports or current projects. It is often not possible to discern whether the summaries have been based on NDA internal opinions, or on peer-reviewed publications, or on reports from other radwaste agencies where there may, or may not, be a settled consensus. That is not meant to imply that these statements are untrue, simply that a considerable process of elicitation appears to have occurred to reach the "NDA view" as presented. To maintain easy readability, it is

understandable that most statements are un-supported by cited evidence. However this means that is impossible for a reader outside the NDA to understand how these assessments have been made and what is the quality of evidence for each Area.

The process has used seven directed questions (p17- 21), each with multiple parts. These cover a very good range of information, and should provide insight into the history and future of each Area. However the results are reported using only a 3 point scale of the style "High, Medium, Low". That is too simplistic, as is shown by the graphical analyses below. A much more quantitative and nuanced suite of conclusions (e.g. a 5 or 10 point scale) could be expected as an output result. There is also no conceptualization of the utility level of each Area. An example of that would be Technology Readiness Levels, developed by NASA in 1989 and now used in some form by many large industrial organizations (TRL 2011). These assess a process or item of equipment through the evolutionary process of Basic, Development, Demonstration and Operational. This type of approach would help to explain the range of work needed on this RWMD programme, and the challenge involved. Some Areas – such as plutonium and HLW storage assessment appear to be at TRL 1, whereas others appear to be ready for use at TRL 8 or more.

As a consequence of the "High, Medium, Low" classification, it is impossible to understand the rankings in importance between the different Areas. These could hypothetically include queries from a reader such as:
• Do all Areas need to achieve a status of "Low" Knowledge Gap?
• For "Urgent" Areas is the "answer" needed before detailed choices of Sites?
• If the "answer" is not needed then, why is it "Urgent"?
• How many person-years of effort is needed to achieve an "Answer"?
• How much will this cost?
• Does previous research history provide encouragement that time can be met?

Analysis of classification categories

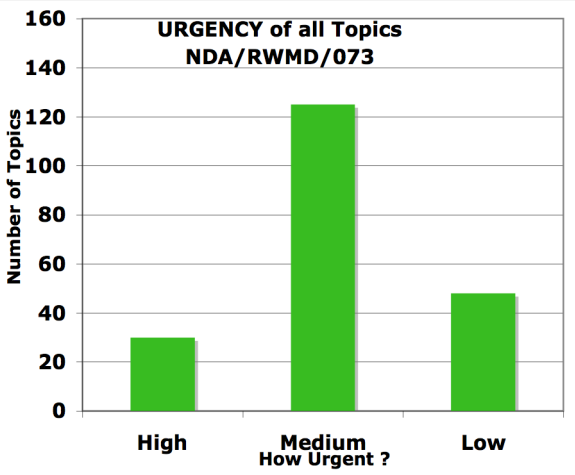
To help portray all the research Areas more visually, a simple analysis is displayed in three graphs below (Fig 4 a, b, c) - one for each of the aspects chosen by the NDA.

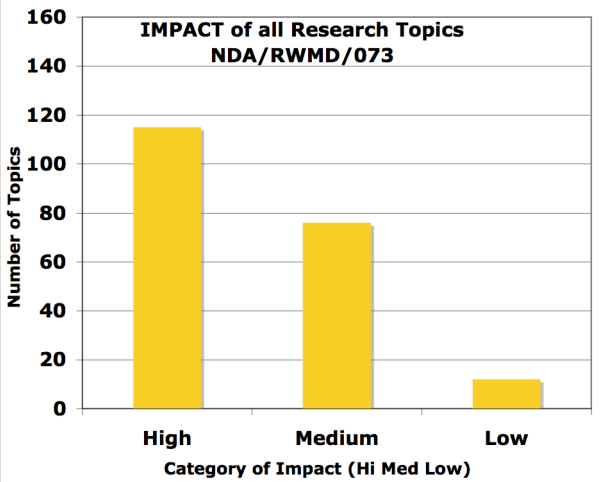
Comments: These graphs show that most of the Areas identified are of medium Urgency, so a delay in commencement is presumably not fatal to the project.

However practically all of the Areas are of high to medium Impact, which implies that all of these subjects need to be satisfactorily answered or worked on before a storage site investigation can start. Supporting that inference are 52 of the 203 Topics stated to be important to the development of a repository (Geological Disposal Facility) concept. Can progress towards a Site identification be undertaken reliably if one quarter of the scientific issues are not resolved?

The Knowledge Gap for 75% of the Areas identified by NDA is "Medium". That could imply that the process by which these Areas were evaluated has not been sufficiently discriminating, as 'average' values are such a common result of the elicitation judgement. Taken at face value, then, this Knowledge Gap implies that the progress of research has moved only partway from "totally unknown" towards a state of knowledge "fit for the purpose" for which it will be used. Does that enable any estimate of the timescale when a useful result will be derived? No timescales are mentioned in this NDA research listing. However it is highly probable that some Areas will require many years of additional research. To take two examples of

difficult Areas. Firstly, 13.3.1 “Total system model development” is about linking all the component parts together, to make tested, working and reliable simulation of the Repository now and into the future. A point of view could be that this type of Topic has been under development since the early 1990’s, and is continually changing because of computer power and now because the waste to be emplaced in the repository also includes HLW, spent fuel, and plutonium. This research and development work will also be affected by Topic 7.2.5 “Coupled Processes” – this is about understanding and modelling multiple effects of heat and chemistry in the storage site combined together, and is stated to be “central to the safety case”. The DECOVALEX project by which this is being investigated has been working since 1992, yet the Knowledge Gap is still cited as “High”. It is hard to guarantee such work will be concluded soon.





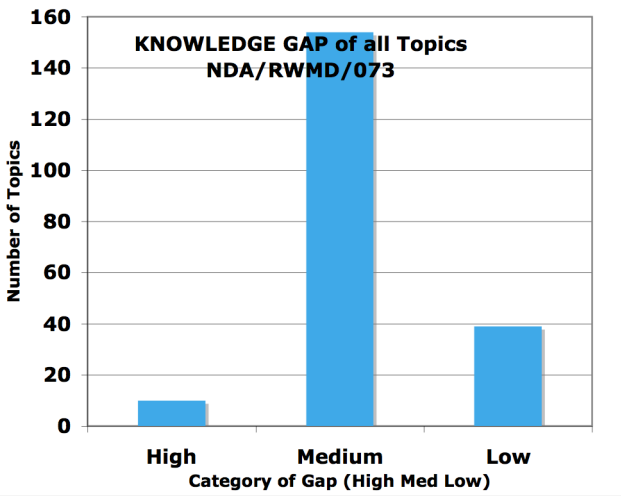


Fig 4a, b, c The 203 different research Areas identified by NDA have been assessed by NDA for *Urgency* (how quickly is this needed), for *Impact* (how important to have knowledge of this before site selection) and *Knowledge Gap* (how far away might NDA be from a workable “answer”). These graphs show analysis of these three aspects. (labelled Topics should be Areas)

In summary, there has been over 20 years of research and some Areas are, maybe, only halfway towards an “answer”. Will another 20 years be required – or another 40, or are some questions un-answerable? That is important because this Area is one of those with an essential contribution to the Repository conceptual design. Secondly, a Topic example is Section 9 “release by the gas pathway”, which has 9 Areas within it. The problem of gas escape from a storage site, and the amount of radioactivity carried to the surface within tens of years, has been under investigation since before 1992 (Rodwell and Nash 1992), and is still cited with many Medium and High Knowledge Gaps. If MOX and plutonium are co-disposed, this problem may become very significantly harder to solve because of heating and fracturing of rock (below).

Comparison of NDA research proposals to problems previously identified.

Problems identified by the NDA

It is very difficult to rapidly understand the overall analysis of diverse Topics identified by the NDA review. Close and detailed reading of the text, combined with analysis of the H, M, L rankings enables an interpretation and summary to be elicited. Topics highlighted by NDA text as the most important include :

- HLW and plutonium change of waste and heat production through time;
- Groundwater movement (locally);
- Coupling of geosphere evolution and fluid flow;
- Short term (decades) release of radioactive ^{14}C from irradiated metals and organics up through the geosphere to reach the biosphere;
- Radionuclide release from plutonium and uranium HLW;
- Development of groundwater models for performance assessment;
- Public and Stakeholder engagement
- Development of a multi-criteria decision analysis method to choose a site

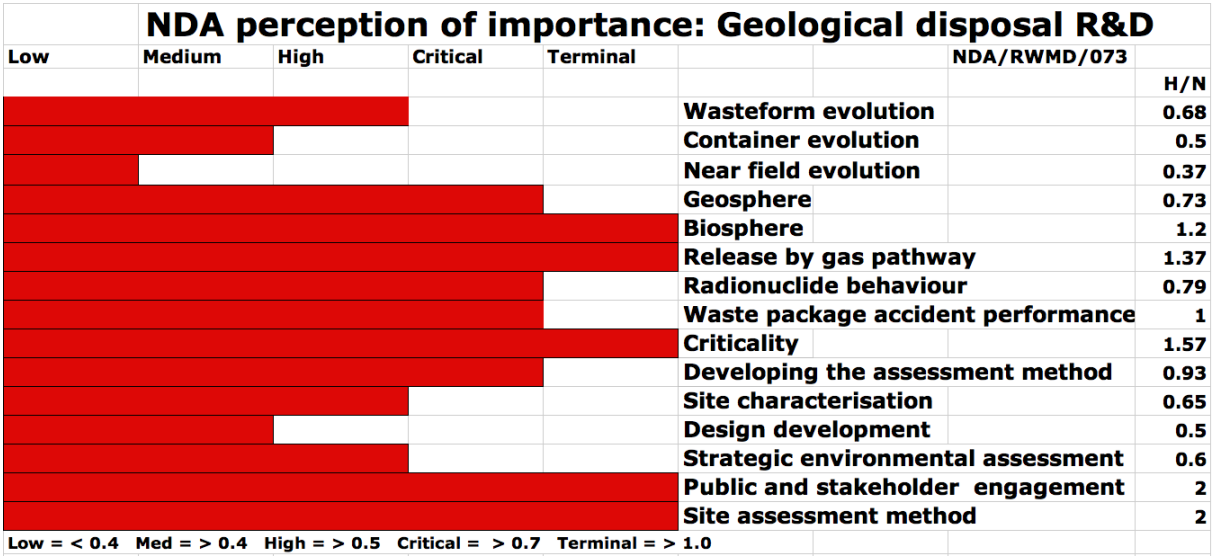


Figure 5 Compilation of "importance' derived in this summary from NDA rankings in the geological disposal R&D report. This has been derived by taking each Topic individually, and counting the total number of "High" assessments in all the Areas within that Topic, and dividing by the number of rows of assessment in all the Areas. Thus, larger numbers are more important. See text discussion below.

Problems identified by organisations outside the NDA

How does the NDA analysis compare to the analyses made by other organizations with interests in radioactive waste? Are the assessments and conclusions similar? Or, if not, where are the differences? A comparison has been made between the types of research issues identified by NDA, and the types of issues identified by external organizations. Four types of report have been briefly reviewed: 1) A professional science organization: European Union Joint Research Centre (2009); 2) A Nuclear experts group outside the NDA process and constructively critical of it (NWAA 2010); 3) Science report for a campaigning green group (Greenpeace 2010); 4) The UK regulator (Environment Agency 2009) where numerous and detailed unresolved problems are described. An item-by item comparison is beyond the present scope. The listing below shows that the great majority of issues are similar between the NDA assessment and the assessment outside of NDA. Major

differences are concealed, because of the very different importance different groups attach to similar issues.

As a narrative summary, some important issues identified by external reviewers are:
- Gas migration from the Repository – H_2 and CH_4 form a very early radioactive dose.
- Package of wastes – canister corrosion
- Heat from wastes – especially HLW, MOX and plutonium; destroys bentonite backfill sorbtion and creates cracks for water flow and forces land uplift.
- Chemical unknowns – oxidation of the Excavation Damage Zone, poor oxidation-reduction reaction data, poor understanding of colloid transport of radionuclides, cellulose (paper) decay increases plutonium solubility, unsuitability of sorbtion batch experiments.
- Groundwater flow paths – local and especially regional paths are unsuitable
- Radiation - estimated dose effects on biota at surface

Benefits of external challenge

There are clear examples that external challenge and review produces produces benefits in improved quality of evidence, robust information, and convergence of scientific debate. One example should make the point.

Nirex proposals before 2005 had under-recognised the role of radioactive ^{14}C leakage. Radioactive waste inventories in the UK have a large amount of ^{14}C. A consensus had been developed that carbon from the waste mix would securely react with the cement. However as well as that carbonation reaction, this ^{14}C also has potential to react with hydrogen to form methane, and form part of a leak of gas which affects the surface within 40 years of closure of the Repository (Nirex 97, Pamina 2008 p67, 75). The gas issue was identified clearly by the Environment Agency (2009), particularly for fractured host rocks – of which there are many in West Cumbria *"it could also be difficult to make a safety case if large gas volumes and/or rapid gas generation is likely to occur, due to the relatively high host rock permeability (above 10^{-8} to 10^{-9} m/s) leading to potentially rapid gas transport to the surface"* and *"There are fundamental limitations in our understanding of the couplings* [of gas evolution and migration] *and their detailed modelling is very difficult."* Review work by the NWAA (2010 p 5,6) publicly identified the link between gas leakage and radioactive ^{14}C, their calculation is that that doses of radiation at the land surface within 40 years of repository closure could be 10 TBq/yr, which is 4,000 times greater than the dose considered 'tolerable' by the Environment Agency. Following the publication of these external challenges leakage of ^{14}C is, in this current NDA document, now considered to be one of the largest potential doses of radiation leaking from a repository. The role and impact of ^{14}C leakage is one of the highest priorities in the current NDA research proposals.

Omissions

There are Topics and Areas which are relevant, but do not appear to be included in this NDA research review. A few are briefly described here.

Modelling: It has been shown since the early 1990's that computer models of natural systems do not provide unique answers (Oreskes et al 1994). Rather, these models can produce many results predicted from the same set of data, or same starting point. The use of models in a natural world is not to provide a single end point, but to help investigate the processes. It is philosophically not possible to use complex

models to “prove” secure site performance at a radioactive waste repository. Typically, many simulations are made and the cluster of results are compared to the safety regulations. But, unless all the possible leakage results have a radioactive dose lower than the regulations, then safety performance can not be guaranteed.

Ocean leakage: The generic flow direction of groundwater across the region of West Cumbria is towards the Irish Sea. The storage concepts developed by Nirex admitted that radioactive leachate would eventually discharge into the Irish Sea. This is likely to be precluded by the OSPAR international conventions because i) this would be a new activity; ii) the radionuclides are not natural.

Using Repositories outside the UK: EU law allows states to enter into agreement to store their waste in another EU state COM(2010) 618 Article 4 (3) *“Radioactive waste shall be disposed of in the Member State in which it was generated, unless agreements are concluded between Member States to use disposal facilities in one of them.”* Consequently, an options evaluation could be considered of the UK storage option against the timescale, costs, safety performance benefits and public perception feasibility, of disposal in (say) France, Finland, or Switzerland.

MOX and plutonium disposal: The UK is only now starting work on MOX and plutonium disposal. Other countries have had programmes on HLW lasting decades. This is cited as “high” Impact on the repository design. Yet there is very little UK expertise, and it is not yet decided if MOX and plutonium will finally be included. That makes the NDA rating of research urgency less than maximum. However, delaying research at this stage leaves the NDA unprepared to dispose of plutonium. To quote the NDA (2010 P) *“If a Repository is not designed to take plutonium, it is likely that a second Repository would ultimately be required to take plutonium. In order to assess opportunities and a full range of options it is necessary to start to review them now.”*

MOX and plutonium: land surface uplift: Very major problems can be anticipated. One such is the effect of heat from these High Level Wastes on the surrounding rock. Heat in Switzerland will produce uplift at the surface ranging from 40 cm to 100 cm within 2,000 to 4,000 years, and affect locations up to 700 km distant (Klubertanz et al 2008). In Switzerland, there is uniform simple geology in the potential location of a Repository. Geology in the UK, especially in West Cumbria, is very fractured and faulted. In such a setting, the uplift may not be smooth, but may be like piano keys, with dislocations along previous fault lines producing earthquake activity noticeable by surface residents, and new fracture pathways of rapid gas release to the surface.

Underground Rock Laboratory: Many other nations intending radioactive waste disposal have excavated cavern laboratories in a similar setting to their intended repository. These allow in-situ tests of rock properties, to refine the basic information needed for repository construction and for long-term security during the next 1 million years. It is remarkable that this NDA review does not provide an argument for or against such a facility. This would be a major item of effort and expense, so that it is strange that this is omitted. There are undoubtedly projects underway in collaboration in rock laboratories with other organizations globally. But rock properties in the unique geological setting of West Cumbria are unlikely to be identical to those in laboratories of France Germany Belgium Sweden or Switzerland, so a UK lab would be needed.

Requirement to fund challengers

A major weakness in the current MRWS system, is that there are only minimal research funds for groups outside the NDA. Even the Environment Agency has to rely on NDA payments to undertake much of their work. External science-based challenge has clearly acted as a check, and produced important changes to previous consensus. It is proposed that communities should be provided with much larger funds to undertake independent review and occasionally to replicate work. An annual budget of 1-10% of the £20M NDA spend on RWMD R&D would be appropriate.

Relevance to West Cumbria

For the West Cumbria communities, at this MRWS stage, three questions could be asked:

1) Are any of these questions and research Areas vital deal-breakers which will specifically include or exclude a suite of potential sites which may exist in West Cumbria? The answer to that is not possible to discern from the information provided. It is known that the Nirex research of the 1990's could not overcome the fundamental uncertainties of complex and un-predictable deep geology, with unsuitable flows of groundwater leaching radioactive material from the wastes and bringing that to the surface and discharging into the Irish Sea. Consequently there is a strong likelihood that those fundamental problems raised in the 1990's still do exist, and after much detailed effort and expense over many years these fundamental problems will still exist, and a new proposed Repository ends up as inadequately secure. By contrast, more research could potentially be good-enough to produce a reliable assessment that a Repository specifically in West Cumbria will perform well. The detailed listings in this current document, of many research problems to be overcome, provide assurance that some of these issues will be systematically examined, but there are no guarantees of success.

2) Does any of this proposed research work require agreement of the West Cumbria community to participate, or could this work continue irrespective of any suite of potential sites? The answer to that appears to be "no agreement is required", as most of this work is generic and deliberately not specific to any identifiable site in West Cumbria. There are numerous statements that site specific information and a specific site design will enable work to be directed onto candidate features of a site.

3) Why has the abundant evidence about West Cumbria from Nirex investigations and the RCF planning inquiry not been included in this NDA research review? The answer to that is presumably that the MRWS process has not yet fixed upon a suite of sites to investigate, so that such local detail is considered "premature". That does of course raise concerns that the MRWS process may be driving this beyond the point of intuitive sense or public confidence. The Nirex process to choose a site in the 1990's considered all of the UK, and claimed to have examined 10 sites in Cumbria, after which sites in West Cumbria beneath Sellafield (site A) and beneath Longlands Farm (site B) were assessed in detail. The Sellafield-A site was rejected during this internal review as being *"significantly the worst of all land-based sites and should not be investigated."* (Nirex 2005 p14). Thus Sellafield Site B was considered to be the best in the UK and

was investigated from 1989 to 1997 with 20 deep boreholes and the leading technical measurements available in Europe, costing £400M. After much detailed work, the complex geology and poorly predictable groundwater flow, carrying dissolved radioactivity towards the surface across the region were two major factors in the decision to reject development of a underground rock laboratory in 1997. If the best site in West Cumbria was rejected in 1997, it is not clear how less-good sites are going to be improved by the research to be undertaken by the NDA from 2011 to 2016.

It is also clear that West Cumbria does not meet international norms for radioactive waste storage sites, being neither predictable and simple in its geology or a region of simple groundwater with long flow paths (see page 2 above). It is also apparent that NDA has an internal opinion that West Cumbria is suitable as a storage site, which runs well ahead of the MRWS process. This was stated by the Repository Director at the NDA *"work done by Nirex following its investigations of a site near Sellafield …. was published in 1997 (after the Public Inquiry) and showed that groundwater flows and flow paths at that location were consistent with the safe disposal of intermediate-level waste"* (Ellis 2010). This probably relates to the Nirex 97 report synthesizing the most advanced assessment by Nirex, and based on the "best site" Longlands Farm. There is no published evidence to support that NDA assertion – the basic measured values of rock and hydrogeology are the same in Nirex publications before, during, and after the Inquiry.

Although the NDA document reviewed here chooses to state that *"The natural geological setting is a key barrier in the system"* (p 56) the same report devotes only 45 lines to a topic which terminated developments in 1997, and shows as "critical" in Fig 5 of this review, and the NDA report proposes no remedies to the problems identified in 1997, making only a general statement (p 59) that computing capacity has advanced during the past 15 years (p 58). There is no guarantee that further research can resolve the inherent uncertainties of modelling and prediction sufficient for the accuracy and precision required for a site in West Cumbria. Secure containment of buried radioactive waste into the future will be dependent on the correctness of extremely complicated and interlocking models, rather than the geology. Before West Cumbria makes a decision to engage, or to disengage, with MRWS a research review of the available local evidence would be extremely sensible.

Conclusions

1) This NDA research review identifies and summaries a huge quantity of recent and current detailed research relating to geological disposal of radioactive waste. That includes ILW, HLW, spent fuel and plutonium. The report provides some confidence that NDA is systematically evaluating many of the detailed factors affecting storage site selection, disposal facility concepts of design and most types of performance issues in the near field and far field, which will have an impact on overall safety.

2) The intention for this report is to inform NDA work during the next 5 years in the run-up to selection of detailed site(s). The work is explained under 15 different

Topics, each divided into multiple Areas. This provides a good overview of the size of the UK problem in choosing and evaluating sites for detailed work. The 203 different research Areas are each assessed in terms of their Impact, Knowledge Gap, and Urgency. A large number of the Areas are classified as “urgent and high impact”.

3) Because the MRWS process is still at a preliminary stage, this NDA review deliberately does not focus on West Cumbria. However most of the work could be applied to West Cumbria, should one or more communities there decide to engage.

4) There is no attempt to place timescales on any of the work. Neither is there any costing. Nor is there any ranking of urgency. Nor is there any assessment of readiness for use. Several detailed reports, to be released during 2010, apparently summarise the state of concepts around different aspects of geological storage proceses, facility design, gas migration etc. However these were not available on the NDA website during late February 2011, and that context could not be evaluated.

5) Summary graphs have been derived from the report, which show that there is insufficient discrimination to decide the importance between many of the research topics. A comparison was made with research topics identified by groups outwith the NDA and compared to a graphical interpretation of “priority” derived from the NDA information. There is a large overlap of Topics and Areas. But it is clear that very different weightings are attached to the importance of Topics by the NDA and by outside groups.

6) Suggestions are made to include additional research Topics, including a review of previous radioactive waste disposal work on West Cumbria. Disposal of MOX and spent fuel in the UK has little research, and may be very difficult. Heat produced from subsurface disposal of such waste may cause uplift and fracturing, making retention of radioactive gas impossible.

7) There is only minimal UK funding to develop scientific reviews and rival work from communities who may be affected. It is clear that constructive criticism from outside the NDA has altered some substantive Topics and Areas. This external work is currently un-supported. This risks that the MRWS process will be fundamentally un-scientific and un-balanced. An arms-length allocation should be made to potential host regions of 1% to 10% per year of the NDA’s own budget. This will result in better scientific consensus and confidence amongst a community and stakeholders.

8) A research-driven agenda from the NDA would ideally include A) discrimination of the important issues, B) selective focus on a few types of disposal site; C) estimate of timescales to resolution; D) cost of resolution; E) evidence of confidence that technical consensus exists outside the NDA.

References

DEFRA 2008 *Managing Radioactive Waste Safely: A framework for implementing geological disposal*, Cm7386, June 2008. Defra, BERR, Welsh Assembly Government, Department of the Environment Northern Ireland, ISBN 0101738625.

EC 2010 Directive management of spent fuel and radioactive waste COM(2010) 618 http://ec.europa.eu/energy/nuclear/waste_management/doc/2010_11_03_proposal_directive_radiactive_waste.pdf

Ellis A 2010 West Cumbria MRWS Newsletter: winter 2010 www.westcumbriamrws.org.uk

Environment Agency 2009 Technical issues associated with deep repositories for radioactive waste in different geological environments SC060054/SR1 http://www.environment-agency.gov.uk/static/documents/Business/e.pdf

European Union Joint Research Centre (2009) Geological disposal of radioactive waste: moving towards implementation. W.E. Falk and K-F Nilsson Joint Research Centre Institute for Energy, Report EUR 23925. http://ie.jrc.ec.europa.eu/publications/scientific_publications/2009/LR-JRC_Reference_Report_IE_Geological%20Disposal.pdf

Greenpeace (2010) Rock Solid, report by H Wallace of GeneWatch. http://www.greenpeace.org/raw/content/eu-unit/press-centre/reports/rock-solid-a-scientific-review.pdf

Klubertanz G, Folly M, Hufschmied P, Frank E. 2008 Impact of the thermal load on the far field and galleries of a HLW-repository. Physics and Chemistry of the Earth 33 (2008) S457–S461.

McDonald 1997 Cumbria County Council, Appeal by UK Nirex Ltd APPIH0900/AI94/247019 http://www.davidsmythe.org/nuclear/inspector's_report_complete.pdf

Nirex June 2005 Review of site selection 1987-1991 TN/477002.

NDA 2010 Geological Disposal Steps towards implementation. NDA/RWMD/013

NDA 2010 P Plutonium Credible Options Analysis (Gate A) 2010 V 2 SMS/TS/B1-PLUT/002/A, http://www.nda.gov.uk/documents/upload/Plutonium-Credible-Options-Analysis-redacted-2010.pdf

Nirex 2005 Review of 1987-1991 Site Selection for an ILW/LLW Repository Technical Note 477002

Nirex 97 An Assessment of the Post-closure Performance of a Deep Waste Repository at Sellafield Volume 4: The Gas Pathway Report no : S/97/012

Nuclear Waste Advisory Associates (2010) NWAA Issues Register March 2010. www.nuclearwasteadvisory.co.uk

OECD 2008 Moving Forward with Geological Disposal of Radioactive Waste http://www.oecd-nea.org/rwm/reports/2008/nea6433-statement.pdf

Oreskes N., Shrader-Frechette K & K. 1994 Verification, Validation, and Confirmation of Numerical Models in the Earth Sciences. Science, Vol. 263 pp. 641-646

PAMINA 2008 http://www.ip-pamina.eu/downloads/pamina2.2.b.2.pdf

Rodwell, W.R. and Nash, P.J. 1992. Mechanisms and modelling of gas migration from deep radioactive waste repositories, June 1992. Nirex report NSS/R250, UK Nirex, Harwell.

TRL 2011 http://en.wikipedia.org/wiki/Technology_readiness_level