Together Against Sizewell C

23rd May 2022

Dear Gareth Leigh,

Sizewell C DCO Application-comments on matters raised by BEIS

As an Interested Party in respect of the Sizewell C planning application [IP no. 20026424], and as members of the BEIS/NGO Forum, we thank you for the opportunity to comment on the findings of your review and the responses which you have received so far.

Together Against Sizewell C (TASC) has been heavily involved from the start of the planning process at the Stage 1 EDF consultation and have responded to all subsequent SZC Co/ NNB Genco consultations. Even at these early stages of the process, we questioned the availability of a potable water supply for the construction and operation of the plant. This is just one of the many critical issues vital to the proposed development which has remained unresolved after years of debate, questioning and inquiry and to which there are still no answers. Your review and the responses have given rise to further considerations which include, but are not limited to the following:-

Lack of potable water supply for operation

TASC note that the Scoping Opinion 2019 [APP-169] stated:
Para 3.3.9 *"The Inspectorate recommends that the ES assess the significant environmental effects associated with the Proposed Development and its interaction with utility receptors/ infrastructure assets, such as (but not limited to) existing gas and water pipelines, overhead/underground electrical cables, sewer network, and potable water supply. This should include consideration of both onshore and offshore receptors and assess impacts during construction, reinstatement, and operation of the proposed development."*
In TASC's opinion the Applicant has clearly failed to consider the '*receptors and assess impacts during… operation of the proposed development"* in relation to the potable water supplies because it has no guaranteed potable water supply. This is supported by Natural England whose comments on the REIS [REP10-199] include the statement in para 2.1.2: *"The water supply is a fundamental component of the eventual operation of the project, and the potential impacts of its construction should be clearly assessed in accordance with sections 4.2 and 5.15 of National Policy Statement EN-1 (NPS EN-1), sections 3.7 and 3.9 of NPS EN-6 and paragraph 3.3.9 of the Planning Inspectorate's Scoping Opinion for the Proposed Sizewell C Nuclear Development (July 2019) [APP-169]."*
Turning to the Applicant's recent submission to BEIS concerning the possibility of a permanent desalination plant, **TASC consider** the suggestions that one could be sited underground just north of the SSSI Crossing or on the Sizewell A site currently earmarked for the Sizewell B outage car park, are totally unacceptable. Both lead to further encroachment of an industrial complex into the Suffolk Coast and Heaths AONB. One can only imagine the likely significant effects of siting an environmentally damaging underground desalination plant in and adjacent to designated wildlife sites (Sizewell Marshes SSSI, Minsmere to Walberswick SSSI and Ramsar site)- that are dependent on the levels and quality of groundwater. To put a desalination plant on Sizewell A land would result in the unacceptable loss of Pill Box Field. This area has been planted as partial mitigation for

the loss of Coronation Wood to enable the relocation of the Sizewell B facilities to make way for the SZC project.
TASC would also like to remind the SoS that in January 2021 the Applicant advised, in its Water Supply Strategy document, that desalination is not an appropriate solution for the supply of potable water to SZC for either the construction or operation phases, this being one of the few statements made by the Applicant with which TASC can whole-heartedly agree.

Mitigation for the impact on the B1122

TASC do not wish to repeat comments made in our earlier DCO submissions but feel that, in the light of many unsubstantiated statements made by the Applicant in their response to your 18th March queries, we must repeat our statement that the Applicant has failed to apply the principal of avoidance first, mitigation second and if these cannot be applied, then compensate. While it is TASC's opinion that the SZC project is unacceptable and should not be granted planning permission, it was mentioned during the DCO examination, that much of the substantial adverse impacts arising from use of the B1122 for all development traffic in the 'early years', could be avoided by putting the SLR, 2VB and park and ride sites in place before development on the main site commences. The Applicant's statements as to why the main development work must start at the same time as the mitigation developments do not stand up to scrutiny:-
-paras 3.1.15, 3.1.16 and 3.1.18 refer to the urgency of the need for nuclear and any delay would impact on the UK's need to decarbonise the electricity grid by 2035. Sizewell C, if consented, is unlikely to be operational until 2035, at the earliest, by which time the grid is expected to be zero carbon so Sizewell C will only have added a huge carbon debt contrary to the UK's aims to reach net zero as a matter of urgency.
-para 3.1.22 contains a disingenuous statement by claiming that Sizewell C will add to energy security. The UK does not have indigenous uranium supplies so is totally reliant on overseas supplies and therefore the policies of governments over which we have no control. Indeed, with Russia and countries under its influence, supplying over 50% of the world's uranium and EDF's close ties with Rosatom, the Russian state's nuclear operator, new nuclear projects, especially with EDF as the developer, appear to be far from secure.
-paras 3.1.26 and 3.1.27 cite the approval of two Scottish Wind Farm projects as being a precedent which justifies potential adverse impacts on European sites. However, the Sizewell C project needs to be differentiated from these projects as: they do not include permanently viewable infrastructure development in the AONB and do not involve building directly on a SSSI.
TASC have seen no evidence that the Applicant has adequately looked at alternatives that avoid or adequately mitigate the impacts from the early years works. The SLR has no legacy benefit, a view supported by Suffolk County Council.

Coastal defences and processes

TASC have already raised our concerns about the lack of detail provided in respect of the Hard Coast Defence Feature [HCDF] so are disappointed to find that the final details, even at this late stage of the process, are still not with the SoS. We do not even know HCDF's exact position, particularly at the southern end. With the HCDF being critical to the viability of the whole project, TASC contend that the project cannot proceed without these details being finalised and in the public domain.
In REP10-247 and REP8-285a (agenda item 3(b)) [please see extract at Annex A below], TASC set out our concerns about the shortcomings in the Applicant's flood risk assessments, in particular the inadequacy of assessments only going up to 2140 when the site will need to be kept safe long after that date.
Referring to question 5.1 in BEIS letter of 18th March, TASC endorse the response prepared by Mr Nick Scarr in his report entitled "Sizewell C- coastal considerations and TR553" together with his previous submissions calling into question the adequacy of the assessment of coastal processes and associated flood risks. TASC also endorse the submissions to BEIS from Bill Parker and the Suffolk Coastal Friends of the Earth report entitled "Comments on responses to SoS's letter of 18th March 2022 concerning coastal processes and the implications for the proposed soft and hard coastal defences". Like Nick Scarr, Bill Parker and Suffolk Coastal FOE, we believe the Applicant has totally underplayed the potential coastal erosion that could occur at Sizewell during the **full** lifetime of the plant over the next century and a half.

The picture below shows the erosion in front of the Sizewell nuclear sites from the April 2022 storm

SZC Co's response to questions from the government of Austria [GoA]

GoA question: Question 1 - What is the timetable of the planned dry interim storage for spent fuel?
SZC co response at para 5.2.2: *"7.7.80 Following this initial storage period in the on-site reactor fuel pool, the spent fuel assemblies would be prepared for transfer to the separate on-site [interim spent fuel store] ISFS, where they would be safely stored until a Geological Disposal Facility is available for transfer, and the spent fuel is suitable for final disposal."*
TASC comment: The Applicant's flood risk assessment only goes up to 2140, therefore the Applicant has not demonstrated that the SZC site and the spent fuel stored there can be kept safe for its full lifetime. Nor can there be any certainty that there will be a Geological Disposal Facility [GDF] available for this radioactive waste.

SZC co response at para 5.2.3 includes the statement: *"This would allow interim storage to be maintained until a Geological Disposal Facility, or an alternative disposal/management route, has been established and the heat levels within the fuel are at levels that permit its disposal"*
TASC comment: The Applicant's statement confirms there is no certainty that there will ever be a UK GDF to store the spent fuel arising from the SZC project. The Applicant then suggests an alternative could be a possibility but has not demonstrated during the SZC examination process, that there is a viable '*alternative disposal/management route'*. TASC's concern is that the spent fuel could be stored at the Sizewell C site indefinitely, effectively making the Sizewell C site a de facto nuclear waste storage facility without there being any community consultation as to whether the community is willing to host such a facility or, indeed, whether the waste could be safely stored there.

GoA question: Question 2 - What is the status of the geological repository for spent fuel and HLW [high level waste]?
SZC Co response at para 5.2.6 *"With regard to the availability of a Geological Disposal Facility, Radioactive Waste Management Ltd have published their plans for the scheduling and implementation of the Geological Disposal Facility"*

TASC comment: While it may be government's intention for there to be a GDF, there is uncertainty that a GDF will be a scientifically proven safe means of storage. This is highlighted by the matters raised by the Nuclear Waste Advisory Associates in their report "NWAA ISSUES REGISTER Outstanding Scientific and Technical Issues Relating to the Production of a Robust Safety Case for the Deep Geological Disposal of Radioactive Waste"- the report is Annex B to this document. TASC understands that the NWAA raised over 100 issues that needed to be resolved by the NDA to demonstrate the viability of a GDF and, while the report was prepared in March 2010, most of these issues remain unresolved.

GoA question: Question 4 - Is it planned to use copper for the spent fuel canisters, and if yes, how will the copper corrosion problem be solved?
SZC Co response at para 5.2.11 states: *"For Sizewell C, fuel assemblies removed from the reactor would be cooled underwater in the fuel building fuel pool for around 10 years during operation; and 3 years at end of generation."*
TASC comment: TASC are surprised that the Applicant is claiming that spent fuel will only need to be stored in the fuel pool for 3 years after operations cease. TASC have a written response from the ONR who have advised us that Sizewell C's fuel will need to be stored in the fuel pool for 10 years for cooling and does not differentiate between during or after end of generation. We therefore question the veracity of the Applicant's claim.

SZC Co response at para 5.2.13 states *"The spent fuel would remain here until disposal at the UK Geological Disposal Facility is available. The intended design life for the ISFS facility is for storage of spent fuel for 100 years, but with the potential to extend to 120 years+ after end of generation."*
TASC comment: SZC Co's statement highlights the disparity between the length of time that spent fuel will be stored on the SZC site and the Applicant's flood risk assessments only going up to 2140 with the Applicant claiming that the site will be decommissioned by that date. In the unlikely event SZC starts operation as soon as 2035, the ISFS facility would be needed from 2045 so 120 years from then takes storage up to 2165 and after that the site would need to be decommissioned. This would take the full lifetime of the SZC site far beyond 2140. Please see the extract from TASC document REP8-285a at Annex A setting out the ONR's comments to TASC regarding the length of time SZC's spent fuel is expected to stay on site.

SZC Co response at para 5.2.15 includes the statement: *"Details of the final disposal container will be confirmed closer to transport to the Geological Disposal Facility and will be subject to regulatory assessment."*
TASC comment: The Applicant's failure to be able to answer whether the final repository containers would be copper based, highlights the uncertainties surrounding the viability of a GDF being a safe way to store radioactive waste for the length of time required.

Additional TASC comment: Referring to the ONR's April 2022 response to the Secretary of State, entitled "Sizewell C: Questions from the Government of Austria", **TASC are concerned** that the ONR have not answered some of the questions as the ONR state: "Having discussed these with NNB GenCo (SZC) Ltd, we agreed that some of the questions required a straightforward factual response regarding the project which we are content for NNB GenCo (SZC) Ltd to provide" and "Using the numbering used in Chapter 8 of the Austrian Government's submission, we are content that NNB GenCo (SZC) Ltd provides answers to the following questions: 8.1 Q1 to Q4 & 8.4 Q2" As TASC have mentioned above, we feel that the Applicant has provided answers that appear to conflict with information provided by the ONR directly to TASC.

<u>Recent developments</u>
TASC wish to draw the SoS's attention to the following recent developments:-

- The SZC Co major partner, EDF, clearly has financial problems. These were set out in our submission in REP2-481j but EDF's financial woes are clearly worsening as mentioned in this [redacted]

- The fault that has led to the Taishan1 EPR reactor having been shut down for the last 10 months has still not been identified/disclosed. This, combined with the vibration problem identified in the Olkiluoto3 EPR reactor and the delays and cost overruns at the Flamanville and Hinkley Point C EPR reactors, must call into question the viability of building an EPR at Sizewell.
- EDF's French nuclear fleet is experiencing severe maintenance issues which demonstrate the French state's problems with energy security due to its over-reliance on nuclear power, as referred to in this [redacted].
- On 20th May 2022, EDF published its 4th announcement advising of delays and cost overruns since Hinkley Point C contracts were signed, the daily Telegraph article [redacted] refers.
- On 21st May 2022 the Daily Telegraph followed up the previous day's announcement with the article [redacted] which includes the following *"It is testament to the sheer incompetence of France's state-backed utility EDF that Hinkley Point C has become Britain's most radioactive construction project and it hasn't even been built yet."*

All the above, support TASC's contention that EDF should not be considered a competent developer. EDF does not have the financial capability or technical competence to justify the UK government's support for EDF building EPR reactors in the UK.

TASC has taken part in the DCO process, submitting many well-researched and powerful arguments and observations, both verbally and in writing as have many other knowledgeable and sincere people. Many critical and very serious points affecting the DCO have been put to the Planning Inspectors and to your officials. At this late stage in the DCO process, we are of the view that, with so many unresolved and even unconsidered factors relating to the viability of this development the Secretary of State cannot possibly be in a position to give Planning permission to such an ill thought-out plan as he does not possess the information required to do so with the confidence necessary for the construction of two nuclear power plants which will be in situ for at least 100 years.

Until outstanding matters are known and resolved, we find ourselves unable to make further comment, and believe sincerely that BEIS and the Secretary of State is in no position to grant Planning Permission.

[redacted]

Pete Wilkinson- TASC Chair
Meadow Cottage, Hubbard's Hill, Peasenhall, Saxmundham, Suffolk IP17 2JN

ANNEX A

Extract from TASC's Deadline 8 DCO submission REP8-285a

Extract from letter from the Office for Nuclear Regulation August 2020:-
"ONR ref HPGE202006066 TASC Review of the Minutes of the ONR/Stop Hinkley Meeting in Bridgewater January 2020 Authors: Chris & Jen Wilson Date: 17 June 2020 Document prepared following Stop Hinkley's (SH) review document of 15th June 2020"
Extract: TASC's question to the ONR: *"4.44 Reference ST's comments that a dry fuel store would be designed to hold fuel for about 120 years- for HPC and the proposed SZC, they will both comprise twin reactors each generating 3600 'high burnup' Spent Fuel assemblies over the sixty year operating lifetime of the plant stored in fuel ponds and then dry containers. The Nuclear Decommissioning Authority discloses, when discussing the non-extant, nondesigned, Geological Disposal Facility for spent fuel that, "based on a canister containing four Sizewell C fuel assemblies, each with the maximum high burn-up of 65 GWd/tU and adopting the canister spacing used in existing concept designs, it would require of order of 140 years for the activity, and hence heat output, of the EPR fuel to decay sufficiently to meet this temperature criterion." All of Sizewell C's Spent Fuel, and, if HPC's DFS is approved and built, HPC's is to remain onsite until it meets this temperature criterion. Our questions are: - a) based on the ONR's awareness of the situation, is the NDA statement suggesting that the dry canisters cannot be placed into a GDF until 140 years have passed?*
b) if the answer to a) is yes, then the DFS would be needed for 200 years i.e. 60 years of operation followed by the cooling period
c) if the answer to a) is no, then how many years is it expected until a dry spent fuel canister would be safe to move off site?

ONR response: *"Noting that we do not have information available yet on Sizewell C, the response is given for Hinkley Point C based on our current understanding. The 140 year cooling period in the Nuclear Decommissioning Authority report (NDA Technical Note no. 11261814 Rev1) is conservative and does not take into account a number of aspects which have been used within the spent fuel management strategy for Hinkley Point C (HPC). For example:*
• Not all fuel within HPC will have a burn-up of 65 GWd/tU. This is the maximum peak burn-up dependent upon reactor core physics and is a bounding value for a spent fuel assembly. The average spent fuel assembly burn-up for HPC will be lower and therefore has lower heat output.
• The thermal output of the disposal canister is calculated based upon a 'mixing strategy' where the average temperature of a canister is calculated. This is a mix of both high and low burn-up spent fuel assemblies, and a mix of spent fuel assemblies with longer and shorter cooling periods, within a single disposal canister.
• Analysis shows that a storage period of 55-60 years post end of generation is required in order to meet the assumed GDF disposal thermal limits for all spent fuel assemblies generated during operation through adoption of this fuel management strategy.
As an example, for HPC (using indicative timescales and dates):
• The assumed availability date for the GDF ~2130 for fuel from new reactors.
• Assumed start of generation of HPC: 2025
• Assumed end of generation of HPC: 2085
• The date from which fuel will be sufficiently cool to start to transfer to the GDF (from 55-60 after end of generation): 2140-2145
• The date by which all fuel will be transferred to the GDF: ~2150-2155 (assumed to take just over 9 years)
• The dry fuel store will not be needed until ~10 years start of operation of HPC: ~2035
• The dry fuel store will then be needed for 50 years remaining operation of HPC, 55-60 years for the fuel to cool and 10 years to allow transfer of fuel to the GDF, which is 115-120 years. Removal of all fuel from site and end of use of the dry fuel store is therefore: ~2150-2155.
• The initial design life for the dry fuel store is 120 years (noting the design is conceived to allow for refurbishment or replacement) which would take it to: ~ 2155 In summary, the number of years before the fuel can be taken off site to the GDF is approximately 55-60 years from end of generation, which is because of the

temperature criterion associated with the GDF canister. Fuel could potentially be moved from site safely earlier (but not currently to the GDF), although this is not planned."

ANNEX B

NWAA ISSUES REGISTER Outstanding Scientific and Technical Issues Relating to the Production of a Robust Safety Case for the Deep Geological Disposal of Radioactive Waste

Nuclear Waste Advisory Associates

Want the whole picture ?

www.nuclearwasteadvisory.co.uk

'NWAA ISSUES REGISTER'

Outstanding Scientific and Technical Issues Relating to the Production of a Robust Safety Case for the Deep Geological Disposal of Radioactive Waste

Context

In October 2009 at a meeting between representatives of the Environment Agency and members of a small number of NGOs, the technical, scientific and ethical hurdles to the development a deep geological facility for the disposal of radioactive wastes were discussed.

The NGO representatives reported that the '*intensified R and D programme*' called for by CoRWM (i) in its July 2006 report does not appear to have been progressed to any significant degree. Very little research data has been put into the public domain, which is of particular concern due to the imperative of adopting a wide ranging and inclusive scrutiny and evaluation of the proposed nuclear waste disposal programme: issues that are potential 'show stoppers' are of special concern and it is essential that these are appraised against an effective and meaningful back drop of public involvement.

As a result of the October meeting, the Environment Agency proposed that an 'issues register' should be compiled. In an E-mail on the 19th November 2009, the Environment Agency reported that:

> "*We cannot be specific about the timescale for developing and launching an issues register because we do not have a full understanding of the technical development required to produce a workable system for web access. We have work in progress and we will provide an update when we have moved forward.*"

In the spirit of advancing the issues register, NWAA has compiled a first draft of what it considers to be the issues which need resolution in the hope that it may inform the Environment Agency project.

The scrutiny and prosecution of an appropriate disposal research programme requires information that is in accessible form. It also requires that adequate time is allowed to consider the research results and their implications.

NWAA looks forward to working with the EA and NDA in an effort to resolve these issues over the coming months and years.

NWAA, March 2010

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Note:

This 'Commentary' document sets in context outstanding technical hurdles related to deep geological disposal of radioactive waste, as compiled by NWAA.

For ease of reference a second document has been prepared that lists these issues without commentary. This second document is the 'NWAA Issues Register'.

Inventory

Magnitude of the Problem

The magnitude of the problem presented by radionuclide stocks depends both on the quantity and the chemical context[1,2] of the radionuclides.

However, present data on waste stocks does not provide sufficient information on:

- radionuclide quantities [3] or
- their chemical context. [4]

For example, waste stream descriptors in the NDA/DEFRA (2008) nuclear waste inventory are not useful in providing information concerning the '*chemical context*' of the radionuclides.[5]

Furthermore, the inventory information in the isotope tables is graded according to both the 'uncertainty' of the data and also its 'reliability'.[6]

Thus it may be seen that the present waste inventory is very far from being sufficient to the task of enabling risk prediction.

Radionuclide risk calculations focus on the radionuclides that are thought to be the most important as contributors to the resultant risk. However, there has recently been a re-evaluation of which radionuclides are significant.[7] This change is a cause for concern

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[1] Lancaster University Environment Centre, Funded PhD Studentship – Radionuclides - The development of a tool for the determination of mobile radionuclides in contaminated groundwater (Feb 2010) http://www.lec.lancs.ac.uk/news_and_events/news/?article_id=869

[2] [**EU JRC (October 2009)**] W.E. Falck and K..-F. Nilsson, "*Geological Disposal of Radioactive Waste: Moving Towards Implementation*", European Union Joint Research Centre (EU JRC) (October 2009) page 18 http://ec.europa.eu/dgs/jrc/downloads/jrc_reference_report_2009_10_geol_disposal.pdf

[3] EU JRC (October 2009) page 10

[4] See for example: [**NDA/DEFRA (March 2008)**] "*The 2007 UK Radioactive Waste Inventory, Main Report*", NDA/DEFRA (March 2008), Defra/RAS/08.002; NDA/RWMD/004. http://www.nda.gov.uk/ukinventory/documents/Reports/upload/The-main-report-of-the-2007-Inventory.pdf

[5] See for example: '7A07 Effluent Sludges/Floc' and '7A13 Sea Disposal Packs (Coffins)' (Source: - NDA (2007) Inventory - Detailed Data /Waste Stream/Data Sheets/Ministry of Defence (pp 1 – 111) - Aldermaston Waste Streams

[6] the 'reliability' relates to whether the data was measured or estimated

[7] For example, in May 2009 the NEA reported that changes in the reported value of the half-life for selenium-79 over the last decade had strongly influenced the final calculated repository dose. See: "*Mobile Fission and Activation Products in Nuclear Waste Disposal* " Workshop Proceedings, La Baule, France (16-19 Jan 2007) OECD NEA (May 2009) NEA No. 6310 (ISBN 978-92-64-99072-2) (pp 31, 38, 39,114) http://www.oecd-nea.org/science/reports/2009/nea6310-MOFAP.pdf

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as it raises the possibility that the current list of radionuclides which are used as the focus of the risk prediction may also be incorrect.

In terms of the wastes that would be expected if a new nuclear build programme were to go ahead, the available inventory information is even less helpful. Thus 'Part 2' of the (January 2010) NDA 'Disposability Report' [8] which sets out the inventory tables, limits itself to isotopic[9] composition alone.[10]

The possible adoption of new reactor types or changes in fuel design would necessitate further research. For example, higher burn-up and MOX [11] fuel require new waste container design and more research on how such containers would behave on disposal.[12] (Considerations include higher temperature and higher risks of brittleness due to increased exposure to radioactivity).[13]

These issues lead to the identification of the following:

1. problems with uncertainty in inventory data;
2. problems with reliability of the sources of the inventory data;
3. problems with lack of information concerning the chemical context of radionuclides;
4. possible selection of 'most significant radionuclides' incorrect;
5. further research necessitated by possible 'New Build' radionuclides.

Gases

Release of Hydrogen Gas[14]

It has been realised for some time (since at least 1987)[15] that a disposal facility would be likely to produce a large quantity of hydrogen gas.[16] Although this gas would not be

See also - EU JRC (October 2009) Page 17

[8] "*Generic Design Assessment: Disposability Assessment for Wastes and Spent Fuel arising from Operation of the UK EPR*", NDA January 2010 Part 2: Data Sheets and Inventory Tables.

[9] An 'isotope' is a particular version of an element in which the number of 'protons' (the positive particles at the centre of an atom) remains the same; but the number of 'neutrons' (neutral particles – also at the centre of the atom) varies.

[10] **[NDA (January 2010)]** "*Generic Design Assessment: Disposability Assessment for Wastes and Spent Fuel arising from Operation of the UK EPR*", NDA January 2010 Part 1: Main Report. Has some mention of the presence of materials such concrete and cellulose (see for example page 51), to all intents and purposes, the information required is simply absent.

[11] 'MOX' – stands for 'mixed oxide' fuel – which contains plutonium as well as uranium

[12] EU JRC (October 2009) page 12

[13] EU JRC (October 2009) page 12

[14] [**Nirex (November 2005)**] "*The Viability of a Phased Geological Repository Concept for the Long-term Management of the UK's Radioactive Waste*" Nirex (November 2005), Report N/122, page 72. http://www.nda.gov.uk/documents/upload/The-viability-of-a-phased-geological-repository-concept-for-the-long-term-management-of-the-UK-s-radioactive-waste-Nirex-Report-N-122-November-2005.pdf

[15] Cooper MJ, Hodgkinson (ed) (1987). The Nirex Safety Assessment Research Programme: Annual Report for 1986/87. NSS/R101 Nirex. (page 113)
See also EU JRC (October 2009) page 20

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radioactive, it would present a problem due to the large volumes involved and the resultant need to provide a release pathway in order to avoid a build up of pressure.[17] Such a release pathway would necessarily also provide an escape route for radionuclides. The provision of such an 'escape route' is contrary to the notion of a disposal facility as a sequence of '*barriers*'.[18]

Despite the fact that the hydrogen problem has been recognised for over twenty years, it is still not clear whether a hydrogen 'over-pressure' would lead to the opening of fractures and the resultant creation of fast 'migration pathways'. [19]

Gas release would be determined by the interaction of a number of different processes. Although these processes are understood on an individual basis, their interaction is not.[20] Thus the following issues arise:

6. the need to allow the release of hydrogen gas which is contrary to the need for 'barriers';
7. lack of clarity as to whether hydrogen pressure will open fractures and result in 'fast pathways';
8. the interaction of processes that would lead to hydrogen release is not understood.

Radioactive Carbon – High Doses within Short Timescale

Radioactive waste stocks contain a large amount of 'carbon-14' which is radioactive. The nuclear industry had predicted that, following disposal, this carbon would be held underground due to a so-called '*carbonation*' reaction with repository cement. However in November 2005, the Environment Agency queried the extent to which such a reaction would take place.[21]

More recently, the nuclear industry has acknowledged that this radioactive carbon could instead react with hydrogen and form methane gas (CH_4). Due to its carbon-14 content, this methane would be radioactive. The presence of the carbon-14 as a gas rather than as a 'cement/carbon' chemical compound would make it much more likely to escape from the disposal facility. Thus, the nuclear industry has calculated that the

[16] The gas would be produced due to the corrosion of iron within an atmosphere that doesn't contain oxygen. The steel would be used both for waste containers and also in structural components of the disposal facility.
[17] **Nirex (November 2005)** pages 55, 72, 73.
[18] EU JRC (October 2009) page 10
[19] EU JRC (October 09) page 20
[20] EU JRC (October 09) page 20
[21] **[EA (November 2005)]** "*Review of Nirex Report: The Viability of a Phased Geological Repository Concept for the long term management of the UK"s Radioactive Waste*" Environment Agency, November 2005, Version 3.1 NWAT/Nirex/05/003 November 2005 page 10 -11
This says: *a key assumption is that all C-14 labelled carbon dioxide does not escape from the repository, but reacts with backfill via a carbonation reaction. In our view, more confidence is needed that complete reaction of carbon dioxide will occur in cracked backfill or that the gas pathway would not lead to unacceptable consequences were this not to be the case."*

escape of radioactive methane would result in a dose four thousand times greater than the dose considered 'tolerable' by the EA.[22] Furthermore, it has been calculated that this dose could arise just forty years after the proposed disposal facility was closed.[23]

These considerations give rise to the following issues:

9. the extent of the 'carbonation' reaction between carbon-14 and cement;
10. the extent of the formation of radioactive methane (CH_4) gas;
11. the magnitude of the dose arising from this exposure and over what timescale.

Site Considerations

Gases and the Site Selection

The gas issue presents a double dilemma for repository site selection. The traditional notion of an ideal disposal site is one that presents a 'barrier'[24] to radionuclide release. However, as discussed above, such a barrier would also prevent hydrogen release. This would result in a pressure build-up and must therefore be avoided. On the other hand, allowing the escape of hydrogen gas would also allow the escape of radioactive methane gas[25] which – as stated above – has been predicted to give rise to a very high dose on a very short timescale.[26]

However, the geological screening criteria set out on pages 74 –75 of the DEFRA White Paper [27] "*A Framework for Implementing Geological Disposal*" (June 2008), do not indicate any sign of cognisance of this issue.

The contradictory site selection requirements[28] are a significant hurdle.

It is of concern that, although site selection issues are presently under consideration by the Cumbrian 'Partnership', the Environment Agency do not see fit to highlight to the

[22] **[EA (February 2009)]** "*Geological Disposal Facilities on Land for Solid Radioactive Wastes: Guidance on Requirements for Authorisation"* Environment Agency, February 2009, page 46 (para 6.3.10) http://publications.environment-agency.gov.uk/pdf/GEHO0209BPJM-e-e.pdf

[23] Sources: [**Nirex (February 2006)**] "*C-14: How we are addressing the issues"* Nirex, February 2006, Technical Note: Number: 498808 and

[Pamina (March 2008)] Simon Norris (NDA) "*Uncertainties Associated with Modelling the Consequences of Gas*", Performance Assessment Methodologies in Application to Guide the Development of the Safety Case, Deliverable (D-N°: D2.2.B.2), 26th March 2008. http://www.ip-pamina.eu/downloads/pamina2.2.b.2.pdf

Nirex (February 2006) page 1 – Tolerable Carbon dose = 2.4×10^{-3} units. (i.e TBq/year)

Pamina (March 2008) page 75 – Predicted Carbon Dose = 10 units. (TBq/year) [10 / 0.0024 = 4,000 times]

Nirex (February 2006) page 12 (Fig 1) – peak dose shown at 40 years post-closure.

[24] EU JRC (October 2009) page 10

[25] containing 'carbon-14'

[26] four thousand times the 'tolerable' dose at forty years 'Post-Closure' see ref. 23

[27] http://mrws.decc.gov.uk/media/viewfile.ashx?filepath=mrws/white-paper-final.pdf&filetype=4

[28] See also **[EA (November 2008)(1)]** "*Gas generation and migration from a deep geological repository for radioactive waste A review of Nirex/NDA's work*", Issue 1, Environment Agency, November 2008. page 79
http://publications.environment-agency.gov.uk/pdf/GEHO1108BOZN-E-E.pdf?lang=_e

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Partnership the imperative of resolving this issue before any further steps are taken towards site-selection.[29] Thus the outstanding uncertainty associated with this issue can be summarised as:

12. Resolution of gas issues and their incorporation into site selection considerations.

Availability of Necessary Site Data

The NDA's approach to characterising a candidate site is unclear.[30] Specifically, the Environment Agency state that the NDA should:

"*...identify what information will be needed and what criteria will need to be met in order to support continued site investigation.*"[31]

High permeability features may dominate water flow; however it is difficult to establish the frequency, spread and distribution of such features [32]

Experiments are currently underway in order to develop methods to enable the distribution and flow characteristics resulting from fractures in the host geology to be established using boreholes.[33]

The interconnection of high-flow features over a regional scale "*cannot be known with certainty*".[34]

These concerns lead to the identification of the following issues for resolution:

13. the development of a clear approach to site investigation;
14. the establishment of a methodology for the determination of the frequency, spread and distribution of high permeability features;
15. the establishment of useful borehole and relevant techniques;
16. the development of methodologies for establishing flow over geographical regions.

Groundwater flow and transport

The move from a generic safety case to a site-specific safety case may not be straight-forward.[35]

DECC's (November 2009) summary document [36] on the arrangements for radioactive waste management, refers to the Finnish case study as an indicator that the technology of

[29] [**EA (January 2010)**] "*Environment Agency scrutiny of RWMD"s work relating to the geological disposal facility - Annual review 2008/09*" Issue 1, Environment Agency, January 2010. NWAT/NDA/RWMD/2009/001 page 17 http://publications.environment-agency.gov.uk/pdf/GEHO0210BRWU-e-e.pdf
[30] EA (January 2010) page 18
[31] EA (January 2010) page 18
[32] EU JRC (October 2009) page 15
[33] EU JRC (October 2009) page 15
[34] EU JRC (October 2009) page 15
[35] EA (January 2010) page 11

disposal is established, specifically stating that 'STUK' (the Finnish regulator) did not identify any reasons why the project could not move forward. [37]

However, a review of the most recent disposal safety case published by the Finnish disposal agency Posiva[38] carried out by a group of Consultants on behalf of STUK[39], reported that the uncertainties in the flow predictions were substantial.[40]

A good understanding of groundwater flow and radionuclide transport at a specific site - including the representation of flow and transport in fractured rocks – needs to be developed.[41]

Thus the following issues remain unresolved:

17. the development of a methodology for moving from a generic to a site-specific safety case;
18. resolution of uncertainties in flow prediction
19. the development of techniques for representing flow and transport in fractured rocks.

Gas/Groundwater Flow

The Environment Agency has recommended additional research into gas/groundwater interaction.[42] Specifically,[43] they have stated that:

• the interactions between gas generation and groundwater flow as well as other processes mean that it is difficult to demonstrate that safety assessments are conservative (i.e. err on the side of caution);

• the impact of groundwater chemistry on gas solubility is poorly known for the types of groundwater that are likely to be found in a UK repository;

[36] **[DECC (November 2009)]** DECC "*The arrangements for the management and disposal of waste from new nuclear power stations: a summary of evidence*", November 2009. https://www.energynpsconsultation.decc.gov.uk/docs/FINAL_NPS_waste_assessment.pdf
[37] DECC (November 2009) para 121, page 26
[38] **[POSIVA (October 2007)]** POSIVA 2006-05 "*Expected Evolution of a Spent Nuclear Fuel Repository at Olkiluoto*" Posiva Oy December 2006, Revised October 2007. http://www.posiva.fi/files/346/Posiva2006-05_revised_081107web.pdf
[39] [**Apted (April 2008)**] Michael Apted et al "*Review of Posiva 2006-05: Expected Evolution of a Spent Nuclear Fuel Repository at Olkiluoto*" (April 2008) page 5 See Annex E of Nuclear Waste Advisory Associates submission to the first consultation on National Policy Statements on Energy for a summary: https://www.energynpsconsultation.decc.gov.uk/docs/responses2010/2027.pdf
[40] Apted (April 2008) page 5
[41] EA (November 2005) see page 11
[42] EA (November 2008) (1) page 75
[43] [**EA (August 2009)**] "*Technical issues associated with deep repositories for radioactive waste in different geological environments*" Environment Agency August 2009, Better regulation science programme. Science report: SC060054/SR1 page 142. http://www.environment-agency.gov.uk/static/documents/Business/e.pdf

• it is unclear whether current predictions of gas/groundwater flow are adequate, in particular, in respect of predictions over larger areas;

• the effect of excavation damaged zones (EDZs) on gas and/or water flow is uncertain.

Thus the issues arising can be summarised as:

20. gas generation and its interaction with groundwater: in particular the implications for the reliability of the risk predictions;
21. the impact of groundwater chemistry on gas solubility is poorly known;
22. current predictions of gas/groundwater flow may not be adequate;
23. the impact of the EDZ on gas/water flow is uncertain.

Construction Issues

Mechanical Questions - Contructability issues.

Construction and constructability issues are the subject of greater attention in research programmes than previously.[44]

It is becoming apparent that it may be necessary to compromise between measures (such as the use of rock anchors) needed to stabilise an excavation and the detriment caused to the safety case by the introduction of foreign material.[45]

There is limited evidence either from rocks or groundwater to demonstrate long-term stability.[46]

The volume of rock around the excavation that is damaged is expected to result in flow pathways.[47] This issue is under investigation.[48]

A disposal facility would be a disturbance to the natural mechanical/flow/heat/and chemical processes at the site.[49] It is recognised that these processes would act to dissipate the disturbance but their interactions are not understood and require further investigation. [50]

The following issues arise:

24. construction and constructability issues are not resolved;
25. compromise may be required between construction requirements and safety requirements;
26. there is limited evidence to demonstrate long-tem stability;
27. the role of the EDZ as a pathway is under investigation;

[44] EU JRC (October 2009) page 14
[45] EU JRC (October 2009) page 14
[46] EA (August 2009) page 142
[47] due to the opening of fractures – caused by stress release
[48] EU JRC (October 2009) page 14
[49] EU JRC (October 2009) page 20
[50] EU JRC (October 2009) pp 20-21

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28. the behaviour of the mechanical/flow/heat/and chemical processes at the site in response to their disturbance is not understood.

An 'Open Phase'

Some proposals for disposal include an extended 'open' phase. This has been proposed in order to enable access to the wastes, and thus to meet community request for 'retrievability' at least for a limited period; however, such an approach would result in the exposure of the underground chamber to '*weathering*' due to the presence of oxygen and humidity.[51]

In addition, an 'open phase' would present a risk of collapse (or 'convergence').[52]

Overall, the implications of delayed closure have not yet been fully investigated.[53]

The issues arising are therefore:

29. the impact of weathering that would be caused by an 'open phase' is not understood;
30. the possibility of a collapse due to an open phase requires further investigation.

Worker Doses

In the (January 2010) Disposability Assessment[54], the NDA reported that it was unwilling to "*make any claim for the acceptability of* (Operational) *doses",* [55] stating, instead, that the estimates of worker dose were intended to *"provide insight into the key issues"*[56]. This indicates that, according to present estimates, worker doses would be unacceptable.

Thus:

31. it is possible that worker doses arising from the work involved with emplacing waste in the repository would be unacceptable.

The Waste Package and Repository Components

The Waste Package Itself

In October 2009, CoRWM[57] expressed concern over the level of R&D effort being devoted to determining the lifetimes of ILW[58] waste forms. CoRWM commented that, given the potential significance of waste form performance for 'disposability', the effort

[51] EU JRC (October 2009) pp 14-15
[52] EU JRC (October 2009) pp 14-15
[53] EU JRC (October 2009) page 15
[54] **[NDA (January 2010)]** "*Generic Design Assessment: Disposability Assessment for Wastes and Spent Fuel arising from Operation of the UK EPR*", NDA January 2010 Part 1: Main Report.
[55] NDA (January 2010) page 91
[56] NDA (January 2010) page 91
[57] CoRWM – the Committee on Radioactive Waste Management
[58] ILW – intermediate level waste

being devoted to resolving uncertainties over product lifetimes did not seem to be sufficient. [59]

The influence of different possible waste forms on the design choices for the repository components is a '*major knowledge limitation*'.[60]

Cement is not suitable as a matrix for all waste forms and therefore other treatments are being considered. This is a particular issue for reactive metals, for which alternative treatment methods are being sought. [61]

Research is required on waste repackaging.[62]

17,000 waste packages have been incorrectly conditioned using cement as the matrix and are due to fracture within 140 years due to an '*expansive*' chemical reaction.[63]

Work on the corrosion rates of steel and copper and container failure is required.[64]

Research is presently being carried out on both the mechanisms and the probabilities of canister failure.[65]

There are particular concerns in respect of copper. The NDA refers to a copper canister wall thickness of 5cm as a means of securing long-term durability.[66] However, according to research published (July 2009)[67], a copper wall thickness of one metre would be required for long term (100,000 year) durability. It is not clear how such a wall thickness would be either logistically or economically achievable.

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[59] **[CoRWM (October 2009)]** "CoRWM report to Government - on National Research and Development for Interim Storage and Geological Disposal of Higher Activity Radioactive Wastes and Management of Nuclear Materials" Report 2543 (October 2009). para 6.3, page 89 http://corwm.decc.gov.uk/media/viewfile.ashx?filetype=4&filepath=/corwm/post-nov 07 doc store/documents/reports to government/2009/2543 corwm report on RandD final 30 october 2009.pdf

[60] EA (August 2009) page 141

[61] CoRWM (October 2009) para 2.15 page 20

[62] CoRWM (October 2009) para 2.18 – page 20

[63] EA (August 2008) "*The longevity of intermediate-level radioactive waste packages for geological disposal: A review*" [NWAT Report: NWAT/Nirex/06/003], Environment Agency, August 2008, page 25 http://environment-agency.resultspage.com/search?p=R&srid=S8%2d2&lbc=environment%2dagency&w=longevity&url=http%3a%2f%2fwww%2eenvironment%2dagency%2egov%2euk%2fstatic%2fdocuments%2fBusiness%2fc%2epdf&rk=4&uid=802543385&sid=15&ts=ev2&rsc=IjCMVqGgQAWT95Na&method=and&isort=score

[64] EU JRC (October 2009) page 12

[65] EU JRC (October 2009) page 12

[66] For an illustration of an EPR spent fuel disposal canister see figure B7, page 27 "*Geological Disposal - Generic Design Assessment: of Disposability Assessment for Wastes and Spent Fuel arising from Operation of the UK EPR*" NDA Technical Note no. 11261814, Summary, October 2009 http://www.nda.gov.uk/documents/upload/TN-17548-Generic-Design-Assessment-Summary-of-Disposability-Assessment-for-Wastes-and-Spent-Fuel-arising-from-Operation-of-the-EPWR.pdf

[67] G. Hultquist et al "*Water Corrodes Copper*" Catal Lett (2009) 132: 311–316: 28 July 2009, Springer Science+Business Media, LLC 2009 http://www.mkg.se/uploads/Water_Corrodes_Copper_-_Catalysis_Letters_Oct_2009_-_Hultquist_Szakalos_et_al.pdf

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The impact of the corrosion products of steel (iron) on repository performance requires further investigation.[68]

Thus the following issues arise:

32. inadequate research exists on ILW wasteform lifetimes;
33. the relationship between waste form and repository design is a 'major knowledge limitation';
34. the selection of appropriate treatment for reactive metals is required;
35. research is required on repackaging;
36. a response to the 'expansive fracturing' that has taken place in waste packages in storage is required;
37. work on container failure, specifically corrosion rates of steel and copper, is required;
38. research into mechanisms and probabilities of canister failure is required;
39. particular problems due to new data on copper corrosion have arisen;
40. the impact of steel corrosion products on repository performance needs further work.

The Components of the Waste Facility

A better understanding of repository components and how they would interact to affect radionuclide release[69] is required. Such work could have important implications for the optimisation of repository design.

The issue arising in this respect is:

41. the interaction of repository components and the resultant impact on the safety case requires further research.

High Level Wastes

The interaction of waste fuel with other repository components needs to be investigated.[70]

The interactions between the glass matrix of vitrified high level waste (HLW) and 'clay-type' materials planned for repository use is difficult to predict.[71]

HLW would be very hot and as such would affect the behaviour of the clay based materials planned for repository use as a backfill. Specifically, the chemical, mechanical and flow behaviour of the clay would be affected.[72] The heat from the wastes would dry

[68] EU JRC (October 2009) page 12
[69] EA (November 2005) pp 10-11
[70] EU JRC (October 2009) page 11
[71] EU JRC (October 2009) pp 11-12
[72] EU JRC (October 2009) page 13

out the clay and alter its '*suction potential*'.[73] The EU is presently setting up a new work area on these issues. [74]

The concerns arising are therefore summarised as:

42. the interaction of waste fuel with other repository components requires further research;
43. it is difficult to predict the interaction of the glass of vitrified high level waste and clay;
44. the chemical, mechanical and flow behaviour of clay would be affected by the high temperature of high level waste.

<u>Clay</u>

Clay behaviour is difficult to predict. Prediction of the combined effects and possible interactions between different mechanisms that would affect clay behaviour are difficult to predict quantitatively. [75, 76]

The capacity of clay to retain radionuclides can be damaged by:

• salty or alkaline water which can increase water flow through clay due to disaggregation and reduced swelling pressure;[77]

• corrosion products can lead to rearrangement of clay minerals.

Not all of these processes are quantitatively understood.[78]

Research is needed on the impact of steel corrosion products on the effectiveness of clay barriers.[79]

Thus the issues of concern in respect of clay can be summarised as:

45. the behaviour of clay is difficult to quantify;
46. the capacity of clay to retain radionuclides can be damaged by salty or alkaline water;
47. radionuclide retention by clay can also be damaged by corrosion products.

<u>Interactions Between the Facility and the Surrounding Rock</u>

In August 2009, the Environment Agency reported the following '*major knowledge gaps*'[80].

[73] EU JRC (October 2009) page 13
[74] EU JRC (October 2009) page 13
[75] EU JRC (October 2009) page 13
[76] In chemistry there are equations that allow chemical behaviour to be quantified. However – for this approach to be workable the system must not be unduly complicated and there must be sufficient measured data to input into the equation.
[77] in a repository context alkaline water would be derived from cement
[78] EU JRC (October 2009) pp 15 -16
[79] EU JRC (October 2009) page 13

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The impact of grouts[81] on repository/rock interaction is poorly understood.[82]

The chemical database is inadequate to the task of predicting cement/clay interactions.[83]

The impact of extremely salty groundwater on repository rock interaction is difficult to predict.[84]

There is insufficient data on possible chemical causes of cavern collapse. Such collapses are therefore difficult to predict. [85]

The effect of repository rock interaction on the behaviour of the EDZ is poorly known. [86]

Impact of resaturation on the facility is difficult to predict. [87]

The likely impact of the inflow of ground water on the behaviour of the facility materials requires evaluation. Ground water contains a number of chemicals apart from simply 'H_2O' and these can have a significant chemical impact.[88] The presence of salt is a particular consideration.[89]

The issues arising can therefore be summarised as:

48. grout/repository rock interaction is poorly understood;
49. the chemical database is inadequate to the task of predicting cement/clay interaction;
50. the impact of salty groundwater on repository/rock interaction is difficult to predict;
51. there is insufficient data to predict chemical causes of cavern collapse;
52. the effect of repository/rock interaction on the behaviour of the EDZ is poorly known;
53. the impact of resaturation on the facility is poorly known;
54. it is not clear what effects the chemicals in groundwater would have on the facility.

[80] EA (August 2009) page 141
[81] used to seal fractures
[82] EA (August 2009) page 141
[83] EA (August 2009) page 141
[84] EA (August 2009) page 141
[85] EA (August 2009) page 141
[86] EA (August 2009) page 141
[87] EA (August 2009) page 143
[88] see for example EU JRC (October 2009) page 18
[89] EA (August 2009) page 141

Chemistry and Contamination Levels

Risk Predictions Not Reliable

Before a disposal facility could be 'sealed up', it would be necessary to be confident that there would be no undue leakage in the future that would necessitate waste recovery. However, current risk predictions do not provide adequate safety guarantees.

As discussed above, DECC [90] refers to the Finnish case study as an indicator that the technology of disposal is established. However, a review of the most recent disposal safety case published by the Finnish disposal agency Posiva[91], carried out by a group of Consultants on behalf of the Finnish regulator STUK[92] commented that:

- the safety importance of processes and data needed to be set out (page 1);
- the definitions of the safety functions of the different parts was vague (page7);
- in particular, the report did not set out clearly which outcomes would lead to unacceptable safety hazards (page 8).

Thus the issues arising can be summarised as;

55. the implications for predicted dose of processes and data are not clear;
56. the definition of repository safety functions is vague;
57. it is not clear which outcomes would lead to unacceptable safety hazards.

Calculating Contamination Levels

A major gap throughout the chemical databases used for risk prediction arises due to the fact that most of the measured data has been obtained at room temperature yet the contamination estimates need to address temperatures that are much higher. Although calculation techniques exist in chemistry to enable extrapolation to higher temperatures, these require 'correction' parameters. Such parameters are largely unavailable in the context of the calculation of radionuclide contamination levels.[93]

The rate of chemical reactions can also be an important consideration but there is a limited amount of data available.[94]

Work is on-going in order to obtain a better understanding of chemical elements such as uranium (element 92) and other, heavier, elements.[95]

Therefore the issues arising are:

58. essential chemical 'temperature correction' data is largely unavailable;
59. similarly, reaction rate information is also largely unavailable;

[90] DECC (November 2009) page 26
[91] POSIVA (October 2007)
[92] Apted et al (April 2008)
[93] EU JRC (October 2009) page 17
[94] EU JRC (October 2009) page 18
[95] EU JRC (October 2009) page 17

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60. a better understanding of the heavier chemical elements (uranium and heavier) is required.

Solubility of Chemicals holding Radionuclides

Mr. McDonald, the Inspector at the 1990s Inquiry into proposals to begin excavation at the nuclear industry's planned disposal site near Sellafield in Cumbria, concluded that the proposed 'chemical containment system' was

"*...new and untried with more experimentation and modelling development indubitably required*". [96]

Although the NDA[97] research consultation document (Summer 2008) refers to the "*extensive research programme*" [98] on radionuclide chemistry, the documents cited are in fact pre-inquiry documents and thus do not address Mr. Mc Donald's concerns.[99] Responding to the 2008 consultation in its March 2009 document, the NDA stated that:

"*...a response to these* [technical] *comments will not appear in our updated strategy document*". [100]

Thus, the NDA's programme to address this underlying concern is not clear.

In addition there are soluble chemical compounds in the waste which were not originally anticipated and which therefore require consideration.[101]

These concerns lead to the following outstanding issues:

61. proof is required that the 'chemical containment' approach put forward by nuclear industry would be effective in isolating the waste;
62. it must be demonstrated that soluble compounds which have only more recently received attention would not result in an undue risk.

[96] C S McDonald (1997) Inspector's Report following 'Nirex RCF' Inquiry, Cumbria County Council, File (APP/H0900/A/94/247019) pp 241-242 - para 6E.70
http://www.davidsmythe.org/nuclear/inspector's_report_complete.pdf
[97] **[NDA (May 2008)]** "*Radioactive Waste Management Directorate (2008). Proposed Research and Development Strategy*", NDA Radioactive Waste Management Directorate, May 2008.
http://www.nda.gov.uk/documents/loader.cfm?url=/commonspot/security/getfile.cfm&pageid=20962
[98] [NDA (May 2008)] page 43
[99] Specifically references [101, 102 and 103 - see page 43] – listed on 75. The Inquiry was held 1995/96. The references listed refer to experiments carried out up to 1993.
[100] NDA "*Response to comments on NDA RWMD's proposed research and development strategy*" Report No. 10019689 (March 2009) page 16
http://www.nda.gov.uk/documents/upload/Research-and-Development-Strategy-for-Geological-Disposal-Facility-NDA-Response-to-Consultation-Results-March-2009.pdf
[101] EA (November 2005) pp 10-11

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Oxygen

Disposal safety cases have two tacit assumptions in connection with the presence of oxygen;

• firstly, that the 'oxidised' state has the greater mobility; and

• secondly, that the corrosion of the available iron (present in steel) would use up the available oxygen so that it would not be available for reaction with the radionuclides.

However, it is beginning to be recognised that the very excavation of an underground cavern would introduce an anomaly into the rock – i.e. the presence of oxygen. This 'anomaly' would be likely to take a considerable time to dissipate.

In the particular case of fractured rock, the assumption that the radionuclides would be retained for long enough to adopt the 'reduced' form (i.e. the chemical form that is the opposite of the 'oxidised' form) is being questioned.[102] Such a revision of thinking could have significant implications for estimated risk.

Furthermore, the correlation between the presence of oxygen and radionuclide mobility itself requires further investigation.[103]

Thus the issues arising from the concerns around the presence of oxygen in the repository environment can be summarised as:

63. the validity of the assumption that the 'oxidised' form of the radionuclides is the more soluble form, must be demonstrated;
64. the assumption that the corrosion of iron would use up the available oxygen must be demonstrated;
65. the role of the 'oxygen anomaly' introduced by the excavation itself must be established;
66. the retention time within fractured rock and the possibility that radionuclides would not be retained for a sufficient time to adopt the 'oxidised' form must be addressed.

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[102] EU JRC (October 2009) page 18

[103] For example see J.E. Cross, D.S. Gabriel, A. Haworth, I Neretnicks, S.M. Sharland and C.J. Tweed "*Modelling of Redox Front and Uranium Movement in a Uranium Mine at Pocos de Caldas Brazil*" NSS/R252 Nirex, 1991 (pp 9,10,19).

A high uranium solubility was predicted for the following four forms of Uranium:

(i) a form that was not fully crystalline (i.e. with an irregular structure)

(ii) a "*non-stoichiometric*" form – (i.e. – a form where the relative amount of the components in the relevant compound isn't a simple ratio)

(iii) a colloidal form – i.e. a large unwieldy form, and

(iv) the presence of uranium (V) – a type of uranium compound in which five of the uranium electrons are involved in its bonding relationship with other chemicals. (Uranium (V) is 'oxidised' with respect to Uranium (IV) – but 'reduced' with respect to Uranium (VI)

Extract of NSS/R252 available here:

http://www.cumbria.gov.uk/elibrary/Content/Internet/538/755/2146/3989195433.pdf

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Large Chemicals – 'Colloids'

Colloids are relevant to risk prediction as they can bind with radionuclides and therefore 'carry' them within flowing groundwater. However, their study presents problems.

Sampling and analysing colloids without disturbing their natural state is difficult. [104]

There are also problems working with radionuclides that are sensitive to the presence of oxygen which means that much of the experimental work has been carried out using uranium (which is not subject to these problems). However, this means that there are considerable research gaps as far as the other radionuclides are concerned.[105]

The interaction between colloids, microbes and radionuclides has not been well researched. [106]

Attachment of radioactive particles to colloids may prevent radionuclides from being caught up in rock pores, thus speeding up their rate of travel. This effect has not been quantified.[107]

The following set of issues associated with colloids must be addressed:

67. techniques for sampling and analysing colloids require further development;
68. much colloid work has been restricted to experimentation with uranium, resulting in considerable research gaps as far as other radionuclides are concerned;
69. the interaction between colloids, microbes and radionuclides has not been well researched;
70. the effect of colloid 'size exclusion' (i,e. the role of colloids in preventing radionuclides becoming trapped in pores due to the size of the colloid) on the speed of radionuclide travel.

Behaviour in Natural Systems

The lack of knowledge concerning the basic chemical behaviour of important radionuclides such as plutonium (element 94), neptunium (element 93) and americium (element 95) [c.f. uranium – element 92] has led to a programme of fundamental research. However, the majority of the research has not been carried out under natural conditions. In particular, for most of the experiments, the radionuclide, salt and 'ligand'[108] concentrations do not reflect those that would be found under natural conditions.[109]

Although studies of natural systems are valuable for some radionuclides, many do not occur in nature and therefore cannot be studied in natural systems.[110]

[104] EU JRC (October 2009) page 19
[105] EU JRC (October 2009) page 19
[106] EU JRC (October 2009) page 19
[107] EU JRC (October 2009) page 19
[108] a 'ligand' binds to a central metal atom to form a 'complex'
[109] EU JRC (October 2009) page 17
[110] EU JRC (October 2009) page 18

Not only are there gaps in the knowledge base about the chemistry of uranium and plutonium, but there are also gaps in chemical data for common major elements.[111]

This leads to the following unresolved issues:

71. the lack of knowledge concerning the basic chemical behaviour of important radionuclides led to a programme of fundamental research. However, the majority of this research has not been carried out under natural conditions and cannot therefore be relied upon as a realistic guide to their behaviour in a repository environment;
72. many radionuclides do not occur in nature and therefore cannot be studied in natural systems;
73. there are gaps in the chemical data for common major elements.

<u>Containment in Alkaline System – cf Detriment to Clay</u>

It has been traditionally assumed that the widespread application of cements would have the beneficial side effect of lowering radionuclide solubility. It has been argued that this would be the case due to the alkaline nature of water released by the cement as ground water washed through it.[112] However, it is now recognised that repository systems which depend heavily on clay [113] would be likely to be detrimentally affected by cement. Specifically (as discussed above) it is predicted that alkaline water would increase flow through clay due to disaggregation and reduced swelling pressure.[114] However, recent work has suggested that:

74. it is now recognised that cement would have a detrimental effect on clay.

<u>'Ionic Strength' Effect – Salty Water</u>

Another important chemical consideration is the effect of 'salty water' on how chemicals react together. This effect is difficult to predict and is 'another well known gap' in the safety case dataset.[115] Therefore, another uncertainty can be summarised as:

75. the impact of salty water on chemical reactions is difficult to predict

<u>Cellulose Breakdown Products + Solubility Increases</u>

In 1989, the International Atomic Energy Agency (IAEA) identified a specific problem relating to the increase in the solubility of radionuclides caused by organic breakdown products that was sufficient to increase the radiological impact of a repository above the

[111] EU JRC (October 2009) page 17
[112] EU JRC (October 2009) page 12
[113] such as the Swedish 'SKB' system for waste fuel which is the reference system for a number of countries.
[114] EU JRC (October 2009) page 15
[115] EU JRC (October 2009) page 17

regulatory target dose.[116] A likely source was thought to be decomposition products of 'cellulose', the woody compound used to make paper. Cellulose break-down products have been observed to increase radionuclide solubility by up to 10,000 fold[117, 118] with plutonium being a particular problem.[119]

The cellulose break down product '*isosaccharinic acid*' is of particular concern. [120] Paper is generally viewed as harmless and innocuous and is widely used within the nuclear industry; its association with such a significant increase in contamination levels, and therefore risk implications, is a matter of great concern.

This issue leads to the concern that:

76. decomposition products of paper can cause a significant increase in radionuclide solubility.

Sorption

Sorption is the process of radionuclide take-up by solid surfaces and it has been studied for many decades.[121] However, the 'batch' technique used in which crushed samples are used to obtain data values[122] is very far removed from the actual uptake mechanisms that would be relevant.[123] Nevertheless, despite the recognition that the measured values "*do not have any predictive capabilities*",[124] they are still widely used in risk estimates.[125]

Equations are available that would more closely represent reality but these are not used due to the lack of data and also the computer capacity that would be required.[126]

The ability of clay to retain radionuclides may be affected by other repository components.[127]

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[116] IAEA in – D. George (1989) NSS/R199 "*The Response to an IAEA Review of Deep Repository Post-Closure Safety R&D and Site Assessment Programmes of UK Nirex Limited*". (p 3)
[117] **[Cross (1989)]** J E Cross et al "*Modelling the Behaviour of Organic Degradation Products*", Nirex 1989 NSS/R151 p(ii)
[118] F T Ewart et al, "*Chemical and Microbiological Effects in the Near Field: Current Status*" Nirex 1988 NSS/G103 p19
[119] Cross (1989) NSS/R151p3
[120] Nicholas D.M. Evans - "*Studies on Metal Alpha-Isosaccharinic Acid Complexes A Doctoral Thesis submitted in partial fulfilment of the requirements for the award of Doctor of Philosophy*" - Loughborough University, July 2003 (pp 24, 42, 272)
[NB Pu $(OH)_4$ is 'tetravalent' – it is this 'valency' which is discussed on both 24 and page 272]
[121] EU JRC (October 2009) pp 17-18
[122] as compared to solid 'block samples' which are used in the 'through-diffusion' measurement technique See "*Using Thermodynamic Sorption Models for Guiding Radioelement Distribution Co-efficient (Kd) Investigations – A Status Report*" Nuclear Energy Agency Oxford workshop (May 1997) Published by the OECD in 2001. http://www.oecd-ilibrary.org/nuclear-energy/using-thermodynamic-sorption-models-for-guiding-radioelement-distribution-coefficient-kd-investigations_9789264192935-en
See also Keita Okuyama et al "*A method for determining both diffusion and sorption coefficients of rock medium within a few days by adopting a micro-reactor technique*" Applied Geochemistry Volume 23, Issue 8, August 2008, Pages 2130-2136 http://cat.inist.fr/?aModele=afficheN&cpsidt=20607551
[123] EU JRC (October 2009) page 18
[124] EU JRC (October 2009) page 18
[125] EU JRC (October 2009) page 18
[126] EU JRC (October 2009) page 18
[127] EU JRC (October 2009) page 16

Concerns associated with sorption can be summarised as:

77. the data used to predict radionuclide take up by solid surfaces is known to be wrong;
78. the capacity of clay to retain radionuclides may be affected by other repository components.

Plutonium and Uranium-235 and Nuclear Energy

Possible Impact Nuclear Energy Chain Reaction

Nuclear wastes contain plutonium and uranium-235, which are able to initiate a nuclear energy chain reaction (or '*criticality*). Both the probability and impact of such an event are not known.[128]

The Environment Agency's language in reference to NDA work on this problem is not scientifically based – i.e. the EA refers to further work in 'building confidence' and 'demonstrating that the probability of a chain reaction is low'. [129] As is discussed below, it is not possible to assume in advance what the outcome of a programme of research will be.

The UK nuclear industry has built up 100 tonnes of separated plutonium which is not currently incorporated into the repository risk estimate.[130] Long term management of this plutonium will need to be considered at some stage, either in the separated form or as 'waste MOX' [131] or in some other form.

This uncertainty gives rise to concerns that:

79. the probability and the impact of a chain release of nuclear energy within a repository remain to be established;
80. the implications of the 100 tonne stockpile of plutonium must be factored in to this consideration.

The Nuclear Weapon Dilemma

Quite apart from the fact that plutonium and uranium-235 are the raw materials for 'State' nuclear weapons, it would also be possible to make a 'dirty bomb' out of more general radioactive wastes. This introduces an additional dilemma into long term waste management.[132] On the one hand, these potential bomb materials should be put out of reach; on the other hand, they should be kept at hand in order to be sure that they have not somehow been accessed by potential bomb makers.

Thus an on-going concern which remains unresolved is:

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[128] EA (January 2010) page 16
[129] EA (January 2010) page 16
[130] EA (January 2010) page 16
[131] 'MOX' – refers to fuel rods that contain both plutonium oxide and uranium oxide.
[132] See also the 'gas dilemma' considered above

81. the dilemma presented by the need to simultaneously keep potential nuclear weapons material out of reach, but at the same time accessible in order to monitor it, has not been resolved.

Biota

Living Things

Better understanding of the long-term implications of the impact of radionuclides on living things [133] is required. In particular, the knowledge gaps with regard to wildlife species and ecosystems include a lack of knowledge concerning:

82. key radionuclides,
83. reference organisms,
84. ecosystem impact;
85. dosimetry – dose calculations in a variety of wildlife species;
86. effects – organisation of data;
87. Relative Biological Effectiveness - the data is dominated by acute doses and by particular groups such as:
88. fish and mammals;
89. pathways;
90. biological uptake;
91. natural background effects;
92. dose effects;
93. quantities and units;
94. genotox techniques; and
95. field testing of models.[134]

Microbes

The potential importance of microbes which can be found deep underground[135] has long been underrated.[136] This is of concern as microbes may well be the determinant factor in the outcome of a reactive chemical system.[137] The role of microbes in proposed disposal systems is not fully understood. [138] Yet despite this, only a few laboratories are undertaking research on microbe/radionuclide interactions. [139]

Thus the issue can be summarised as:

96. The role and effect of microbes in proposed disposal systems is not fully understood.

[133] NEA Contribution to the Evolution of the International System of Radiological Protection, NEA, OECD 2009.
http://www.oecd-nea.org/rp/reports/2009/nea6440_Evolution_Int_System_RP.pdf
[134] **[Strand et al (2004)]** Strand P, Brown J E, and Iospje M, "*Protection of the environment from ionising radiation: International Union of Radioecology's Perspective*", Paper presented to the 11th Congress of the International Radiation Protection Association (IRPA) 2004 http://irpa11.irpa.net/pdfs/2h15.pdf
[135] EU JRC (October 2009) page 20
[136] EU JRC (October 2009) page 19
[137] EU JRC (October 2009) page 20
[138] EU JRC (October 2009) page 20
[139] EU JRC (October 2009) page 20

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Limitations of Further Research

Further Research will not necessarily provide desired outcomes

The Environment Agency has pointed out that it is possible that the results of disposal research programmes may not actually indicate that disposal would be safe.[140] In particular, in their response to the NDA Research Consultation (Summer 2008), the Environment Agency pointed out that the relationship between the research that the nuclear industry has carried out and their incorporation of this into the proposed disposal system is not clear. Specifically the Agency stated:

"*Much R&D has been commissioned over the last 20 years but its impact on the evolution of NDA's facility design is not easy to discern … The claimed link between R&D and the development of the DSS* [Disposal System Specification] *and facility design needs further substantiation. Similarly for the feedback between the generic safety assessments and R&D."* [141]

The EA further commented that not all research findings would be 'acceptable' in terms of the demonstration that it would be possible to produce a robust safety case for disposal and the NDA must be clear how they deal with such data. In particular the Environment Agency states:

"[i]*t is particularly important to counter any suspicion that research findings will be deemed 'acceptable' regardless of what the research actually identifies.*" [142]

It is also clear also that research may identify additional questions; the EA document states:

"[f]*urther research has the potential to increase uncertainties, e.g. by revealing unforeseen complexities or additional processes influencing the system under study. While a well defined and executed research programme can answer fundamental questions, uncertainty is a normal characteristic of science, and as such, additional questions (and uncertainties) are often raised.*" [143]

The Environment Agency also pointed out that although the NDA repeatedly referred to research as a means of 'confirming' assumptions such a purpose is without foundation. Instead, research work should be seen as 'testing' or 'trialling' – thus:

"[a]*ll references to underground R&D activities are stated to be to "confirm" aspects of site performance ("confirmatory tests"). No mention is made …* [of] *trailing, testing or demonstrations*" [144]

[140] **[EA (November 2008)(2)]** "*Environment Agency, Response to Nuclear Decommissioning Authority Consultation on – Radioactive Waste Management Directorate Proposed Research and Development Strategy*" , Environment Agency, November 2008. http://www.environment-agency.gov.uk/static/documents/Research/1976__RWMD_Proposed_RD_strategy.pdf see page 6
[141] EA (November 2008) pp 6-7
[142] EA (November 2008) page 4, para 4.3
[143] EA (November 2008) page 6
[144] EA (November 2008) page 5

Furthermore, the Environment Agency refers to the issue of 'Confirmation Bias' as follows:

"The words "confirm" or "confirmatory" appear 15 times throughout the [Summer 2008 NDA Research Consultation] *document. NDA should provide assurance that it can manage issues associated with "confirmation bias".* [145]

These issues make it abundantly clear that:

97. further research may not provide desired outcomes.

Timescales

Timescales

Radionuclides within the proposed inventory of radioactive waste will be harmful for over one million years into the future and flow conditions and other properties relevant to the safety case are expected to vary over this timescale.[146] However, a review[147] of the most recent Finnish safety case[148] carried out on behalf of the Finnish regulator indicated that there were problems in the prediction of how repository behaviour will change over time. The review concluded that:

"*...analyses of the safety importance for many of the evolutionary processes and associated data are absent*" (p9);

"*...it remains unclear whether Posiva really understands and can prioritise the safety-importance implications of acknowledged uncertainties in the normal evolution processes.*" (p5) (see also p10)

This is of concern as DECC specifically refers to the Finnish case study as an example of a proven approach to long term waste management.[149]

Clearly, the assumption that predictions can be made one million years into the future is intrinsically questionable.

This gives rise to the following concerns:

98. the impact of the timescales involved – and in particular the way that relevant processes will change over time - is not understood;
99. risk predictions over one million years are intrinsically questionable.

[145] EA (November 2008) page 5
[146] EU JRC (October 2009) page 15
[147] Apted et al (April 2008)
[148] POSIVA (October 2007)
[149] DECC (November 2009) page 26

Possible Future Mining

Future mining at a disposal site could cause a fatal dose of radiation.[150]

The Environment Agency states that a repository developer should assume that such mining would be "*highly unlikely to occur*".[151] However, their reasoning for this is not clear. Two examples give cause for concern:

• high level waste disposal sites have been referred to as potential 'copper mines';[152]

• rare earth metals are now a 'boom industry' after previously being considered as 'geological oddities.' [153] Thus the exclusion of sites on the grounds that they could be considered as mines under present day criteria does not take into consideration the fact that minerals presently viewed as worthless may become valuable in the future.

Thus the concern in this area can be expressed as:

100. the Environment Agency argues that future mining at the repository site would be 'highly unlikely'. However, their reasoning for this is not clear. The examples of copper and the rare earths indicate that this assumption may be incorrect. Such mining could cause a fatal dose.

Methodology for Risk Prediction

Methodology applied in Risk Prediction

The methodology used for the risk predictions is not based on straight-forward algebra. Data values are estimated using 'elicitation' techniques and the actual calculations are carried out using a 'Monte Carlo' approach.

Much of the data used is not actually measured, but is obtained through '*data elicitation by expert judgement*'. 'Expert elicitation' refers to a method of 'synthesising data' [154] based on the judgement of experts – in other words 'educated guessing.' The Dutch research organisation 'RIVM' in a report specifically on data elicitation, concluded:

"*With respect to the evidence base, it seems obvious that, at some point, the scientific evidence base would be so thin as to render quantitative expert judgement useless.*"[155]

[150] EA (February 2009) page 51 para 6.3.36
[151] EA (February 2009) page 51 para 6.3.37
[152] spoken comments at 'Royal Society of Chemistry' events - Summer / Autumn (2009)
[153] Milmo, C "*Concern as China clamps down on rare earth exports*", Independent on Sunday 2nd January 2010 http://www.independent.co.uk/news/world/asia/concern-as-china-clamps-down-on-rare-earth-exports-1855387.html
[154] **[RIVM (2008)]** Slottje, P., Sluijs, J.P. van der and Knol, A.B. "*Expert Elicitation: Methodological suggestions for its use in environmental health impact assessments"*, (RIVM Letter report 630004001/2008) 2008 (page 7) ['RIVM' – 'The National Institute for Public Health and the Environment' (RIVM) is a centre of expertise in the fields of health, nutrition and environmental protection. It mainly carries out work for the Dutch government.] http://www.rivm.nl/bibliotheek/rapporten/630004001.pdf
[155] RIVM (2008) page 22

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Furthermore, rather than specifically referring to parameter values that would be found under particular conditions, the nuclear industry instead use 'probability density functions' (or 'pdfs') for the risk calculations. The range of data points is, quite routinely, extremely large (of the order of 'one to ten thousand' units – or even 'one to 100 million' units).[156]

The nuclear industry then obtains a value for the predicted risk using a so-called 'Monte Carlo' approach in which parameter values are 'sampled' in order to obtain an 'expectation value' of radionuclide release. [157]

Concern over the methodology in risk calculations is therefore summed up as:

101. the techniques used in risk prediction – namely 'data elicitation,' the use of 'probability density functions' to describe parameter distribution, and the use of the 'Monte Carlo' technique for data selection - are highly questionable.

[156] D Swan and C P Jackson (SERCO) '*Formal Structured Data Elicitation of Uranium Solubility in the Near Field - Report to Nirex*' (SA/ENV/0920 Issue 3 - March 2007 – page 6
[157] NDA (January 10) Part 1 page 96

Process Concerns

Concerns associated with the relationship between the Environment Agency and the Nuclear Decommissioning Authority

As the NDA has not yet made a formal application to the Environment Agency in connection with a disposal facility[158], the role of the EA is to provide advice to the NDA. This is a commercial arrangement and the EA charge the NDA for the advice received. [159]

Although the EA states that this arrangement will not mean that they are compromised[160], it is the NDA – and not the EA – that are taking the lead on developing the "*permissioning schedule*"[161] for the repository.

The forthcoming deregulation of the Environment Agency's waste and pollution control function through the 'Environmental Permitting Programme' (EPP) [162] is of concern.

The following issues must be addressed:

1. the EA presently has no regulatory locus in respect of the NDA;
2. it is the NDA which is taking the lead on the development of the 'permissioning schedule' for repository development;
3. the forthcoming deregulation of the Environment Agency's waste and pollution control function through the 'Environmental Permitting Programme' (EPP) is of concern due to its emphasis on the minimisation of the bureaucratic burden rather than the optimisation of the protection of the environment.

Rigour of 'Evidence Base'

In the autumn of 2008, the Planning Inspector for the Cumbria County Council's Hearing on the draft '*Minerals and Waste Core Strategy and Development Control Policies*' (the 'Waste Planning Framework') requested that the NDA present a Submission indicating whether their waste management policies were based on "*a robust and credible evidence basis?*" [163]

[158] EA (January 2010) page 5
[159] EA (January 2010) page 5
[160] EA (January 2010) page 5
[161] EA (January 2010) page 7
[162] See or example http://www.defra.gov.uk/environment/policy/permits/
and also: House of Lords, Hansard, 2nd March 2010, The Environmental Permitting (England and Wales) Regulations 2010 http://www.publications.parliament.uk/pa/ld200910/ldhansrd/text/100302-gc0002.htm#10030273000024
[163] Cumbria County Council, Waste Planning Framework, November 2008
NDA Response to 'Schedule of Matters and Issues Arising"
[ED 19 Ref: WMN/NDA/G/009]