'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 especial 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

Contents

Note:

This 'Issue Register' document lists the outstanding technical hurdles related to deep geological disposal of radioactive waste, as compiled by NWAA.

For contextual background on these issues, please see the document: 'NWAA Issues Register - Commentary'.

Inventory

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

Gases

6. the need to allow the release of hydrogen gas[6] which is contrary to the need for 'barriers'[7]
7. lack of clarity as to whether hydrogen pressure will open fractures and result in 'fast pathways'[8]
8. the interaction of processes that would lead to hydrogen release is not understood[9]
9. the extent of the 'carbonation' reaction between carbon-14 and cement [10]

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[1] 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

[2] NDA/DEFRA (March 2008)

[3] NDA/DEFRA (March 2008)

[4] See: "*Mobile Fission and Activation Products in Nuclear Waste Disposal*", Workshop Proceedings, La Baule, France (16-19 Jan 2007) OECD NEA (May 2009) (pp 31, 38, 39,114 NEA No. 6310 (ISBN 978-92-64-99072-2) http://www.nea.fr/html/science/reports/2009/nea6310-MOFAP.pdf
See also – [**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 17 http://ec.europa.eu/dgs/jrc/downloads/jrc_reference_report_2009_10_geol_disposal.pdf

[5] EU JRC (October 2009) page 12

[6] [**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 55 & 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

[7] EU JRC (October 2009) page 10

[8] EU JRC (October 2009) page 20

[9] EU JRC (October 2009) page 20

[10] [**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.
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

10. the extent of the formation of radioactive methane (CH_4) gas [11]
11. the magnitude of the dose arising from this exposure and over what timescale[12]

Site Considerations

12. resolution of gas issues and their incorporation into site selection considerations
13. the development of a clear approach to site investigation[13]
14. the establishment of a methodology for the determination of the frequency, spread and distribution of high permeability features[14]
15. the establishment of useful and relevant borehole techniques[15]
16. the development of methodologies for establishing flow over geographical regions[16]
17. the development of a methodology for moving from a generic to a site-specific safety case[17]
18. resolution of uncertainties in flow prediction [18]
19. the development of techniques for representing flow and transport in fractured rocks [19]
20. gas generation and its interaction with groundwater: in particular the implications for the reliability of the risk predictions [20]
21. the impact of groundwater chemistry on gas solubility is poorly known[21]

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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."
More recently: [**Quintessa (April 2008)**] R. Metcalfe et al. *NDA work on gas generation and migration from a deep geological repository: A review undertaken on behalf of the Nuclear Waste Assessment*, Quintessa April 2008, page 76 http://www.environment-agency.gov.uk/static/documents/Business/GEHO1108BOZN-E-E.pdf says:"*The efficiency of the carbonation reaction in removing 14C- labelled carbon dioxide is central to the safety case in both the operational and post-closure phases. Further work is required to build confidence that this reaction is able to remove carbon dioxide without compromising the other backfill functions."*

[11] [**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

[12] See Nirex (February 2006) and Pamina (March 2008)

[13] [**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 18 http://publications.environment-agency.gov.uk/pdf/GEHO0210BRWU-e-e.pdf

[14] EU JRC (October 2009) page 15

[15] EU JRC (October 2009) page 15

[16] EU JRC (October 2009) page 15

[17] EA (January 2010) page 11

[18] [**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

[19] EA (November 2005) see pp 10-11

[20] [**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

[21] EA (August 2009) page 142

22. current predictions of gas / groundwater flow may not be adequate [22]
23. the impact of the 'excavated damage zone' on gas/water flow is uncertain[23]

Construction Issues

24. construction and constructability issues are not resolved[24]
25. compromise may be required between construction requirements and safety requirements[25]
26. there is limited evidence to demonstrate long-term stability[26]
27. the role of the 'excavated damage zone' (EDZ) as a pathway is under investigation[27]
28. the behaviour of the mechanical/flow/heat/and chemical processes at the site – in response to their disturbance – is not understood[28]
29. the impact of 'weathering ' that would be caused by an 'open phase' is not understood [29]
30. the possibility of a collapse due to an open phase requires further investigation[30]
31. it is possible that worker doses would be unacceptable[31]

The Waste Package and Repository Components

32. inadequate research exists on ILW wasteform lifetimes[32]
33. the relationship between waste form and repository design is a 'major knowledge limitation'[33]
34. the selection of appropriate treatment for reactive metals is required[34]
35. research is required on repackaging[35]
36. a response to the 'expansive fracturing'[36] 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 [37]

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[22] EA (August 2009) page 142
[23] EA (August 2009) page 142
[24] EU JRC (October 2009) page 14
[25] EU JRC (October 2009) page 14
[26] EA (August 2009) page 142
[27] EU JRC (October 2009) page 14
[28] EU JRC (October 2009)pp 20-21
[29] EU JRC (October 2009) pp 14-15
[30] EU JRC (October 2009) pp 14-15
[31] **[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. page 91
[32] [**CoRWM (October 2009)**] "*CoRWM report to Government: Report on National Research and Development for Interim Storage and Geological Disposal of Higher Activity Radioactive Wastes and Management of Nuclear Materials*" CoRWM, October 2009, Report 2543, para 6.3, page 89. http://corwm.decc.gov.uk/media/viewfile.ashx?filetype=4&filepath=corwm/Post-Nov%2007%20Doc%20Store/Documents/Reports%20to%20Government/2009/2543%20CoRWM%20Report%20on%20RandD%20Final%2030%20October%202009.pdf
[33] EA (August 2009) page 141
[34] CoRWM (October 2009) para 2.15 page 20
[35] CoRWM (October 2009) para 2.18 – page 20
[36] P K Abraitis, "*The longevity of intermediate-level radioactive waste packages for geological disposal: A review*" Environment Agency, August 2008 [NWAT Report: NWAT/Nirex/06/003] page 25 http://www.environment-agency.gov.uk/static/documents/Business/c.pdf
[37] EU JRC (October 2009) page 12

38. research into mechanisms and probabilities of canister failure is required[38]
39. particular problems due to new data on copper corrosion have arisen [39]
40. the impact of steel corrosion products on repository performance needs further work[40]
41. the interaction of repository components and the resultant impact on the safety case requires further research[41]
42. the interaction of waste fuel with other repository components requires further research[42]
43. it is difficult to predict the interaction of the glass of vitrified high level waste and clay[43]
44. the chemical, mechanical and flow behaviour of clay would be affected by the high temperature of high level waste[44]
45. clay behaviour is difficult to quantify[45]
46. the capacity of clay to retain radionuclides can be damaged by salty or alkaline water[46]
47. radionuclide retention by clay can also be damaged by corrosion products [47]
48. grout/repository rock interaction is poorly understood [48]
49. the chemical database is inadequate to the task of predicting cement/clay interaction [49]
50. the impact of salty groundwater on repository/rock interaction is difficult to predict [50]
51. there is insufficient data to predict chemical causes of cavern collapse[51]
52. the effect of repository/rock interaction on the behaviour of the EDZ is poorly known [52]
53. the impact of resaturation on the facility is poorly known[53]
54. it is not clear what effects the chemicals in groundwater would have on the facility[54]

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[38] EU JRC (October 2009) page 12

[39] 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

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

[40] EU JRC (October 2009) page 12

[41] EU JRC (October 2009) pp 20-21

[42] EU JRC (October 2009) page 11

[43] EU JRC (October 2009) pp 11-12

[44] EU JRC (October 2009) page 13

[45] EU JRC (Oct '09) page 13

[46] EU JRC (October 2009) page 15 (in a repository context alkaline water would be derived from cement)

[47] EU JRC (October 2009) page 15

[48] EA (August 2009) page 141

[49] EA (August 2009) page 141

[50] EA (August 2009) page 141

[51] EA (August 2009) page 141

[52] EA (August 2009) page 141

[53] EA (August 2009) page 143

[54] EA (August 2009) page 141

55. the implications for predicted dose of processes and data is not clear[55]
56. the definition of repository safety functions is vague[56]
57. it is not clear which outcomes would lead to unacceptable safety hazards[57]
58. essential chemical 'temperature correction' data is largely unavailable[58]
59. similarly, reaction rate information is also largely unavailable [59]
60. a better understanding of the heavier chemical elements (uranium and heavier) is required[60]
61. proof is required that the 'chemical containment' approach put forward by nuclear industry would be effective in isolating waste[61]
62. it must be demonstrated that soluble compounds which have only more recently received attention (Non-aqueous phased liquids) would not result in an undue risk[62]
63. the validity of the assumption that the 'oxidised' form of the radionuclides is the more soluble form, must be demonstrated[63]
64. the assumption that the corrosion of iron would use up the available oxygen must be demonstrated [64]
65. the role of the 'oxygen anomaly' introduced by the excavation itself must be established [65]
66. the retention time within fractured rock and the possibility that radionuclides would not be retained for a sufficient time to adopt the 'reduced' (oxygen removed) form must be addressed [66]
67. techniques for sampling and analysing colloids requires further development[67]

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[55] Apted (April 2008) page 1
[56] Apted et al (April 2008) page 7
[57] Apted et al (April 2008) page 8
[58] EU JRC (October 2009) page 17
[59] EU JRC (Oct 2009) page 18
[60] EU JRC (Oct 2009) page 17
[61] Compare - 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
with "*Response to comments on NDA RWMD's proposed research and development strategy*" NDA, March 2009, Report No. 10019689 page 16
[62] EA (November 2005) page 11
[63] 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. 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
[64] EU JRC (October 2009) page 18
[65] EU JRC (October 2009) page 18
[66] EU JRC (October 2009) page 18
[67] EU JRC (October 2009) page 19

68. much colloid work has been restricted to experimentation with uranium resulting in considerable research gaps as far as other radionuclides are concerned[68]
69. the interaction between colloids, microbes and radionuclides has not been well researched[69]
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 needs to be assessed[70]
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[71]
72. many radionuclides do not occur in nature and therefore cannot be studied in natural systems[72]
73. there are gaps in the chemical data for common major elements[73]
74. it is now recognised that cement would have a detrimental effect on clay[74]
75. the impact of salty water on chemical reactions is difficult to predict[75]
76. decomposition products of paper can cause a significant increase in radionuclide solubility[76,77,78]
77. the data used to predict radionuclide take up by solid surfaces is known to be wrong [79]
78. the capacity of clay to retain radionuclides may be affected by other repository components. [80]

Plutonium, Uranium-235 and Nuclear Energy

79. the probability and the impact of a chain release of nuclear energy within a repository remain to be established[81]
80. the implications of the 100 tonne stockpile of plutonium must be factored in to this consideration[82]
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.

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[68] EU JRC (October 2009) page 19
[69] EU JRC (October 2009) page 19
[70] EU JRC (October 2009) page 19
[71] EU JRC (October 2009) page 17
[72] EU JRC (October 2009) page 18
[73] EU JRC (October 2009) page 17
[74] EU JRC (October 2009) page 15
[75] EU JRC (October 2009) page 17
[76] J E Cross et al "*Modelling the Behaviour of Organic Degradation Products*", Nirex 1989 NSS/R151 p(ii) Abstract: http://www.mrs.org/s_mrs/sec_subscribe.asp?CID=11918&DID=327521&action=detail
[77] F T Ewart et al, "*Chemical and Microbiological Effects in the Near Field: Current Status*" Nirex 1988 NSS/G103 p19
[78] 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]
[79] EU JRC (October 2009) page 18
[80] EU JRC (October 2009) page 16
[81] EA (January 2010) page 16
[82] EA (January 2010) page 16

Living Things

knowledge gaps with regard to wildlife species and ecosystems include a lack of knowledge concerning: [83]

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.
96. the role and effect of microbes in proposed disposal systems is not fully understood[84]

Limitations of Further Research

97. further research may not provide desired outcomes [85]

Timescales

98. the impact of the timescales involved – and in particular the way that relevant processes will change over time - is not understood [86]
99. risk predictions over one million years are intrinsically questionable
100. the Environment Agency argues that future mining at the repository site would be 'highly unlikely.[87] However, their reasoning for this is not clear. The examples of copper and the rare earths[88] indicate that this assumption may be incorrect. Such mining could cause a fatal dose.

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[83] 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

[84] EU JRC (October 2009) page 20

[85] "*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)

[86] See EU JRC (October 2009) page 15 and Apted (April 2008) pp 5,9,10

[87] "*Geological Disposal Facilities on Land for Solid Radioactive Wastes: Guidance on Requirements for Authorisation"* Environment Agency, February 2009, page 51 http://publications.environment-agency.gov.uk/pdf/GEHO0209BPJM-e-e.pdf EA (Feb '09)

[88] See for example Chahal Milmo, "*Concern as China clamps down on rare earth exports*" Independent, January 2nd 2010 http://www.independent.co.uk/news/world/asia/concern-as-china-clamps-down-on-rare-earth-exports-1855387.html

Methodology for Risk Prediction

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' [89] technique for data selection - are highly questionable.

Process Concerns

1. the EA presently has no regulatory locus in respect of the NDA [90]
2. it is the NDA which is taking the lead on the development of the 'permissioning schedule [91] 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 [92] due to its emphasis on the minimisation of the bureaucratic burden – rather than the optimisation of the protection of the environment.
4. the NDA does not have "*a robust and credible evidence bas*[e]" for their waste management policies[93]
5. it is of extreme concern that neither Public nor NGOs will be given the opportunity to scrutinise repository proposals in Planning fora.

[89] NDA (January 2010) Part 1 page 96
[90] EA (January 2010) page 5
[91] EA (January 2010) page 7
[92] See or example http://www.defra.gov.uk/environment/policy/permits/
and also:
House of Lords - Draft Statutory Instrument Debate (Tues 2nd Mar '10)
The Environmental Permitting (England and Wales) Regulations 2010
[93] Cumbria County Council, Waste Planning Framework (Nov '08) NDA Response to 'Schedule of Matters and Issues Arising" [ED 19 Ref: WMN/NDA/G/009] 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*' requested that the NDA present a Submission indicating whether their waste management policies were based on "*a robust and credible evidence basis?*"