PMD 13-P1.167

File / dossier : 8.01.07
Date: 2013-08-13
Edocs: 4186569

Oral intervention from

Rachel Western

In the Matter of

Ontario Power Generation Inc.

Proposed Environmental Impact Statement for OPG's Deep Geological Repository (DGR) Project for Low and Intermediate Level Waste

Joint Review Panel

September 16 to October 12, 2013

Intervention orale par

Rachel Western

À l'égard de

Ontario Power Generation Inc.

Étude proposée pour l'énoncé des incidences environnementales pour l'Installation de stockage de déchets radioactifs à faible et moyenne activité dans des couches géologiques profondes

Commission d'examen conjoint

16 septembre au 12 octobre 2013

Canada

Joint Federal Review of Ontario Power Generation's Proposed Deep Geologic Repository for Low and Intermediate Level Radioactive Wastes

DGR Joint Review Panel Hearing Written Submission in Support of an Oral Intervention

Review of Ontario Power Generation's Safety Case

For the Proposed Deep Geological Repository for

Low and Intermediate Level Radioactive Wastes

Dr. Rachel Western BA(Oxon) PhD MRSC

August, 2013

DGR Joint Review Panel Hearing Written Submission in Support of an Oral Intervention

Review of Ontario Power Generation's Safety Case For the Proposed Deep Geological Repository for Low and Intermediate Level Radioactive Wastes

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August 2013

Prepared for Northwatch

1. Introduction

Ontario Power Generation (OPG) is proposing to build a Deep Geological Repository (DGR) for Low and Intermediate Level Waste (L&ILW) near the existing Western Waste Management Facility at the Bruce nuclear site in the Municipality of Kincardine Ontario. The Nuclear Waste Management Organisation, on behalf of OPG, has prepared a preliminary safety report for the proposed repository.

In January 2012 a Joint Review Panel was established to review the proposal. The Panel will examine the information necessary for the consideration of the licence application under the 'Nuclear Safety and Control' act. This document - prepared for Northwatch - is a submission to that review process.

Central to the thesis of this document is that OPG has not provided a robust safety case for the proposed repository, and so they should not be given a licence under the Nuclear Safety and Control act. A 'safety case' is an integration of the arguments put forward by the proponent to describe the safety – and the level of confidence in the safety – of a project, such as the proposed deep geological repository[1].

There are many reasons why it is difficult to produce a robust safety case for a repository. In March 2010 a group of UK consultants on nuclear waste - Nuclear Waste Advisory Associates - published a list of 101 technical, scientific and ethical hurdles to the development of a deep geological facility for the disposal of radioactive wastes. [2] In August 2011 the Radioactive Waste Management Division of the UK's Nuclear Decommissioning Authority listed 500 issues which need to be resolved but also noted that 400 internally raised issues had been removed from the list because these have already been identified as information needs within the RWMD R&D programme. [3] A March 2012 document confirms

[1] Paraphrased from definition provided by Ontario Power Generation, in Section 15, pg 15-33, Main EIS

[2] 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, NWAA March 2010 http://www.nuclearwasteadvisory.co.uk/wp-content/uploads/2011/06/NWAA-ISSUES-REGISTER-COMMENTARY.pdf

[3] RWMD Approach to Issues Management, NDA, August 2011 http://www.nda.gov.uk/loader.cfm?csModule=security/getfile&pageid=47986 The figure of 900 outstanding issues was also mentioned verbally at a UK Government Advisory Committee know as

the number of outstanding issues as 500.[4] This document focuses on the chemistry-related difficulties of producing a reliable safety case.

Radionuclides can migrate from a repository by dissolving in the underground water system or by carriage as a gas. Both of these routes involve complex chemical processes and it is the contention of this report that OPG has not demonstrated sufficient chemical knowledge of the repository and its environs to enable sufficiently rigorous chemical calculation of the extent of radionuclide escape – and hence they are unable to provide to the Panel with a robust evaluation of repository safety.

Central to OPG's safety case is the claim that the repository will be essentially dry – such that water will not reach the radionuclides and carry them back to the surface. This claim is not robust; OPG does not have sufficient understanding of the baseline hydrogeology to support such a claim.

Subsequently, OPG must carry out a further safety assessment based on the assumption that water will reach the radionuclides and they will dissolve. However, carrying out such calculations will be very complex, due to the wide diversity of the chemical behaviour of the radionuclides and the wide range of their possible solubilities.

This report illustrates the complexities involved by looking at three materials generally thought to be innocuous, and addresses the significant detriment that they would have on radionuclide behaviour. Finally the report looks at the example of carbon and shows that where a more in depth approach was taken it was found that the risk guidance level in a UK case was exceeded.

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the Geological Disposal Implementation Board, Number mentioned verbally at Geological Disposal Implementation Board meetings.

[4] RWMD Approach to Issues Management, NDA March 2012 http://www.nda.gov.uk/documents/upload/Geological-Disposal-RWMD-approach-to-issues-management-March-2012.pdf

2. Assumption of Low Saturation – It's Importance and It's Weakness

Central to OPG's safety case is that the repository would exhibit very low saturation (i.e. be essentially dry) such that water will not reach the radionuclides and subsequently enable their migration from the repository to the environment..

> "*H-3 is assumed released instantly to the gas phase in the DGR and C-14 is released relatively rapidly to the gas phase. However, the small degree of repository resaturation means that other radionuclides remain within the wastes as they are only released on contact with water. Most of the total radioactivity decays without being released.*" [5]

> "*The detailed gas and groundwater calculations indicate that the repository will not resaturate over the timescales considered in the assessment (beyond one million years) due to the gas pressure within the repository and the relative impermeability of the host rock and shaft seals. This is important because it increases the volume available for gas and minimizes the potential for radionuclides to be released into groundwater and to migrate from the repository.*" [6]

The low saturation is expected to last an extremely long time.

> "*Calculations for the Reference Case show repository saturation remains extremely low, peaking at 0.7% after about 3000 a before falling to essentially zero and remaining at this low level*" [7]

> "*It might take many hundreds of thousands or even millions of years to resaturate.*" [8]

Essentially OPG assumes that a balance of gas pressure against water flow will keep the waste dry and thus the majority of the radionuclides deep underground. Thus:

> *"The detailed gas and groundwater calculations indicate that the repository will not resaturate over the timescales considered in the assessment (beyond one million years) due to the gas pressure within the repository and the relative impermeability of the host rock and shaft seals.*
>
> *This is important because it increases the volume available for gas and minimizes the potential for radionuclides to be released into groundwater and to migrate from the repository.*" [9]

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[5] OPG's Deep Geologic Repository for Low and Intermediate Level Waste – Post Closure Safety Assessment - NWMO DGR-TR-2011-25 – March 2011, page 168
http://www.nwmo.ca/uploads/DGR%20PDF/Licensing/Postclosure-Safety-Assessment.pdf

[6] Ibid, page 195

[7] Ibid, p105

[8] Ibid p76

Professor Stuart Haszeldine (OBE) of Edinburgh University has pointed out some of the difficulties associated with this assumption:

> *"The proposition that gas generation will keep the repository dry is unusual. This depends on accurate and precise understanding of the rates of gas generation and the rates of water ingress. There are two contradictions. Firstly, for gas generation to occur needs water to enable the reaction processes. If gas generation dispels water from the repository, then gas generation will reduce in volume. Consequently, it is not clear how these opposing effects will balance. The second contradiction is that a repository must be sealed to allow only slow water ingress, but must allow rapid gas egress to avoid pressure buildup."*[10]

In addition to the complexities associated with the gas pressure / water pressure balance, there is the added difficulty that OPG does not understand the baseline hydrogeology and so are not in a position to be able to make reliable long term hydrogeological predictions. OPG does not demonstrate through their Application that they presently have sufficient understanding of the baseline hydrogeology. In fact, they acknowledge that they do not:

> "*The geosphere is clearly key to the DGR safety. In general, the attributes of the geosphere are sufficiently well known to support the safety assessment. However, some aspects are still uncertain, such as the cause of the over/underpressures.*" [11]

This is despite the fact that considerable work has been undertaken to understand the causes of these under and overpressures [12] that drive the water flow underground. OPG refers to many possible causes including glacial processes, and osmosis – but do not provide a conclusive explanation. The further work is described in the OPG report 'Geosynthesis' Nuclear Waste Management Organisation report NWMO DGR-2011-11 R000[13]
Of further concern is the fact that the vertical hydraulic conductivities have not been directly measured, but have been inferred.

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[9] OPG's Deep Geologic Repository for Low and Intermediate Level Waste – Post Closure Safety Assessment - NWMO DGR-TR-2011-25 – March 2011, page 195
http://www.nwmo.ca/uploads/DGR%20PDF/Licensing/Postclosure-Safety-Assessment.pdf
[10] Personal Note – See Appendix Three
[11] Ibid, p xiv
[12] Ibid p50
[13] http://www.nwmo.ca/uploads/DGR%20PDF/Licensing/Geosynthesis.pdf at section 5.4.10.

OPG states:

> "*The horizontal conductivity of the rock is well established from site characterisation. However, the vertical hydraulic conductivities have not been directly measured, but have been inferred from modelling and other factors.*" [14]

Geosphere permeability is the most significant control on repository inflow:

> "*The water-limited cases, although a more accurate representation of processes, have been shown to be very sensitive to assumptions regarding geosphere permeability, which is the most significant control on repository inflow.*" [15]

and a relatively high permeability fracture zone cannot be ruled out . [16] At Table 5.3 (page 80) of the OPG Post Closure Safety Assessment document (DGR-TR-2011-25) OPG list a number of potentially compromising arguments relating to the long term safety of the proposed DGR. On page 81, it is reported that site investigations could fail to identify a high permeability fracture zone or a fault. Although it is reported that such a feature is included in a 'what if' scenario – the vertical fault scenario described (page 132) considers a fault 500 m away from the repository, which is not conservative.

[14] Ibid p 203
[15] Ibid p B7
[16] Ibid, p81

3. The Importance of Chemistry

Given that OPG's assumption of an essentially dry repository is not robust, as the baseline hydrogeology has not been established, it is essential that OPG carry out risk assessment calculations on the assumption that the radionuclides could dissolve and migrate away from the repository and towards the surface. This would depend on a chemical understanding of the wastes and their environs. However, the development of such an understanding is not straight forward. It may be argued that in this context pessimistic values for chemical data may be used. However, values that are pessimistic in one context may be optimistic in another context, as outlined by Serco in their 2011 report:

> "*Values may be pessimistic for one pathway, but not another.*" [17]

An example would be that of sorption, which is the capacity of surfaces to absorb contaminants. Superficially it would appear that it would be conservative to assume that sorption was low and so the rock and other surfaces would not take up the radionuclides and hold them back from the surface. However, this would not be a conservative assumption as it is possible that contaminants could sorb onto mobile particles and reach the surface by this method.

Chemistry is central to the safety assessment since it determines the solubility of the radionuclides in the water that migrates away from the repository. The solubility of the radionuclide in the water thus contaminated determines the toxicity and thus ultimate dose of the water that will ultimately be discharged into the biosphere. However the solubility of a given radionuclide depends on a number factors and it is not possible using current understanding and computing power to derive a figure with any utility.

In the UK a technique known as 'data elicitation by expert judgement' is used. For this process a group of people discuss what the appropriate range to sample from is to derive the contamination level. However given that the ranges are so large the procedure is essentially meaningless.

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[17] Serco - Key processes and data for the migration of C-14 released from a cementitious repository, April-2011, page 14
http://www.nda.gov.uk/documents/upload/Key-processes-and-data-for-the-migration-of-C-14-released-from-a-cementitious-repository-April-2011.pdf

There are about ninety different types of chemical elements and they link up with each other in millions of different ways to form the vast complexity of the materials that make up our world. These different chemical compounds behave differently and an important difference, in this context, is the differences in how much they will dissolve and so how contaminated the underground water supplies will become.

Each of the radioelements has essentially the same characteristics as the non-radioactive version of the element and so is subject to the same enormous range of chemical behaviours and so whichever solubility or sorption that is pertinent to the calculation of what will reach the surface is in all real senses unknowable.

Examples of the ranges for the data are given below:

- data range for carbon - 100 to 0.000001 units.[18]
- range of data five orders of magnitude for technetium [19]
- up to eight orders of magnitude variation for uranium [20]

As can be seen the numbers involved are extreme – for example: when the nuclear industry tested their leak rate calculations at a uranium mine in Brazil, they underestimated the leak rate by 200 million .[21] In the discussion of the results, four different possible reasons for the large error were considered (pp 12-13). The issue was not resolved and the fact that there were four different possible causes of the error is of serious concern.

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[18] National Nuclear Laboratory, NNL (08) 9537, Jan 2009 Issue 2, "*Data packs for use in the elicitation of solubility and sorption of carbon species*", page 9 Figure 1, http://www.nda.gov.uk/documents/biblio/upload/Data_packs_for_use_in_the_elicitation_of_solubility_and_sorption_of_carbon_species.pdf

[19] Serco - Formal structured data elicitation of technetium solubilities and sorption distribution coefficients in the near field , February 2010, page 6
http://www.nda.gov.uk/documents/biblio/upload/Formal-structured-data-elicitation-of-technetium-solubilities-and-sorption-distribution-coefficients-in-the-near-field.pdf

[20] Serco - Formal structured data elicitation of uranium solubility in the near field, March 2007, page 6
http://www.nda.gov.uk/documents/biblio/upload/Formal-structured-data-elicitation-of-uranium-solubility-in-the-near-field.pdf,

[21] Nirex - Pocos de Caldas Modelling Study (NSS/R252) April 1991
page 10 - Uranium (mg/l) - calculated 1.4 x 10^{-11} ; measured approx. 0.4 x 10^{-3}
The text at pages 12-13 sets out for possible reasons for the error in the calculation. The issue was not resolved.

Such large errors hardly seem credible, but they are easy to understand when you look at the way the nuclear industry does their leak rate calculations. What they try to do is put a figure on how much of a particular element – for example Uranium, Plutonium or Carbon – will dissolve. [22] For the example cited above a particular computer code 'CHEQMATE' was used that combines chemical and transport considerations. It was concluded that for the computer to generate reliable results accurate information on the chemical context of the radionuclide was needed. (p i) Atoms generally don't travel solo – they almost always link up with other atoms. An example is water: H_2O is made up of two hydrogen atoms and one oxygen atom – three atoms altogether. For example, at page 136 of the Postclosure Safety Assessment document (DGR-TR-2011-25) it is commented that uncertainties remain relating to the detailed evolution of chemical conditions. Without this information OPG must rely on guesswork in their predictions of how much of the buried radionuclides will reach the Biosphere. The fact that OPG do not apply an adequate approach to the chemistry of the radionuclides may be appreciated by the fact that OPG refer to 'radionuclides' and 'chemicals' as though radionuclides themselves were not chemical entities.[23]

As an example of how important it is to know what type of chemical an element is found in, diamonds and sugar may be compared. Diamonds are pure carbon and don't dissolve at all – sugar is carbon linked up with hydrogen and oxygen and is extremely soluble. There is no sensible answer to the question – how soluble is carbon. Similarly there is no sensible answer to the question how soluble is uranium – or plutonium. Uranium and Plutonium are in the actinide group of chemical elements and display very complex chemical behaviour. A common assumption in safety assessment calculations is that they would exist in an insoluble form in a repository – but they are very susceptible to linking up with other chemicals to form 'complexes' which are highly soluble.

[22] NDA - Geological Disposal – RWMD approach to issues management – March 2012NDA Report no. NDA/RWMD/081 Version 2 – page 25 Section 1.7 http://www.nda.gov.uk/documents/upload/Geological-Disposal-RWMD-approach-to-issues-management-March-2012.pdf. A radionuclide is a radioactive chemical element.

[23] OPG's Deep Geologic Repository for Low and Intermediate Level Waste – Post Closure Safety Assessment - NWMO DGR-TR-2011-25 – March 2011, see for example pp (vi) (xiii) (xxii) http://www.nwmo.ca/uploads/DGR%20PDF/Licensing/Postclosure-Safety-Assessment.pdf

OPG have run a test case in which they assume that the repository is wet [24] (see Appendix One) – however, this test case assumes that:

> "*the shaft seals continue to provide an effective barrier*" [25]

This is not a robust assumption. In December 2012, the establishment of the 'DOPAS' Project was announced. [26] This is a 15.7 million euro joint European project to test the efficacy of repository seals. (See Appendix Two) Therefore it cannot be assumed that repository seals are an established, proven technology. Thus OPG's statement that they have run a test case which has shown that a wet repository would meet safety standards is not reliable.

To illustrate the importance of an adequate chemical understanding of the chemical system and the difficulties associated with this, this report will use three case studies of materials that are quite inert and innocuous in the everyday world, but can have quite severely deleterious effects on the hazard presented by radioactive waste. The three materials in question are paper, cement and plastic. Finally the report will look at the radionuclide carbon-14 and consider a review in 2008 of the complexity of its chemistry and the failure to take a conservative approach such that in 2012 it was reported that its release would exceed risk targets.

3.1 Paper

Paper is made of the wood based material cellulose and as cellulose breaks down in the repository environment it forms a chemical known as isosaccarhinic acid [27]– 'ISA'.

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[24] http://www.nwmo.ca/uploads/DGR%20PDF/Licensing/Postclosure-Safety-Assessment.pdf
OPG's Deep Geologic Repository for Low and Intermediate Level Waste
Postclosure Safety Assessment: Groundwater Modelling, March 2011, Prepared by: Geofirma Engineering Ltd. NWMO DGR-TR-2011-30 - Page196

[25] Ibid page 197

[26] http://www.posiva.fi/en/news/topical_at_research/joint_development_of_plugging_and_sealing_technology_for_geological_disposal_facilities_-_the_dopas_project.html

[27] Assessment of effects of cellulose degradation, March 2013, page 4
http://www.nda.gov.uk/documents/biblio/upload/ Assessment-of-effects-of-cellulose-degradation -NNL-12-12239-Part-A-Issue-4.pdf

Cellulose is present in OPG wastes and is referred to in the reference inventory for the Deep Geologic Repository.[28]

In October 2011 Serco Group plc[29] stated in a report for the UK Nuclear Decommissioning Authority (NDA):

> "*The treatment of detriments to radionuclide sorption[30] in the geosphere has been identified as a key uncertainty in performance assessments for a geological disposal facility (GDF). Potentially the most significant detrimental process affecting radionuclide chemistry is the formation of complexes with organic compounds that may be present in the groundwater (such as natural humic substances) or released from a GDF[31]. Volumetrically, the most important potential sources of organic complexants within a GDF will be cellulosic materials such as paper, wood and cloth present in the wastes. Cellulosic materials have been shown to degrade under the alkaline conditions relevant to cement-based GDF concepts, and the resulting degradation products to complex some radionuclides, causing solubility enhancement in the near field and sorption reduction in both the near field and the geosphere. Historically, a significant amount of work had been undertaken to study the effects of cellulose degradation products (CDPs) on the sorption of a number of radionuclides onto a range of rock types.*" [32]

OPG plan to use cement in the repository [33] - so the UK case may be compared as the cement context is a heavy determinant of the chemical context.In March 2013 UK's National Nuclear Laboratory reported:

> "*The degradation of cellulosic material under alkaline anaerobic conditions expected in the ILW disposal area in a geological disposal facility (GDF) in the UK will*

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[28] Reference Low and Intermediate Level Waste Inventory for the Deep Geologic Repository December 2010, Prepared by: Ontario Power Generation, Inc. 00216-REP-03902-00003-R003, p 14 http://www.nwmo.ca/uploads/DGR%20PDF/Licensing/Reference-L-ILW-Inventory.pdf

[29] http://www.serco.com/; Serco is a UK based government services company.

[30] Sorption is the take-up of chemicals by surfaces

[31] GDF – Geological Disposal Facility

[32] Serco - Sorption detriments in the geosphere the effect of cellulose degradation products - Phase I experimental study. October 2011, page 5 http://www.nda.gov.uk/documents/upload/Sorption-detriments-in-the-geosphere-the-effect-of-cellulose-degradation-products-Phase-I-experimental-study-October-2011.pdf

[33] Attachment 1 to OPG Letter, Laurie Swami to Dr. Stella Swanson, "Deep Geologic Repository Project for Low and Intermediate Level Waste – Submission of Responses to the First Sub-set of Package #9 Information Requests", CD# 00216-CORR-00531-00178 – page 122 – Cementation http://www.ceaa.gc.ca/050/documents/p17520/87797E.pdf

"Table 1: Summary of Waste Treatment and Conditioning Option (associated with response to IR-EIS-09-476)" *produce soluble organic compounds that are able to form complexes with disposed radionuclides. These complexes may increase radionuclide migration.*" [34]

Of concern is the fact that in this 2013 document it was reported that there was an additional chemical identified that could have the similar harmful effects of ISA, but had not been focussed on before. It was stated that:

"*One of the more significant findings is the presence of potentially large concentrations of xylo-isosaccharinic acid (X-ISA); a hemi-cellulose degradation product originating from the wood pulping process. This finding is significant because X-ISA is structurally similar to ISA and therefore may be expected to exhibit comparable complexing behaviour. Although X-ISA is a common by-product known in the paper-milling industry, it has not been a focus of attention in the context of nuclear waste disposal*." [35]

Cellulose degradation products have been a focus of research for over twenty years. [36 37, 38] Experiments have tried to mimic the ISA behaviour in the lab and computer calculations have been set up to try and predict the implications. It is of concern that during this time this other damaging chemical was not identified. This is important because in the procedure to assign a migration rate to the radionuclides a 'conceptual model' – or description of the chemical environment is built up. That this description does not include a key facet is of serious concern.

Studies of cellulose break down products are not robust as the following quote from National Nuclear Laboratory in September 2010 shows. Thus, following a suggested improvement to the model, it was realised that:

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[34] NNL - Assessment of effects of cellulose degradation Products on Europium and Thorium - NNL-12-12239 Part A Issue 4, March 2013, page 3 http://www.nda.gov.uk/documents/biblio/upload/Assessment-of-effects-of-cellulose-degradation-NNL-12-12239-Part-A-Issue-4.pdf

[35] Ibid, page 5

[36] The chemical and microbial degradation of cellulose in the near field of a repository for radioactive wastes M.M. Askarieh a,*, A.V. Chambers b, F.B.D. Daniel b, P.L. FitzGerald b, G.J. Holtom b, N.J. Pilkington b, J.H. Rees b Waste Management 20 (2000) 93-106
aUnited Kingdom Nirex Limited, Curie Avenue, Harwell, Didcot, Oxfordshire OX11 0RH, UK
bAEA Technology plc, Harwell, Didcot, Oxfordshire OX11 0RA, UK
Accepted 21 August 1999
http://www.bvsde.paho.org/bvsacd/cd43/holton.pdf

[37] AEA 'The Identification and Degradation of Isosaccharinic Acid – A Cellulose Degradation Product', BF Greenfield et al (1994)

[38] Serco - "*A Review of Cellulose Degradation and the fate of degradation products under repository conditions*" September 2010, pp 5,7 http://www.nda.gov.uk/documents/biblio/upload/A-Review-of-Cellulose-Degradation-and-the-fate-of-degradation-products-under-repository-conditions.pdf

“*Basing this modification on the available experimental data does assume that the cotton cellulose used in these experiments is representative of the cellulosic wastes likely to be present in a UK repository. This assumption is unsupported and it should be noted that cellulose from different sources can have very different characteristics such as DP* [degree of polymerization] *and crystallinity, it might be better in future to correlate cellulose degradation rates to physical characteristics of the material rather than its origins, however, the practicality of this approach would require testing.*” [39]

Similarly in October 2011, Serco reported that:

“*Overall, the chosen model ternary system haematite-thorium-ISA does not appear to be as well-suited as expected as a basis for on-going development of a thermodynamic model of ternary system interactions owing to the limited impact of ISA on thorium sorption in this system. In addition there are uncertainties concerning sorption reversibility and the attainment of thermodynamic equilibrium for this system over experimental timescales. The impact of CDP*[40] *leachate in reducing thorium sorption to haematite appears to be significant, however. Clearly more understanding is required concerning the presence of additional complexants and/or the operation of other processes (e.g. possible competition for surface sites by calcium ions) that control thorium sorption in the presence of the new CDP leachate.*” [41]

This is important to OPG as they state that their approach is consistent with international practice. [42]Thus a detriment that is a ‘key uncertainty’ [43] in the safety case is not understood. As the behaviour of the breakdown products of cellulose is not understood the process of deriving a predictive tool to establish what hazard would be presented by the proposed repository is jeopardised and the risk presented by the repository is unknown.

3.2 Cement

[39] Ibid page 26

[40] CDP – Cellulose Degradation Product

[41] Serco - Sorption detriments in the geosphere the effect of cellulose degradation products - Phase I experimental study. October 2011, page 7 http://www.nda.gov.uk/documents/upload/Sorption-detriments-in-the-geosphere-the-effect-of-cellulose-degradation-products-Phase-I-experimental-study-October-2011.pdf

[42] OPG’s Deep Geologic Repository for Low and Intermediate Level Waste – Post Closure Safety Assessment - NWMO DGR-TR-2011-25 – March 2011, page 23 http://www.nwmo.ca/uploads/DGR%20PDF/Licensing/Postclosure-Safety-Assessment.pdf

[43] Ibid, page 5

OPG plan to use cement in the repository, [44] This is problematic as grout compounds can cause problems concerning corrosion of chemically active metals and hydrogen evolution and because of these concerns the alternative of polymer encapsulation is being considered in the UK. In January 2011 it was reported that:

> "*The most common method of conditioning intermediate-level radioactive wastes (ILW) before storage and disposal is their immobilisation in a cementitious matrix. Encapsulation in cement offers several advantages, but grout compounds can cause problems concerning corrosion of chemically active metals and hydrogen evolution. For the encapsulation of wastes for which cements may not be appropriate, organic polymers are being considered. A polymeric material, *vinyl ester styrene (VES), has already been used as a waste encapsulant in the UK.*" [45]

However, polymer based encapsulants have their own associated problems:

> "*There is the possibility that non-aqueous phase liquids (NAPLs) could be generated from polymer encapsulants affected by radiolytic degradation. NAPLs could transport associated radionuclides through fractured and porous media faster than radionuclides would migrate in an unperturbed groundwater system subject to advective-dispersive transport. Buoyancy forces are the principal driving force for the upward migration of NAPLs that are lighter than water. Work is in hand to understand better the significance of NAPLs. Organic compounds arising from the degradation of the polymer could also complex with radionuclides. These effects have been taken into account by allowing up to a factor of ten increase in radionuclide solubility and decrease in sorption.*" [46]

Apart from the problems with the grout, cement is also problematic due to the 'superplasticiser' additives used in cement manufacture and solubility experiments have generally shown an increase in actinide solubility in the presence of most classes of superplasticiser, with polycarboxylates increasing solubility of U and Pu by up to 4 orders of magnitude. [47]

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[44] Attachment 1 to OPG Letter, Laurie Swami to Dr. Stella Swanson, "Deep Geologic Repository Project for Low and Intermediate Level Waste – Submission of Responses to the First Sub-set of Package #9 Information Requests", CD# 00216-CORR-00531-00178 – page 122 – Cementation http://www.ceaa.gc.ca/050/documents/p17520/87797E.pdf

[45] Serco - Polymer Encapsulation Final, January 2011, page v
http://www.nda.gov.uk/documents/biblio/upload/Serco_report_Polymer_Encapsulation_Final_14_Jan_2011.pdf

[46] Ibid, page v

[47] NNL - Current status paper on the potential use of Superplasticisers in a Geological Disposal Facility, NNL (12) 11905 - Issue 4, page 52

While identified as significant, the problem is still not well understood and further research is required

> "*It is* [therefore] *essential to investigate realistic superplasticiser : cement ratios in any experimental assessment of superplasticiser.* "[48]

This is problematic as the superplactisers that could potentially be used as an alternative to cement in a geological disposal project have not yet been developed.

> "*Since the first potential use of superplasticiser in a GDF constructional application will not be before 2027, both cement powders and superplasticisers are likely to have changed. The extent of this change may be significant in terms of functional groups, minor additives, recommended dosages and therefore the interactions between the additives and cement phases. It may therefore be inappropriate to carry out extensive research on the performance of specific proprietary superplasticiser products for such applications at this stage.*" [49]

This means that current experimental data may not be relevant, meaning that it may not be possible to carry out meaningful safety assessments in this area.

3.3 PVC

In January 2013 the international consulting firm Amec reported to the UK nuclear waste agency the NDA that PVC, which is a widely used form of plastic, could have a detrimental impact on repository performance. Thus:

> "*A number of the radioactive waste streams that will be disposed to a GDF will contain organic polymeric materials. Some of these materials could have potential impacts on repository performance, especially polymers such as polyvinylchloride (PVC), which are complex mixtures of polymer, plasticisers, stabilisers and fillers.*" [50]

> "*Over long timescales, solid polymeric materials may undergo degradation by thermal, chemical, microbial or radiolytic means to produce shorter organic molecules that could affect the desired evolution of a repository through detrimental interactions. For example, some of the shorter organic molecules that are generated during the ageing processes in a polymer could exist as non-aqueous phase liquids or NAPLs that are immiscible in water. .....If long-term ageing of the polymeric*

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http://www.nda.gov.uk/documents/biblio/upload/Superplasticiser-Position-Paper-RWMD-comments-issue-4-Approved.pdf

[48] Ibid

[49] Ibid, pp 51-52

[50] Amec - The role of PVC additives in the potential formation of NAPLs. January 2013, page 7 http://www.nda.gov.uk/documents/biblio/upload/NDA-PVC-Review-_Jan-2013_Final.pdf

> *materials in a repository were to increase the amount of NAPLs, this could potentially accelerate radionuclide release from the near field and could also affect sorption properties of the backfill and rocks.*" [51]

One group of chemicals in the PVC that are of concern are common phthalate plasciticisers; thus Amec reported:

> "*flexible forms of PVC contain high levels of common phthalate plasticisers such as di-ethylhexyl phthalate (DEHP). These plasticisers could diffuse from the PVC under the action of heat, radiation or high pH during interim storage or after disposal in the GDF and have the potential to form NAPLs, in many cases buoyant NAPLs.*" [52]

Unfortunately there is only limited data available to assess the impact of these chemicals on repository performance – thus:

> "*The most extensive work carried out on PVC as a wasteform has been under landfill conditions and these studies show that over time, microbes have the capability to catalyse the complete degradation of some of the PVC plasticisers to water-soluble or gaseous species, but these studies do not consider any radiation-induced effects."* [53]
>
> *"there are only limited data available that describe the behaviour that might be expected under the conditions predicted in a GDF environment (combined chemical and radiolytic stressors).*" [54]

These data limitations have implications for the rigour of the safety case. As discussed above, an understanding of the chemical behaviour of the radionuclides and their chemical environment is needed in order to make predictions of the rate of radionuclide migration from the repository to the surface. As PVC break down products have the capacity to bring radionuclides in solution it is vital that they are understood.

3.4 Carbon-14

In November 2008, meetings were convened by the UK radioactive waste agency the Nuclear Decommissioning Authority to discuss key processes for carbon species migrating from a repository. The meetings were written up by the consultancy Serco. The participants were from NDA, Serco and other consultancies. The conceptual model that represented best

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[51] ibid
[52] ibid
[53] ibid
[54] ibid

understanding was discussed. A simplified version of the model for use in repository performance assessments was proposed. In March 2009, further meetings were held to carry out an elicitation of the uncertainties in the parameters for the simplified model. [55]

Examples were cited where long held opinions that tended to give a lower dose were incorrect and had to be replaced with assumptions that the repository could be more dangerous than previously thought. For example it had been thought that a reaction known as 'carbonation' would trap the carbon and hold it in place deep underground. However, further work led to the realisation that this would not be as prominent as originally thought – thus leading to a greater release of carbon.

> "*Previously, carbonation was taken to be 100% efficient, but now it is thought that methane will not be involved in carbonation. It was also noted that carbonation will only be taking place on the surfaces of the pores or fractures through which water is flowing.*" [56]

Similarly it had been assumed that the radioisotopes were evenly mixed with the non-radioactive isotopes. However this assumption had to be abandoned.

> "*It was commented that the previously made assumption of isotopic equilibrium between 14C and the total stable carbon inventory of the repository is unrealistic, and probably not cautious.*" [57]

The behaviour of carbon is quite complex leading to the need to modify the model – however it was concluded that:

> "*overall, the model would be quite complicated.*" [58]

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[55] Serco - Key processes and data for the migration of C-14 released from a cementitious repository, April 2011, page 5
http://www.nda.gov.uk/documents/upload/Key-processes-and-data-for-the-migration-of-C-14-released-from-a-cementitious-repository-April-2011.pdf

[56] Ibid, page 18

[57] Ibid, page 14

[58] Serco- Key processes and data for the migration of C-14 released from a cementitious repository, April 2011, page 33
http://www.nda.gov.uk/documents/upload/Key-processes-and-data-for-the-migration-of-C-14-released-from-a-cementitious-repository-April-2011.pdf

The difficulty of having a complex model is exacerbated by the fact that the parameters - ie the data – to feed into the model are not known with sufficient precision. This is known as being poorly 'characterised'. The consultants commented:

> "*Information on many of the parameters was already available within the NDA programme. However, the uncertainties in some key parameters had not been fully characterised.*" [59]

Once the carbon has left the repository it is argued that it will be taken up by the host rock in a process known as sorption – but there is little work on carbon and sorption in rock. In January 2009 National Nuclear Laboratories reported that:

> "*The small range of experimental studies that have examined 14C sorption and isotope exchange on rocks and minerals has prevented the far field data set being delineated into categories for; hard rock/sandstone and clay-rich rocks. The information and data collated indicates that the presence of calcite is a key control on inorganic sorption in the far field. Understanding of the nature and sorption process of organic forms of 14C in the far field is not well advanced*" [60]

As well as a lack of understanding of the sorption, the process of solubility is also poorly understood. Thus it was noted that:

> "*the scope of the preparation of the data pack had been to collate data relating to sorption and solubility of carbon, recognising that the processes were not well defined. It was suggested that, after the discussion, the scope of the data pack might be broadened and more data sought.*" [61]

Following these data revisions, in December 2012 it was reported that using the current modelling basis, the calculated release of carbon-14 exceeded the risk guidance level. [62] This is particularly relevant to the OPG case because – for an unspecified reason – carbon is

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[59] Ibid page 33

[60] NNL - Data Packs for Use in the Elicitation of Solubility and Sorption for Carbon Species in a Cementious Near Field and for Sorption in the Far Field, NNL (08) 9537,, January 2009, page 54 http://www.nda.gov.uk/documents/biblio/upload/Data_packs_for_use_in_the_elicitation_of_solubility_and_sorption_of_carbon_species.pdf

[61] Serco - Key processes and data for the migration of C-14 released from a cementitious repository, April 2011, page 14 http://www.nda.gov.uk/documents/upload/Key-processes-and-data-for-the-migration-of-C-14-released-from-a-cementitious-repository-April-2011.pdf

[62] NDA - Carbon-14 Project Phase 1 Report NDA/RWMD/092, December 2012 p(v) http://www.nda.gov.uk/documents/biblio/upload/Carbon-14-Project-Phase-1-Report.pdf

treated as a special case in the OPG safety case. [63] The fact that carbon is treated differently than the other radionuclides suggests that there is concern over its potential release rate from the repository.

4. Conclusion

Given that the assumption of an essentially dry repository is not robust, as the baseline hydrogeology has not been established and the gas modelling is problematic, it is essential that OPG carry out risk assessment calculations on the assumption that the radionuclides could dissolve and migrate away from the repository and towards the surface.

This report shows by using the example of three everyday materials – paper, plastic and cement – that building up a chemical understanding of the wastes and their environs can be extremely challenging and complex. It has also been shown – using the example of carbon – that building up a more realistic understanding could lead to the calculation of a dose that exceeds safety guidance. OPG has yet to demonstrate that it has the required understanding to be able to make a credible safety case for the DGR.

OPG should not be given permission to go ahead with the construction and operation of the proposed Deep Geological Repository. This is because they are unable to establish what the migration rates of the radionuclides to the surface would be – and hence the danger that it would present. This problem cannot be expected to be resolved within the mandate of this Joint Review Panel.

[63] OPG's Deep Geologic Repository for Low and Intermediate Level Waste – Post Closure Safety Assessment - NWMO DGR-TR-2011-25 – March 2011, pp 102, 147
http://www.nwmo.ca/uploads/DGR%20PDF/Licensing/Postclosure-Safety-Assessment.pdf

APPENDIX ONE

Resaturation and the Safety Case

http://www.nwmo.ca/uploads/DGR%20PDF/Licensing/Postclosure-Safety-Assessment.pdf

OPG's Deep Geologic Repository for Low and Intermediate Level Waste
Postclosure Safety Assessment:
Groundwater Modelling
March 2011
Prepared by: Geofirma Engineering Ltd.
NWMO DGR-TR-2011-30

This Appendix contains extracts from pp 195-197 of OPG's March 2011 Post Closure Saftety Assessment. The extracts are concerned with the importance of low saturation to the safety case.

[Highlighting added for emphasis]

Page195

7.3.2.1 Repository Resaturation

The detailed gas and groundwater calculations indicate that the repository will not resaturate over the timescales considered in the assessment (beyond one million years) due to the gas pressure within the repository and the relative impermeability of the host rock and shaft seals.

This is important because it increases the volume available for gas and minimizes the potential for radionuclides to be released into groundwater and to migrate from the repository.

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To bound uncertainty surrounding repository resaturation, the NE-RS calculation case represents a fully resaturated repository from closure. This case maximizes the release of radionuclides from the wastes into groundwater, while the gas pathway is not modelled. The AMBER model for this case adopts groundwater flow rates from the reference FRAC3DVS-OPG case; i.e., including the observed underpressures in the Ordovician formations.
The amount of radioactivity remaining in the waste and the amount released are shown in Figure 7.28 for the NE-RS case. The figure shows that the full inventory is released by the time that the Zircaloy wastes have completely corroded, by 500,000 years. This differs from the Reference Case, in which almost all radioactivity remains within the wastes due to the very low level of repository resaturation.

…

Page 197

The calculated radionuclide transfer fluxes from the monolith to the base of the shafts are shown in Figure 7.29 and compared against the total for the Reference Case. The figure shows that the greater amount of water in the repository and the associated greater release of radionuclides from the wastes results in higher calculated radionuclide fluxes to the base of the shafts.

…

The greater radionuclide flux into the shafts means that there is also greater migration of radionuclides up the shafts than in the NE-RC case. However, the shaft seals continue to provide an effective barrier, such that calculated radionuclide fluxes to the Shallow Bedrock Groundwater Zone are effectively zero, being less than 1 Bq/a throughout the calculation period.

…

In summary, although early resaturation of the repository increases the corrosion of the wastes and the release of radionuclides from the wastes and repository via groundwater, the impacts remain very small and the safety of the repository system is not sensitive to repository resaturation.

APPENDIX TWO

European Research on Sealing

This Appendix reproduces a web page on the December 2012 announcement of research into repository sealing. It relates to the discussion on page 10 of this document of the assumption by OPG that shaft sealing can be relied upon should the repository resaturate.

[Highlighting added for emphasis]

http://www.posiva.fi/en/news/topical_at_research/joint_development_of_plugging_and_sealing_technology_for_geological_disposal_facilities_-_the_dopas_project.html

Topical at research

31.12.2012 12:48

Joint development of plugging and sealing technology for geological disposal facilities - the DOPAS Project

Launch of European-wide cooperation on plugging and sealing technology

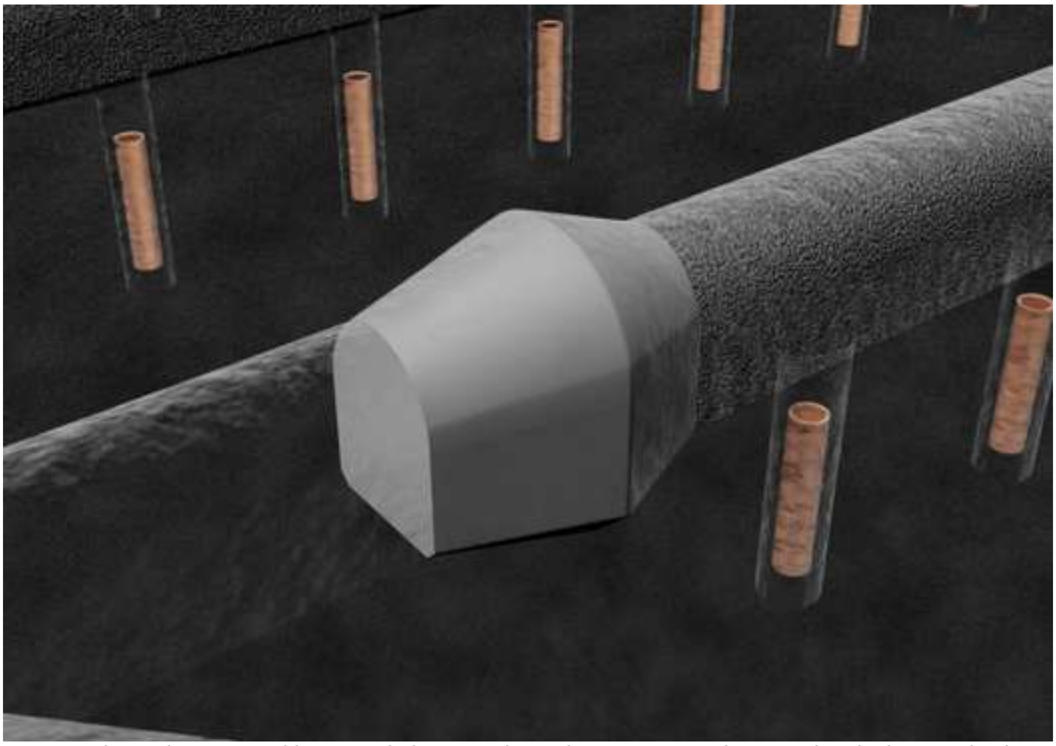
Fourteen nuclear waste management organisations and research institutes from eight European countries are participating in a technology development project for testing plugging and sealing systems for geological disposal facilities for radioactive waste - the DOPAS project ("Full-Scale Demonstration Of Plugs And Seals"). The project is built around a set of full-scale underground demonstrations, laboratory experiments, and performance assessment studies.

The project budget is €15.7 million, and is jointly funded by the Euratom's Seventh Framework Programme (€8.7 million) and European nuclear waste management organisations. The project is running in the period September 2012 – August 2016, and is being coordinated by Posiva Oy, a nuclear waste management company in Finland.

The project will compile the design basis of plugs and seals, develop new technology for plug and seal materials and for the assembly and construction of plug and seal systems, carry out full or partial design of the systems, and perform five full-scale plug and seal tests. The tests will be carried out in research facilities representative of varying geological environments in Finland, France, the Czech Republic, Sweden and Germany. In addition, the performance of the plugs and seals will be assessed and compared to design requirements. A further task is to inform the wider radioactive waste management community about the work and results of DOPAS, via attendance at international scientific meetings and project publications.

In 2016, the project team will organise an international seminar on plugging and sealing technology for geological disposal of radioactive waste.

The impetus to the cooperation comes from the Strategic Research Agenda of the Implementing Geological Disposal of Radioactive Waste - Technology Platform (IGD-TP).



As example Posiva's Deposition tunnel plug experiment in ONKALO underground rock characterization facility in Olkiluoto, Finland

”As part of the DOPAS project, Posiva will perform the deposition tunnel's full-scale plugging test in the underground rock characterization facility, ONKALO, in Finland," says Posiva's Johanna Hansen, coordinator of the DOPAS project. The plug design has already started, and the construction will be carried out in 2013-2014. Other Finnish project partners are VTT and B+Tech.

"Excavation of the plug area with wire sawing is also a new and innovative task for Posiva as part of the deposition tunnel plug construction test. A low-pH concrete, especially developed for geological disposal conditions, will be used for the plugging structure. The reason for using this type of special concrete is to maintain the chemical conditions of the underground geological environment as natural as possible," says Hansen.

Johanna Hansen from Posiva coordinates the DOPAS project.

APPENDIX THREE

Professor Stuart Haszeldine on Gas

This Appendix reproduces a personal note prepared by Professor Stuart Haszeldine (OB) on gas modelling in the OPG safety case.

[Highlighting added for emphasis]

Thoughts on gas in Canadian Rad waste disposal for Rachel Western

Professor Stuart Haszeldine OBE 12 February 2013 s.haszeldine@ed.ac.uk

1) The Canadians undertook a significant geological screening before proceeding to accept volunteer sites. Consequently their sites may be better positioned geologically than those in the UK.

2) Most Canadian radwaste sites are proposed in Ontario or Saskatchewan, which is (i) low-lying topography, with (ii) an abundance of old sediment, or crystalline metamorphic and granite rock. Both of these factors will tend to reduce the intensity, flux, or rate, of groundwater flow, which is fed from the surface.

3) Canadian sites are apparently to receive ILW. This generates very little heat in comparison to HLW or spent fuel.

4) In a deep repository, the gas generation after emplacement is due to 3 processes. One, reaction of any metallic iron or steel to produce CO_2 and CH_4. Two, radiolysis of water. Three, thermal or bacterial breakdown of emplaced waste - this could be particularly relevant for resins which have been used during surface operations to capture radioactive 14C.

5) If the waste mix contains additional 14C from materials which have been enriched at surface, (for example, filters), then the gases generated can contain radioactivity with much larger 14C concentrations than expected(i.e., enriched in 14C)

6) A repository usually has to fulfill two entirely contradictory aims: A) to let the gas generated in the first 10,000 years escape, to avoid pressure buildup and fracturing of the rock; B) to stop, or greatly reduce, the inflow and throughput of groundwater.

7) Some generic repository designs do not undertake complete backfill of the horizontal tunnels into which the ILW is emplaced. This leaves a connected void along the top of the tunnel network, which can act as a rapid transit route for gas, or for groundwater to move throughout the repository.

8) Emplacement of the waste will require the tunnels to be dry, i.e. filled with air. After emplacement of waste and backfilling, an initial expectation would be that groundwater refills the tunnels with water. This may move rapidly, or slowly, depending on the regional setting of the hydrogeology.

9) In principle, it could be possible that the rate of gas generation from within a repository could be faster than the rate of water ingress to the repository tunnel network during this re-saturation period. That balance will depend on the accurate, and precise, simulation through the first 1000 years time after waste emplacement, of the rate of gas generation, and the rate of water ingress.

10) There needs to be extremely good confidence in the understanding of gas generation rates. It is not clear how this can be established experimentally, unless all the waste types and their packaged final form, has been experimentally investigated using groundwater compositions, temperatures, and surrounding geochemistry buffering, to match that of the proposed repository. Recent experience with copper canister corrosion rates in Sweden, shows that many decades of engineering dogma concerning corrosion rates can be questioned by low-cost, long-term, experiments, which have revealed much more rapid corrosion than expected, probably due to bacterial surface actions. This is a warning that laboratory measurements are not simple to extrapolate into nature, and even in controlled engineered settings. (P. Szakálos, 2007, 2009, http://www.mkg.se/uploads/A3_folder_MKG_eng__may_2011.pdf)

11) There needs to be equally good confidence in the rate of water ingress to the repository complex. Particularly if there is void space along the top of the tunnel network, then entry of water into one section of the repository can connect into the remaining tunnels throughout the complex. A volumetric calculation is needed, because even if one fracture provides water input, then that may not be a sufficiently large flow rate to fill the tunnel network until many hundreds of years have passed.

12) If the waste remains dry, after the repository is filled, backfilled, and sealed, then many of the gas generating reactions will not occur. Thus, most of the gas generation will only occur after the repository has become water saturated. If the resaturation occurs rapidly, within decades or hundreds of years, then 14C will still be radioactive. If the resaturation can be delayed for thousands

or tens of thousands of years, then the half life of 14C means that very little 14C radioactivity could remain, so that gas generation may not produce radioactive gas.

13) In summary, the proposition that gas generation will keep the repository dry is unusual. This depends on accurate and precise understanding of the rates of gas generation and the rates of water ingress. There are two contradictions. Firstly, for gas generation to occur needs water to enable the reaction processes. If gas generation dispels water from the repository, then gas generation will reduce in volume. Consequently, it is not clear how these opposing effects will balance. The second contradiction is that a repository must be sealed to allow only slow water ingress, but must allow rapid gas egress to avoid pressure buildup. For the proposition to work requires that these contradictions are both balanced.

END