Response to EA Consultation
on the Guidance to the Nuclear Industry on
What Criteria they Would Need to Meet
to be Given Permission to Dispose of Nuclear Waste
(the So-Called 'GRA'[1] Consultation[2])

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9th September 2008

This document focuses on one particular aspect of the consultation documents, and supports this with four Appendices.

Achieving Reliable Risk Calculation
for Radioactive Waste Disposal is not Feasible

Central to both of the EA Consultation Documents that are under consideration is the notion that that it is feasible to generate a reliable calculation of the risk that would arise from the disposal of radioactive waste – and as a result of this ensure that the risks that would arise would be extremely low. Thus the risk assessments referred to in the documents are based on the notion of keeping the risk at or below 'one in a million' – i.e.:

> "*the assessed radiological risk to a person representative of those at greatest risk should be consistent with a risk guidance level of 10^{-6} per year (ie. 1 in a million per year.)*" [3]

However, such a target of risk is simply not scientifically demonstrable or achievable in theory or practice. It is in the nature of chemical elements and also geological and biological systems to behave in a variable and hence unpredictable manner such that they make reliable risk/time calculations into the far future not only difficult but virtually impossible. Thus is hard to see what information could be used as a basis for the claim that the radiological impact from a repository would not exceed the target. . Not only is this incapable of substantiation but it does not begin to address the sub-lethal impacts. Worse, it ignores the possible effects which could result should a poorly characterised repository be constructed and used and, as a result, generate high doses.

Over the following pages four Appendices will be set out to support this contention.

1.The Importance of Chemistry
2. Chemical Considerations and the Possible Error Range

3. Possible Risks from Radioactive Methane
4. Methane and the Contradictory Implications for Site Selection

[1] Guidance for Requirement on Authorisation
[2] There are actually two documents under consideration – one for deep disposal on nuclear waste – and one for shallow
[3] See EA Consultation Document (Re; Deep Disposal) May 2008 p38

1. THE IMPORTANCE OF CHEMISTRY

The Importance of Chemistry in the Prediction of the Risk that Would Arise if Nuclear Waste Were to be Buried

Summary:

*Fundamental to the prediction of the risk that would arise from the burial of nuclear waste are the **Chemical Equations** used to quantify the estimated amounts of radioactivity that would dissolve in the Underground Water Supplies.*

It was established in the 1990s that the Nuclear Industry simply did not have the necessary data to carry out the required calculations. Subsequently a paper from the 'IAEA' (International Atomic Energy Agency') published in October 2007 indicates that this is still the case.

*In fact, this IAEA report states that the necessary research is: "**far from being complete**". Given that this is the case it is clear that the nuclear industry are simply not in a position to provide the necessary underlying data that would be required in order to demonstrate that they could meet the 'one in a million' target that is set out in the EA Consultation document.*

Main Paper

In the 1990s the Nuclear Industry failed in their attempts begin building a deep nuclear waste disposal facility in the bedrock beneath Cumbria. This failure occurred because they were unable to provide convincing evidence at a Planning Inquiry that they actually knew what the implications for the health of people in the future would be if they were allowed to go ahead with their plans.

In particular their methodology for working out the amount of radioactivity that would find its way back up to the surface was inadequate.

Two key factors in the calculation of how dangerous the water that would seep out of a nuclear waste burial site are:

- How much radioactivity would dissolve in the underground - water supply system; and,
- Where this contaminated water would end up.

The direction that the contaminated water would take depends on the underground pressures acting on it as it flowed out of the burial site.

Just how contaminated – and therefore how harmful - such leaks would be depends on how much radioactivity this water would carry. To work this out in advance demands an absolutely enormous amount of chemical data. At the Inquiry it was established

that the nuclear industry simply did not have the data to justify their claims that the risks that would arise from the burial of nuclear waste would be insignificant.

Thus, the report of the Technical Assessor at the Inquiry (Colin Knipe) – which was published in March 1997 concluded, (under the heading of "Further Work Programmes" (p64)) that:

> "*The evidence suggests that considerably more experimentation and model development is needed on radionuclide solubility, sorption and general thermodynamic relationships over the range of temperatures and chemical conditions relevant to a Sellafield repository, from natural groundwaters in the distant geosphere to the special conditions in and around the degrading waste and repository chemical barrier.*" (C.142)

It should be noted that although this quote specifically mentions "*chemical conditions relevant to a Sellafield repository*" – there are difficulties in ascribing the appropriate chemical parameters to use in order to ascertain the predicted contamination levels of the flow away from a radioactive waste burial site - ***whatever the proposed location***.

For example, the Nuclear Energy Agency (NEA)[4] held a workshop on 'Sorption' in Oxford in May 1997.[5] Subsequently, the Proceedings were published by the OECD OECD in 2001. The title of the publication was:

> "Using Thermodynamic Sorption Models for Guiding Radioelement Distribution Coeffient (Kd) Investigations – A Status Report"

On page 97 of the document Mr Hans Wanner, of the Swiss Federal Nuclear Safety Inspectorate (HSK); stated:

> "*The term "uncertainty" is commonly connected with "error" in a statistical sense, but a statistical basis rarely exists for Kd [sorption] values because they depend on too many unknown parameters. Hence the assignment of an uncertainty to a Kd value is usually a priori unscientific and unjustifiable*"

Furthermore, in his (Mr Colin Knipe's) statement that: "*considerably more experimentation and model development is needed* " – he is also referring to "*the degrading waste and repository chemical barrier."*

These two points are important – because it is commonly believed that the Nuclear Industry failed to get the go-ahead for excavation work at their planned deep burial site (near Sellafield) in the 1990s solely on the grounds that locating a burial facility in ***that particular area*** would be unwise.

It is critically important to realise that there are fundamental difficulties associated with the notion of burying radioactive waste – ***whichever location is suggested***.

[4] The 'Nuclear Energy Agency' is part of the 'Organisation of Co-operation and Development' (OECD)

[5] "Using Thermodynamic Sorption Models for Guiding Radioelement Distribution Coeffient (Kd) Investigations – A Status Report"

Chemical Terms

The term '***solubility***' refers to the capacity for a solid to be taken up by a liquid that it is in contact with – for example sugar is very 'soluble' in tea. In the context of nuclear waste disposal it refers to the radioactive chemicals in the wastes being picked up by the water that would flow through the disposal facility.

The word '***sorption***' refers to the capacity of surfaces to pick out chemicals from the liquid that flows over them. This occurs when there is a particular chemical affinity between the chemicals held in the liquid and the exposed surface of the solid.

The word '***thermo-dynamics***' is the word used by Chemists to refer to the methodology they use to work out whether or not a given chemical reaction will happen. A data-set referring to specific conditions must be available – and then the actual conditions pertinent to the necessary calculation needs to be set out. With the appropriate data and equations, the notion is that the extent to which chemical elements will re-group from one set of combinations to another (ie undergo a chemical reaction) can be worked out.

In September 2001, when the Government (the Department of Food and Rural Affairs) published their consultation paper on radioactive waste management policy[6] the first page of Chapter One (page 9), at para 1.3, stated that:

> "*In March 1997 the then Secretary of State for the Environment decided not to give Nirex [7] planning permission for the RCF.[8] This decision* **called into question whether at that time an underground repository for the disposal of radioactive wastes could be scientifically justified** *or publicly acceptable. This led to a completely new look at radioactive waste management policy in the UK.*"

This issue of **scientific doubt** is fundamental - as it goes to the heart of whether or not the Nuclear Industry are able to make reliable predictions of the risk that would arise if they went ahead with nuclear waste burial.

In October 2007 the 'IAEA' (the International Atomic Energy Agency) published a document on the more recent findings concerning the solubility of radioactive wastes

[6] The document was entitled 'Managing Radioactive Waste Safely' Proposals for Developing a Policy for Managing Solid Radioactive Waste in the UK

[7] '**Nirex**' is an Acronym for the body that was charged with developing Nuclear Waste Disposal Facilities. It stands for the '**N**uclear **I**ndustry **R**adioactive waste **EX**ecutive;

[8] '**RCF**' stands for 'Rock Characterisation Facility'. This was the name for the proposed Excavation down into the bedrock. If it had been given the go-ahead it would have comprised two deep shafts plus galleries out from the shaft into the surrounding rock. Although the Nuclear referred to this proposed structure as a 'Laboratory' Friends of the Earth argued that it was a 'Trojan Horse' for what would inevitably become a Dump.

when they are in the environment of a burial facility.[9] On page three, the report states;

> "The capacity to model [10] all the effects involved in the dissolution[11] of the waste form, in conditions similar to the disposal site, is the final goal of all the research undertaken by many research groups over many years. As we will see in this report, **this kind of investigation is far from being finished**" (emphasis added)

The fact that the research is: "**far from being complete**" indicates that the nuclear industry are not in a position to provide the necessary underlying data that would be required in order to demonstrate that they could meet the 'one in a million' target that is set out in the EA Consultation document.

[9] The title of the report is: "Spent Fuel and High Level Waste: Chemical Durability and Performance under Simulated Repository Conditions Results of a Coordinated Research Project 1998–2004" http://www-pub.iaea.org/MTCD/publications/PDF/te_1563_web.pdf IAEA-TECDOC-1563 (October 2007)

[10] 'Model' refers here to an approach to making predictions using equations.

[11] 'Dissolution' refers here to the process in which solids dissolve in liquids

2. Chemical Considerations and the The Possible Error Range

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The majority of the pores and fractures that make up the 'underground voids' in the UK are filled with water. Thus if radioactive waste were to be buried it would very quickly become saturated. This means that if the chemical compounds that contain the wastes happen to be soluble they will be carried away from the waste drums – and depending on the water pressure system – they may end up in crops or drinking water supplies.

Before a decision can be made to bury radioactive wastes – there must be some degree of certainty that the resultant leaks would not be too dangerous. In particular, two key factors must be investigated:

- the underground water system – which will determine where and when the leaks will end up; and

- the contamination levels of these leaks .

This short paper looks at the question of how reliable the Nuclear Industry's predictions of the Contamination Level are. It uses as an example the experiment carried out by the Nuclear Industry in 1991 at the 'Pocos de Caldas' Uranium Mine in Brazil.

In this experiment the hypothesis that was tested was that the Chemical Information that was fed into the Nuclear Industry's Computer would enable an accurate prediction of the Uranium Contamination Levels in the underground water found at the site to be made.

The data was duly fed in to the Computer – and the Contamination level that was predicted was:

$$1.4 \times 10^{-11} \text{ mg/l} \quad \text{(pp 9,19)}$$

However, when actual contamination levels were measured the contamination level that was found was:

$$3 \times 10^{-3} \text{ mg/l} \quad \text{(p10)}$$

These figures mean that the Nuclear Industry under-estimated the Uranium contamination of the underground water at the Mine by a factor of:

200 Million Fold.

Although such a large error range may seem extraordinary – one only needs to think about the difference between the solubility of the Carbon that is in a Diamond and the solubility of a Carbon that is in Sugar - to realise that to attempt to come up with Estimates of the solubility of a **Chemical Element** – without having accurate information on its chemical surroundings (particularly in terms of what else it is bonded to) is liable to lead to wildly mistaken predictions.

The Nuclear Industry and the Government are presently proposing that the go-ahead should be given for Nuclear Waste Burial – without ensuring beforehand that the predictions of the radioactive contamination levels of the resultant leaks would be are sufficiently reliable.

Source for the Information on the Uranium Experiment:

Cross (1991) NSS/R252

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

Possible Explanations of the Pocos de Caldas Error in the Prediction of Uranium Contamination Level

Nirex - Pocos de Caldas Modelling Study (NSS/R252) April 1991 pp 12-13
Verbatim Extract
(Emphasis and Summary added)

"*Comparison of the calculated uranium concentration with the field measurements shows quite good agreement in the oxidised region, where the calculated value falls well within the range of field values.*

However, in the reduced region, the predicted value is significantly lower than that observed. There are a number of possible reasons for this discrepancy. The base-case run assumed that the uranium concentration was controlled by a fully-crystalline uraninite[12] *phase.*

There is, however, evidence from the field measurements for the presence of pitchblende at the site [5]. Pitchblende is a term that is used to describe the dense botryoidal variety of uraninite that is commonly found in veined deposits. This naturally-occuring form is likely to be only ***partially crystalline****. Also, natural uraninite always shows a* ***higher degree of oxidation*** *than the stochiometric formula, usually in the range* $UO_{2.0}$ *to* $UO_{2.25}$ *17.*

To scope these effects, the calculation was repeated assuming amorphous UO_2 *as the solid phase in the reduced region, to represent the partial crystallinity. This calculation predicted a total uranium concentration in solution of* 5.3×10^{-3} *mg/l, which is now higher than the field measurement.*

To scope the effect of the partial oxidation of the uraninite solid, some aqueous speciation calculations were carried out with HARPHRQ, assuming U_3O_8*, as the stable solid. The predicted solubility in the reduced region was then about* 2×10^{-3} *mg/l, which falls within the range of field values.*

Both predictions are therefore more consistent with the field observations. Another possible explanation for the underestimate for the uranium concentration may be that some uranium was associated with ***colloidal material****, which has resulted in the measurement of enhanced uranium solubilities in the field measurements.*

Uranium (V) *species were omitted from these calculations. Further sensitivity tests were performed, including these species. The predicted solubility was increased, and is in agreement with that calculated in the modelling study of Lichtner18, who used a database in which U(V) species were included.*"

[12] Largely $UO_{2i)}$

Summary of the **Four** possible explanations

Thus, four possible explanations for discrepancy between predicted concentration and measured concentration:

i) not fully crystalline,
ii) non-stoichiometric
iii) colloids,
iv) Uranium (V)

The fact that there were four possible reasons why the nuclear industry calculation could have been out by a factor of eight orders of magnitude is indicative of the extremely variability of the parameters in question – and thus puts into question the whole scientific edifice on which the nuclear industry's 'Risk/Time' curves are based.

Clearly this has serious implications for the veracity of the 'Risk/Time' curves that are presently put forward – and thus for the entire basis of the 'Authorisation' process that the Environment Agency have put forward.

Radioactive Carbon and Deep Burial

Would it Escape Quickly as Methane Gas;
or
Would it get Chemically Lodged in the Cement Underground?

Implications of this
Chemical Research Question
for the Autumn 2008

'Site Selection Process'

for the Proposed Deep Burial Programme for Radioactive Wastes

It is extremely important that a cautious approach is taken to the long-erm management of Carbon-14 (the radioactive form of carbon) - in order that the number of people in the future who suffer ill health – or even death – though coming into contact with it, is minimised.

In November 2005 the Environment Agency wrote:

> "*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* **[ie becomes chemically lodged in the cement within the proposed burial facility]**."[13] (my emphasis)

In contrast - a February 2006 Nirex [14] Technical Note:[15]

> "*C-14: How we are addressing the issues*"

presents the possibility that the Carbon-14 instead being lodged in the cement is able to escape from the burial facility as methane gas (CH_4) - through travelling quickly upwards s through the fractures and pores in the overlying rocks – until finally reaching people at the surface.

If this were to be the case then the impact on risk then – according to Nirex [16]:

- the risk that an individual could die because they have become contaminated by the leakage of radioactive carbon from Radioactive Waste buried in their neighbourhood – could reach a figure as high as ***one in a thousand***.

  This is in contrast to the 'one in a million' target referred to in the EA Consultation document.

- furthermore Fig 1 (referred to above) indicates that this particularly high risk could occur just ***forty years*** after the burial facility had been closed up.

  Again this is in contrast to the expectation that the highest risk would not arise until one million years into the future.

The conclusion of the Nirex (Feb 2006) document is that:

> "*If, through further work, the calculated rates and quantities of carbon -14 containing methane generated were not to be significantly reduced, compared with those used in the scoping calculation presented here, it could be necessary to establish* ***siting criteria*** *that would ensure that significant*

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[13] Environment Agency 'Nuclear Waste Advisory Team' Review of Nirex Report: '*The Viability of a Phased Geological Repository Concept for the Long-term Management of the UK's Radioactive Waste*' EA Reference: NWAT/Nirex/05/003 (November 2005) (Version 3.1) page 10

[14] 'Nirex' was a Nuclear Industry 'Executive' set up in 1982 (under the Thatcher Adminstration) to to deal with the burial of nuclear waste. Twenty five years later in 2007 they were subsumed within the 'Nuclear Decommissioning Authority'. They had not established a disposal facility by this time.

[15] Technical Note No: Number: 498808

[16] Technical Note No: Number: 498808 [See p12 (Fig 1)]

gaseous release to the biosphere would be unlikely." (page 14) [Emphasis Added]

a) released quickly and intensively

(due to the fact that it has bonded chemically with four hydrogen atoms to form CH_4 - '*methane gas*')

or,

b) Locked into the Cement within the Facility (through' Carbonation')

A completely different picture would be predicted if – instead of bonding with hydrogen – the radioactive carbon became locked in to the structure of the cement which it is planned to use as 'back-fill' within the facility.

Cement has an extraordinarily complex structure and chemistry. This means that the establishment of whether or not 'carbonation' would take place (see Environment Agency quote above) is not a straight-forward matter.

As Nirex commented in February 2006 [17] the implications of these two very different possibilities for the behaviour of the carbon (either locking into cement – or being carried off as gas) mean that:

"it could be necessary to establish ***siting criteria*** *that would ensure that significant gaseous release to the biosphere would be unlikely".* (page 14*)*

Thus given that the early phases of site selection are currently underway (ie communities are presently considering whether to enter discussions towards accepting a facility) – it is imperative that such discussions are informed by reliable information on the possible risk implications.

This means that the current understanding with respect to whether radioactive carbon would escape quickly as a gas or, instead, be expected to be locked underground far in the future must be an intrinsic part of the '*site selection*' debate.

It is **absolutely essential** that the investment in the necessary scientific research and experimentation is not stymied due to taking place against a back-drop in which there is a strong political under-tow wishing to drive forward a programme of 'New-Build' for nuclear power stations. The risk being that – given that new reactors would also (of course) produce nuclear waste – there would necessarily be a political expediency in playing down the risks associated with current waste stocks.

This means that the Research Programme into the extent of carbonation must be:

i) given the necessary time to take its course

ii) not wholly reliant on the nuclear industry for its funding

[17] Nirex Technical Note "*C-14: How we are addressing the issues*"

iii) subject to 100 % availability for external scrutiny

Some Requirements for Ensuring Adequate Scrutiny

1) the Research Results should be freely and openly available,

2) the Research Reports should be provided in such a form that they makes sense to lay people

3) the Reports should set out clearly the Back-ground of topic under consideration:

- in particular what has led to the decision to undertake the work ,and also

- the contribution that the findings make to the development of an understanding of the issue at hand.

4) there should be an Executive Summary so that they key points can be garnered from the report without having to spend the time reading all the way through it.,

5) the Abstract and Executive Summary should not be disingenuous – but should authentically set out the actual report findings and the true nature of their implications, and finally,

6) references should be sufficiently comprehensive – and readily available.

4. The 'Methane Problem' and the Contradictory Implications for Geological Site Selection Criteria

On 12 June 2008 DEFRA published the '*Implementing Geological Disposal White Paper*'. This document calls on Communities to volunteer as potential neighbourhoods in which nuclear waste should be buried.

On page 63, the role of the British Geological Survey is set out – and at Appendix B (pp 73 to 75) the approach to geological criteria is set out.

This text shows no clear recognition of the need to resolve the contradictory site selections that arise as a result of the methane issue when compares to the hydrogen issue.

As discussed above – in February 2006 (and also in the earlier November 2005 'Viability' Report [18]) – Nirex identified the need to carry out more research on the potential for large risks arising due to the release of methane gas. It was concluded that if calculations indicated that methane looked as though it would be a problem, then there may be a need to adjust the site selection criteria.

Clearly, if methane were to be a problem, the 'site-selection' criteria – would need to be:

- **Would not** allow the escape of Gas

However, in contrast, the section within the 'Viability Report' which addresses the 'Gas Issue' starts off with the Statement:

> "*Post-closure performance assessments* [Risk/Time Predictions] *have consistently shown that* ***there would be no significant risk from over-pressurisation due to gas generation for a repository in a hard fractured host rock***" [19](Emphasis Added)

The issue here is that when the iron that is present in steel corrodes under '*anaerobic conditions*' ie – conditions in which oxygen is not present - then hydrogen gas is released. Oxygen gas comprises 20% of air; however, within bedrock, the gaps (fractures and pores) are filled with water, not air, and thus the conditions underground are essentially anaerobic – thus they are the conditions that would lead to the production of hydrogen.

In 1985/86 when Nirex carried out an initial review of their plans to bury nuclear waste they immediately realised how significant the 'hydrogen' issue was [20]and subsequent to that early work the requirement for a route for gas release has been central to calculations carried out on the 'viability' of disposal.

[18] Nirex 'Viability Report' November 2005 – Nirex Report N-122 (page 14)
[19] Nirex Report Number N/122 (November 2005) (page 55)
[20] Cooper MJ, Hodgkinson (ed) (1987). The Nirex Safety Assessment Research Programme: Annual Report for 1986/87. NSS/R101 Nirex. (page 113)

Thus, when the issue of hydrogen gas production is considered – the necessary site-selection criteria must be:

- **<u>Would</u>** allow the escape of Gas

Clearly, Nirex (now subsumed within the NDA), can't have it both ways – either the appropriate geology for the deep burial of nuclear waste would be one that would allow the release of gas – or it would be one that would not.

Until this issue of the appropriate geological site-selection criteria is resolved – it is difficult to see how the British Geological Survey can be in a position to carry out an initial (Stage 2) 'screening' – as is referred to on page 63 of the DEFRA White Paper [21](para 7.10).

On September 4th 2008 – in response to an information request concerning the 'current state of play' concerning the gas issue, the NDA referred to a PAMINA document on the issue. This is entitled: "*Uncertainties Associated with Modelling the Consequences of Gas*" and was written by Simon Norris from the NDA and published in March 2008. The Executive Summary of the document states:

> "*Studies such as this are therefore part of a staged approach to further develop understanding regarding the treatment of uncertainty for gas issues in the safety case, and to identify key aspects affecting the consequences of repository-derived gas to act as a focus both for further research activities*" (page (ii))

Specifically, concerning the Carbon-14 problem, the report concludes:

> "*The effect of the carbonation reaction in preventing Carbon-14 release is a topic requiring further investigation*" (page 6)

Given that the March 2008 report calls for more research on the gas issue it is clear that the underlying concerns are far from being resolved.

[21] http://www.defra.gov.uk/environment/radioactivity/mrws/pdf/white-paper-final.pdf