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THE DEVELOPMENT AND USE OF BROCHURES TO COMMUNICATE SAFETY ISSUES FOR A GEOLOGICAL DISPOSAL FACILITY FOR RADIOACTIVE WASTE

DELIVERABLE (D-N°: D2.1.B.3)

Author(s): **P.J. Hooker, P.J. Richardson and D.A. Galson (Galson Sciences Ltd)**

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Foreword

The work presented in this report was developed within the Integrated Project PAMINA: **P**erformance **A**ssessment **M**ethodologies **IN** **A**pplication to Guide the Development of the Safety Case. This project is part of the Sixth Framework Programme of the European Commission. It brings together 26 organisations from ten European countries and one EC Joint Research Centre in order to improve and harmonise methodologies and tools for demonstrating the safety of deep geological disposal of long-lived radioactive waste for different waste types, repository designs and geological environments. The results will be of interest to national waste management organisations, regulators and lay stakeholders.

The work is organised in four Research and Technology Development Components (RTDCs) and one additional component dealing with knowledge management and dissemination of knowledge:

- In RTDC 1 the aim is to evaluate the state of the art of methodologies and approaches needed for assessing the safety of deep geological disposal, on the basis of comprehensive review of international practice. This work includes the identification of any deficiencies in methods and tools.

- In RTDC 2 the aim is to establish a framework and methodology for the treatment of uncertainty during PA and safety case development. Guidance on, and examples of, good practice will be provided on the communication and treatment of different types of uncertainty, spatial variability, the development of probabilistic safety assessment tools, and techniques for sensitivity and uncertainty analysis.

- In RTDC 3 the aim is to develop methodologies and tools for integrated PA for various geological disposal concepts. This work includes the development of PA scenarios, of the PA approach to gas migration processes, of the PA approach to radionuclide source term modelling, and of safety and performance indicators.

- In RTDC 4 the aim is to conduct several benchmark exercises on specific processes, in which quantitative comparisons are made between approaches that rely on simplifying assumptions and models, and those that rely on complex models that take into account a more complete process conceptualization in space and time.

The work presented in this report was performed in the scope of RTDC 2.

All PAMINA reports can be downloaded from http://www.ip-pamina.eu.

D2.1.B.3
Version 1.0

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P.J. Hooker, P.J. Richardson and D.A. Galson

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Galson
SCIENCES LTD

5 Grosvenor House, Melton Road, Oakham, Rutland LE15 6AX, UK
Tel: +44 1572 770649   Fax: +44 1572 770650   www.galson-sciences.co.uk

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Report History

This document has been prepared under the PAMINA Project for the European Commission by Galson Sciences Limited, with partial support from the Nuclear Decommissioning Authority (NDA). This report is PAMINA Deliverable No. D2.1.B.3.

Version 1.0 responds to comments from Lucy Bailey of the NDA on Review Draft 1.0 Version 1.0 (dated 15 June 2009).

The Development and Use of Brochures to Communicate Safety Issues for a Geological Disposal Facility for Radioactive Waste				
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Executive Summary

This work has been undertaken within the context of the European Commission (EC)-sponsored Integrated Project PAMINA (***P***erformance ***A***ssessment ***M***ethodologies ***in*** ***A***pplication to Guide the Development of the Safety Case). Research and Technology Development Component 2 (RTDC2) is designed to develop a better understanding of the treatment of uncertainty in performance assessment and the safety case. Task 2.1.B under RTDC2 is evaluating approaches for communicating about confidence and uncertainties in a safety case for a geological disposal facility (GDF).

As part of Task 2.1.B, Galson Sciences Limited (GSL) and the Nuclear Decommissioning Authority (NDA) held a stakeholder workshop in Manchester in October 2007, designed to evaluate a variety of means for communicating about the safety of a GDF. As a follow-up activity, the project team developed a set of six illustrated brochures outlining a number of issues related to long-term safety of a GDF. These issues had been identified by workshop participants as important, and included the potential impacts of climate change, metal corrosion, future human disturbance, and radionuclide transport on safety, and the presentation of safety assessment results; an introductory brochure was also developed to set the context of a safety case and its uncertainties.

The brochures were circulated to a wide range of individuals, who were asked to read them and respond to a number of specific questions intended to determine whether the brochures had improved their understanding and helped to address any concerns. The individuals included participants from the stakeholder workshop, and others such as NDA library staff, GSL administrative staff and family members, plus other miscellaneous contacts. In addition, they were circulated to members of the EC COWAM in Practice (CIP) National Stakeholder Groups in Romania, Slovenia and Spain, and to a stakeholder group in northern France. Although the CIP national co-ordinators arranged for the brochures to be translated prior to circulation, responses were only received from Slovenia.

The responses received from Slovenia and from the UK are presented in a summary manner to capture the overall perceptions and views that people expressed about the brochures. Although the UK respondents were relatively few (16) and not representative of the general public, replies to the questionnaires did reveal some interesting results:

- Respondents who were already suspicious of the nuclear industry before seeing the brochures seemed to remain sceptical.
- The information seemed to give confidence in most of the respondents that it is possible to assess the long-term safety of a GDF despite uncertainties about the far future.
- Most respondents thought that the way that uncertainties are being handled was reasonable.

- Most respondents felt that the way the information was presented was helpful in aiding understanding.
- Greater store would need to be placed on the use of high-quality diagrams in the production of publicly orientated material.
- Using a bar chart to compare a regulatory dose target or calculated doses for a GDF to radiological impacts from different sources of naturally occurring radiation helped understanding for a lay person.
- Where natural analogue arguments and images have been used in the brochures, the comments were generally positive and complimentary.
- When calculated annual individual risks are presented as a function of time, the use of linear scales is preferable to using logarithmic scales.
- Presenting annual doses or risks attributable to specific radionuclides – whether over time, or as bar or pie charts at the time of peak impacts or at other times - did not help improve understanding for a lay audience.

These conclusions may be of help in projects involving communication with lay audiences that require presentations of safety assessment results for a GDF and explanation of how uncertainties are treated in the safety case.

It is recommended that future research focuses on development and evaluation of a single brochure that takes account of the findings of this study. The brochure could be evaluated by groups that were more representative of the general public, to determine if this means of communication could deliver a net positive effect in lifting public confidence.

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The Development and Use of Brochures to Communicate Safety Issues for a Geological Disposal Facility for Radioactive Waste

1 Introduction

1.1 Background and Aims

Development of a safety case for the management of long-lived radioactive waste involves consideration of the evolution of the waste and engineered barrier systems, and the interactions between these and relatively complex, natural systems, such as climate and geology, which are also evolving. The timescales that must be considered are much longer than the timescales that can be studied in the laboratory or during site characterisation. These, and other factors, give rise to various types of uncertainty, e.g., on scenarios, models, and parameters, which need to be taken into account when assessing long-term performance of a geological disposal facility (GDF). Owing to the range of different types of uncertainties, it is important to follow a clear strategy for dealing with uncertainties when developing a safety case.

The European Commission (EC)-sponsored Integrated Project PAMINA (***P***erformance ***A***ssessment ***M***ethodologies ***in A***pplication to Guide the Development of the Safety Case), which has 27 partner organisations and is running in the period 2006 to 2009, has the aim of improving and developing a common understanding of performance assessment methodologies for various disposal concepts for spent fuel and long-lived radioactive waste in different geological environments.

Galson Sciences Limited (GSL) is responsible for the co-ordination and integration of the Research and Technology Development Component "RTDC2" of the PAMINA Project. RTDC2 is designed to develop a better understanding of the treatment of uncertainty in performance assessment and the safety case. Task 2.1.B under RTDC2 is evaluating approaches for communicating about confidence and uncertainties in a safety case.

As part of Task 2.1.B, GSL, with assistance and support from the Nuclear Decommissioning Authority (NDA), organised a stakeholder workshop in Manchester in October 2007. At the workshop, a number of different media (video, posters, and presentations) were used to communicate various aspects of geological disposal and to gather information from the stakeholder participants about their concerns regarding the safety of a geological disposal facility (Hooker and Greulich-Smith, 2008). While communication of basic technical information was considered necessary, the workshop participants felt that key safety issues, uncertainties and knowledge gaps that become apparent when having to consider facility performance over hundreds of thousands of years should also be presented. Issues of particular interest included impacts of future climates, and the long-term performance of engineered components (canisters, backfill) and the surrounding geology. The potential for accidental access by an unknowing public in the far future was also highlighted.

As a follow-up to the workshop, a set of six illustrated brochures was developed to cover some of the concerns raised at the workshop and to explain how the inevitable uncertainties regarding long-term safety are being addressed by those involved in implementing geological disposal of radioactive waste.

A primary aim of this follow-up exercise was to test whether or not the information presented in the brochures on the uncertainties surrounding long-term safety of a geological disposal facility would result in a feeling of reassurance or confidence that the facility would be safe. In order to achieve this aim, the brochures were circulated to a wide range of individuals, who were asked to read them and respond to a number of specific questions set out in some questionnaires. The questions were intended to determine whether the brochures had improved understanding and helped to address concerns.

This report interprets the responses to the questionnaires and, on this basis, develops recommendations on ways in which the treatment of uncertainty in safety assessment might be communicated to the public in a more understandable and defensible fashion. In discussing questionnaire responses, we do not attribute specific responses to individual respondents.

1.2 The Participants

The ideal audience for this exercise was intended to be drawn from members of the general public. In order to focus on suitable candidates, GSL and NDA decided that it was also important to include participants from the Stakeholder Workshop held in Manchester in October 2007.

The brochures were also circulated to other individuals such as NDA library staff, GSL administrative staff and family members, plus other miscellaneous contacts. In addition, they were circulated to members of the COWAM in Practice (CIP) National Stakeholder Groups (NSGs) in Romania, Slovenia and Spain, and to a stakeholder group in northern France. CIP is another EC-sponsored project, and is focused on stakeholder involvement in decision making. The CIP national co-ordinators arranged for the brochures to be translated prior to circulation. However, only the Slovenian NSG made a response. The brochures were also sent to the secretariat of the Committee on Radioactive Waste Management (CoRWM) in the UK, for possible circulation among committee members, but unfortunately no responses were received.

To offer wider access, the brochures and questionnaires were also placed on the public area of the PAMINA website. However, no replies were received from the PAMINA website. The reason for this is not known, but it could be that the time perceived necessary to make the replies to the questionnaires was considered to be too long.

In the end, 25 individuals (9 in Slovenia and 16 in the UK) provided responses to the questionnaires. The list of respondents is presented in Table 1.1. It should be noted that the participants are few in number and are not representative of members of the public, either in the UK or in Slovenia. This point is discussed further in the report.

Table 1.1. List of respondents.

2007 PAMINA Workshop Participants	
John Lamb	Hunterston Site Stakeholder Group (Chair)
Peter Lanyon	Nuclear Submarine Forum and Shut Down Sizewell Campaign
Kenneth MacDougall	Hunterston Site Stakeholder Group and Ardrossan Community Council
Mark Woodger	Essex County Council (now Maldon District Council)
CIP NSG Members	
9 Slovenia members	Summary views were submitted to GSL, derived from the responses given by 9 members
CoRWM Members	
	No replies
NuLeAF *	
Catherine Draper	Assistant to the Executive Director
Miscellaneous Individuals	
Janet Hughes	GSL Administrative Manager
Jo Hewitt	NDA administrative staff
Stephanie Keenan	NDA administrative staff
Sam Galson	Family member of GSL staff
Caroline Hooker	Family member of GSL staff
Stephen Hodgson	Family member of GSL staff
Paul Bertenshaw	Agronomist and small business owner
Philip Henderson	Management information team leader
Katrina Turton	Office Manager
Sheila Neate	Housewife
Graham Neate	Retired civil engineer

* Nuclear Legacy Advisory Forum.

1.3 Structure of Report

The rest of this report is divided into the following sections:

- Section 2 describes the brochures and the questionnaires.
- Section 3 summarises the responses to the questionnaires. The views and comments are kept anonymous.
- Section 4 provides an evaluation of the responses.
- Section 5 presents the conclusions we have drawn from the responses and from this exercise in general.
- Section 6 lays out some suggested next steps and recommendations that could be usefully considered by a waste management organisation.
- Section 7 lists the references used in this report.
- Appendix A presents the brochures.

2 The Brochures and Questionnaires

The brochures and questionnaires were developed primarily by Phil Richardson, Paul Hooker, and Daniel Galson of GSL, but before the finalised material was circulated to potential respondents, the brochures and questionnaires were reviewed by Lucy Bailey and Michael Poole of the NDA (RWMD).

2.1 The Brochures

The brochures are presented in Appendix A. We tried to present the information in the brochures in an easily understandable form. It was decided to keep each brochure relatively short (about two pages), and to use non-technical language, as far as possible, so as to make the content accessible to a wide audience. However, a balance had to be struck between simplicity of language and a need to communicate proper technical meaning. An intelligent teenager was in mind as a potential reader when drafting the brochures.

Other assumptions were applied in drawing up the brochures, e.g., that most readers would have some idea that radioactive waste comes from the nuclear industry or bomb-making activities and that some of it is dangerous for a very long time. Brochures on topics describing the sources of radioactive waste and the different categories of the wastes were therefore not considered. A brochure on long-term waste management options as alternatives to geological disposal was also not considered, as geological disposal is internationally recognised as the best practicable environmental option for higher-activity wastes and has been selected for higher-activity wastes in the UK. The focus was rather on the need to describe the nature of uncertainties in the safety case. Nor did the brochures deal comprehensively with all of the uncertainties associated with the future. For example, possible terrorist attacks as a form of deliberate human intrusion were not considered in the brochures, and neither were the possible impacts of human error and earthquakes.

As explained, the brochures were developed to introduce the treatments of uncertainty in a safety case, with explanations of how knowledge of natural systems and expert judgement are used to assess the safety of a geological disposal facility. The six brochures developed were:

- Introductory Brochure: Safety of a Geological Disposal Facility for Radioactive Wastes.
- #1 Climate Change: Climate Change Impacts on the Safety of Geological Disposal of Radioactive Wastes.
- #2 Metal Corrosion: Metal Corrosion in a Geological Disposal Facility.
- #3 Human Disturbance: Human Disturbance of a Geological Disposal Facility.
- #4 Radionuclide Movement: Radionuclide Movement from a Geological Disposal Facility and its Consequences.

- #5 Assessment Results: Safety Assessment Modelling Results for a Geological Disposal Facility.

The Introductory Brochure describes the process of safety assessment and modelling, and places these activities in their overall context. This brochure also introduces the other five brochures and directs the reader to two questionnaires that were provided to allow comments to be made on the combined package and on individual brochures.

2.2 The Questionnaires

A major aim of the questionnaires was to find out how effective, in the eyes of the respondents, the brochures were in communicating about uncertainty and its treatment for building confidence in long-term safety issues. The questionnaires were made reasonably short, and were designed to elicit views on whether or not the brochures helped to support confidence in a safety case, and whether or not the brochures helped the reader to gain a better understanding of how we are coping with incomplete knowledge.

The questions were designed to explore a reader's reactions to the brochures, e.g., to discover whether the current ways of reporting safety assessment results can be understood by a lay public.

2.2.1 General Questions

There was a general questionnaire covering all of the brochures, and this is reproduced below:

General Questions on all Brochures

Taken together, have the brochures increased your confidence in, or provided you with additional reassurance about, the way that the safety of a geological disposal facility is assessed?

If no, are there any statements, facts or diagrams that caused you to feel less confident about the way our uncertainties about the future are addressed in the safety assessments? Please provide examples if you can.

If yes, are there any particular ways in which the information was presented that gave you a feeling of confidence about the way safety is assessed? Please clarify what these are.

In your view, which brochure contained the most appropriate level of detail? In other words, which brochure appeared to contain the right amount of information to enable you to gain a better understanding of the issue, without causing confusion or leaving you with gaps in your knowledge that you feel should have been addressed?

In your view, which brochure contained the least appropriate level of detail? This might be the brochure that contained in your view too much irrelevant or confusing detail, or the brochure that failed to answer the questions you have on that issue.

Have any of the brochures increased your level of understanding on a particular issue? If yes, which one(s)?

Do any of the brochures make you want to learn more about a particular issue? If yes, which one(s)?

Whilst all responses will remain anonymous, it would help us to analyse and interpret your answers if you could give us some indication of how old you are, your school/college qualifications, and type of job by filling in the table below. In addition, we would like to know the level of your prior knowledge of issues related radioactive waste disposal.

Age (years)	
Qualifications (please state your highest qualification, for example: PhD; arts or science degree; arts A-level; GCSEs; International Baccalaureate)	
Type of job, if employed Other occupation	
Prior knowledge (please state either ‘some’, ‘limited’, or ‘none’)	

2.2.2 Questions for Each Brochure

There was a questionnaire designed to cover each of the brochures, and this is reproduced below:

Questions for each brochure (please specify)

Does this brochure give you confidence that it is possible to assess the long-term safety of a geological disposal facility despite our uncertainties about the future regarding this particular issue?

If yes, what is it about the information we have included that gives you this confidence?

Do you feel that the way the uncertainties about the future regarding this issue are handled is reasonable?

If not, how do you think this should be handled?

Did you find the way the information was presented helpful in understanding the issue?

Is there other information you feel should be included?

Specific questions for Brochure #5 (Safety Assessment Modelling Results for a Geological Disposal Facility)

Is Figure 2 easier to understand than Figure 1?

Does the bar chart in Figure 3 help in your understanding?

Does the pie-chart representation of the calculated annual risks in Figure 4 help in your understanding?

Is it easier to view and understand calculated peak radiation *dose* shown in Figure 5 rather than the calculated peak *risks* in the other Figures?

Is there any particular way of presentation that gave you a feeling of confidence about the results? Please clarify what this is.

3 Questionnaire Responses

Some responses were supplied in formats different to those of the questionnaires, and because of this it would be problematic to present full details of all the comments made. Furthermore, it was considered that inclusion of all of the views in full detail would not add any extra value to the summary material presented in this section. We considered it important to present an overall appreciation of the responses in order to illustrate respondents' perceptions of the brochures. Therefore, rather than reproduce each individual response for each question asked, we have drawn together the main impressions that were expressed in answering each question.

Section 3.1 summarises the responses to the general questions, and Section 3.2 summarises the responses to the specific questions for each brochure.

As a methodological point, we checked our interpretation of the Slovenian results with Nadja Zeleznik, who compiled the Slovenian responses to the questionnaire, and she verified our interpretation.

3.1 Responses to the General Questions

A general point was made by one UK respondent, who thought that the phrasing of the questions conveyed the impression that the brochures were directed towards creating confidence (which they are, deliberately so, but in a way that we considered to be open and transparent). However, if a reader is already suspicious, this bias in the brochures would increase the feeling of suspicion. The respondent thought the questions should have been asking whether or not a reader felt more knowledgeable, rather than more confident, after reading a brochure.

For different reasons, three of the sixteen UK respondents felt strongly that none of the brochures was fit for purpose or appropriate. One thought the brochure format "*archaic*" and "*nonsense*" when more modern means of communication are available. A second thought that none of the brochures had been "*honestly composed. All showed bias and spin*". A third thought the brochures were inaccessible, being far too technical and academic. The third respondent felt that there was nothing in the brochures to address "*here and now*" concerns, and that the brochures were unlikely to offer concerned individuals in potential siting areas any comfort that things were all right and that there was nothing to worry about. On this last point, however, we need to stress that we were not trying to allay people's fears or address specific concerns; rather, we were aiming to see whether or not the ways of treating issues of uncertainty that surround the development of a safety case are giving rise to feelings of confidence.

Two UK respondents expressed the view that a single brochure was enough. One respondent thought the Introductory Brochure was sufficient, and the other felt that a single brochure organised into the separate topics with a summary of how all the issues interlink was preferable to having several brochures.

Each of the general questions is presented below with a summary of the responses and views received from the respondents.

3.1.1 General Question 1

Taken together, have the brochures increased your confidence in, or provided you with additional reassurance about, the way that the safety of a geological disposal facility is assessed?

The summarised responses from the CIP NSG in Slovenia gave 4 “No” replies and 5 “Yes” replies.

The sixteen UK respondents gave 5 “No” replies and 7 “Yes” replies, with 4 not answering the question.

A qualification remark sometimes accompanied a UK “Yes” reply. One person said “*the brochures gave a small increase in confidence – more generally a clarification*”. Another wrote “*Very impressed with the amount of research that has been carried out on all aspects of safe geological disposal*”.

One respondent was concerned about human error, a topic not addressed in the brochures.

3.1.2 General Question 2

Qualifications usually accompanied a “No” reply, as the next question was:

If no, are there any statements, facts or diagrams that caused you to feel less confident about the way our uncertainties about the future are addressed in the safety assessments? Please provide examples if you can.

The summary from the CIP NSG in Slovenia mentioned a general lack of trust that a GDF could be safe in the long term, particularly when the results of mathematical calculations and assessments evolve with time.

A UK respondent commented that the brochure format used assumed the reader had some technical knowledge, when the brochures should be aimed at a layman. Another respondent felt the brochures were inaccessible, with “*too much in all of them*”, and all of them “*written for a scientifically and risk mature audience*”.

A UK respondent wanted to know whether this process (the set of brochures) is for policy decision or reference only; the respondent felt that it should be made clearer to members of the public what they are reading.

Another UK respondent wanted more information on the nature and amounts of radioactive waste that require long-term management.

3.1.3 General Question 3

If yes, are there any particular ways in which the information was presented that gave you a feeling of confidence about the way safety is assessed? Please clarify what these are.

Two Slovenian respondents cited brochure #4 on radionuclide movement, but no particulars were given as to why the information in that brochure was reassuring.

A UK respondent commented that the series of brochures worked well, dealing with the safety concerns "*simply and clearly*", whilst another respondent thought the brochures were "*relatively accessible linguistically to the non-nuclear public*". One respondent perceived an "*openness*" with which the problems were covered.

One UK respondent thought that the concerns and scenarios listed had been supported and explained by scientific and historical evidence that showed how they could be dealt with and "*so make disposal safe*". Another thought that the use of analogy with archaeological artefacts, rather than relying wholly on theoretical models, "*should inspire confidence in the general public*". In a similar way, another UK respondent felt the "*charts comparing data to naturally occurring doses makes it easier to assess relative risks*" (see the diagram in brochure #4).

3.1.4 General Question 4

In your view, which brochure contained the most appropriate level of detail? In other words, which brochure appeared to contain the right amount of information to enable you to gain a better understanding of the issue, without causing confusion or leaving you with gaps in your knowledge that you feel should have been addressed?

In the Slovenian summary, three cited brochure #1, one cited brochure #3, two listed brochure #4, and two mentioned brochure #5. Two UK respondents thought the Introductory Brochure said it all in terms of the issues, one saying it presented an "*excellent overview*". Table 3.1 summarises the responses.

Table 3.1. Brochures containing the most appropriate level of detail.

Brochure	UK Responses	CIP NSG Slovenia Responses
Introductory Brochure	2	-
Brochure #1 Climate Change	1	3
Brochure #2 Metal Corrosion	3	-
Brochure #3 Human Disturbance	1	1
Brochure #4 Radionuclide Movement	3	2
Brochure #5 Assessment Results	-	2

3.1.5 General Question 5

In your view, which brochure contained the least appropriate level of detail? This might be the brochure that contained in your view too much irrelevant or confusing detail, or the brochure that failed to answer the questions you have on that issue.

In the Slovenian summary, three cited brochure #1, three cited brochure #3, and three mentioned brochure #5.

Half of the UK respondents who replied to this question mentioned brochure #5 on the safety assessment results (Table 3.2).

Table 3.2. Brochures containing the least appropriate level of detail.

Brochure	UK Responses	CIP NSG Slovenia Responses
Introductory Brochure	-	-
Brochure #1 Climate Change	1	3
Brochure #2 Metal Corrosion	1	-
Brochure #3 Human Disturbance	1	3
Brochure #4 Radionuclide Movement	2	-
Brochure #5 Assessment Results	5	3

3.1.6 General Question 6

Have any of the brochures increased your level of understanding on a particular issue? If yes, which one(s)?

All nine of the Slovenian respondents said “No”, a surprising summary given that four claimed to have little prior knowledge and five said they had no prior knowledge. In addition, five said the brochures had increased their confidence about the way the safety of a GDF is assessed (Section 3.1.1). Given the apparent internal inconsistency of the Slovenian responses, it is possible that something was lost in the translation of the question from English. Four of the UK respondents also replied “No”.

The positive replies from UK respondents are summarised in Table 3.3.

Table 3.3. Brochures increasing an understanding of issues.

Brochure	UK Responses
Introductory Brochure	-
Brochure #1 Climate Change	2
Brochure #2 Metal Corrosion	2
Brochure #3 Human Disturbance	3
Brochure #4 Radionuclide Movement	2
Brochure #5 Assessment Results	2

3.1.7 General Question 7

Do any of the brochures make you want to learn more about a particular issue? If yes, which one(s)?

There was no reply to this question in the summary response from the CIP NSG of Slovenia.

Five of the UK respondents replied "No", and seven did not make replies. Table 3.4 lists the brochures that four UK respondents felt had made them want to learn more about particular issues. Three of the four who replied positively to this question were women.

Brochures #2 and #4 caught the interest of one particular respondent because they featured explanations by analogy.

Table 3.4. Brochures making UK respondents want to learn more.

Brochure	Responses
Introductory Brochure	-
Brochure #1 Climate Change	1
Brochure #2 Metal Corrosion	1
Brochure #3 Human Disturbance	2
Brochure #4 Radionuclide Movement	1
Brochure #5 Assessment Results	-

3.2 Responses to the Specific Questions for Each Brochure

Each of the six brochures is treated separately, with each question marked in bold type with a summary of the responses set out beneath. It should be noted that some of the 16 UK respondents gave patchy or nil responses to some of the questions, and this is reflected in the different numbers of "Yes" and "No" replies reported below in Tables 3.5 – 3.26.

3.2.1 Introductory Brochure

Q1: Does this brochure give you confidence that it is possible to assess the long-term safety of a geological disposal facility despite our uncertainties about the future regarding this particular issue?

The replies are summarised in Table 3.5.

Table 3.5. Summary of the responses to Q1 for the Introductory Brochure.

	Yes	No
UK Respondents	7	3
CIP NSG Slovenia Respondents	5	4

Q2: If yes, what is it about the information we have included that gives you this confidence?

The Slovenian respondents thought that designing a GDF and depicting what it would look like gave them confidence.

It was reassuring to several of the UK respondents that a range of uncertainties and concerns of the public in relation to long-term safety were being taken seriously. One respondent thought that the Introductory Brochure "*gave a good understanding of the overall concept of a facility*". Another felt that the language was clear, concise and easy to understand (as in brochure #3), and of a standard not matched by brochures #2, #4 and #5.

Q3: Do you feel that the way the uncertainties about the future regarding this issue are handled is reasonable?

The replies are summarised in Table 3.6.

Table 3.6. Summary of the responses to Q3 for the Introductory Brochure.

	Yes	**No**
UK Respondents	5	3
CIP NSG Slovenia Respondents	7	2

A UK respondent asked why the safety case is not called a "*danger case*", as we are not able to assess all of the dangers, contrary to the message in the brochure.

Q4: If not, how do you think this should be handled?

The Slovenian view was that data, generally, were missing. The precise nature of the missing data was not explained.

The UK responses gave no coherent thoughts in answer to this question.

Q5: Did you find the way the information was presented helpful in understanding the issue?

The replies are summarised in Table 3.7.

Table 3.7. Summary of the responses to Q5 for the Introductory Brochure.

	Yes	**No**
UK Respondents	5	2
CIP NSG Slovenia Respondents	8	1

The statement in the brochure that 'Most people probably think that all that is ever proposed is to dump it in a hole in the ground and walk away' was considered by one UK respondent to be "*insulting to the intelligence of the general populace*". This respondent felt that walking away was not something considered likely, as the site would be managed on an ongoing basis, in some form or other. This same respondent pointed out that the adjective 'so-called' that was applied to the word 'scenarios' in the brochure should also be removed, as scenario is a common enough word.

Q6: Is there other information you feel should be included?

Five of the Slovenian responses thought "No", and one thought "Yes" (but the type of information was not described). Three respondents considered that the timescale, presumably of the assessment framework, must be defined.

One UK respondent asked: "*Why bentonite clay?*" This is with reference to the diagram on the first page of the brochure, a diagram that three other UK respondents also found inadequate. One of these respondents thought that the diagram was confusing, and did not understand the central cut-away, whilst another said the rock in the diagram "*looks unrealistically impermeable*".

A UK respondent wanted more facts about the wastes (what they are, their sources, and their dangers), the timescale and design life of the facility, and the nature of the facility.

3.2.2 Brochure #1 Climate Change

Q1: Does this brochure give you confidence that it is possible to assess the long-term safety of a geological disposal facility despite our uncertainties about the future regarding this particular issue?

The replies are summarised in Table 3.8.

Table 3.8. Summary of the responses to Q1 for Brochure #1.

	Yes	No
UK Respondents	8	2
CIP NSG Slovenia Respondents	7	2

One UK respondent thought the brochure "*gives a very bleak confidence in the survival of the human race*", never mind the survival of a facility.

Q2: If yes, what is it about the information we have included that gives you this confidence?

The Slovenian summary simply remarked: "*Our knowledge*".

One UK view was that the information is wide-ranging, and confirms a "*feeling that a deep facility would be far safer in the long term than surface storage. However, I am not certain that it is detailed enough to convert those who are set against geological disposal*". Another respondent thought the general concerns had been addressed, but access to greater detail may be necessary for those who need it.

Q3: Do you feel that the way the uncertainties about the future regarding this issue are handled is reasonable?

The replies are summarised in Table 3.9.

Table 3.9. Summary of the responses to Q3 for Brochure #1.

	Yes	No
UK Respondents	8	3
CIP NSG Slovenia Respondents	5	4

A strong view was made by one UK respondent that the brochure was too academic and technical. However, in contrast, another UK respondent thought the brochure "*would be a good introduction to the issues for complete lay people*."

One UK respondent was doubtful of the validity of the models used to describe climate change. Another took issue with the statement in the brochure 'It appears certain that climate change will continue to occur, irrespective of the amount of greenhouse gas emissions', saying that this is "*a wide sweeping statement which others would disagree with*."

Q4: If not, how do you think this should be handled?

The Slovenian summary noted that large climate change effects would be felt in 50 years as well as in a thousand years.

One UK respondent felt that the brochure should be about the short term and "*here and now*" concerns.

Another respondent wanted more modelling to address the uncertainties from climate change.

A view was expressed that the timings of climate change should be related to the "*design life*" of the facility.

Two respondents considered that the reference to the Swedish approach to handling climate change uncertainty adds to a feeling of confusion.

Q5: Did you find the way the information was presented helpful in understanding the issue?

The replies are summarised in Table 3.10.

Table 3.10. Summary of the responses to Q5 for Brochure #1.

	Yes	No
UK Respondents	8	2
CIP NSG Slovenia Respondents	5	4

The brochure figure was considered by some UK respondents as unhelpful.

Although answering "Yes", one UK respondent thought that there was a tendency to use long sentences in the brochure. Also, the same respondent commented that "*in the first section there is a reference to radionuclides which is not explained in this brochure, but is in brochure 4. It would aid clarity if the title of the third section was amended to 'The importance of climate change in…". In the final section, the use of passive words such as would and should introduces an element of doubt. The use of will and shall would inspire more confidence in the statements made*." However, another UK respondent asked "*perhaps the language used could be softer, move away from saying 'will' and use 'may' or 'could'?*"

Q6: Is there other information you feel should be included?

The summary from Slovenia suggested that details should be presented about climate change effects that are happening now.

One UK respondent wanted more visual images in the brochure, answers to some questions relating climate change impacts on the stability of the host rock mass, and information on the validity of climate change models.

Another UK respondent thought that "*A reference to a thorough geological survey of the site to ensure that it is physically capable of withstanding the effects of climate change would, I think, show that due consideration is being given to all aspects which could affect the GDF*."

A UK respondent commented that perhaps an assessment of the problems that would arise from climate change if wastes are stored at the surface could be included.

3.2.3 Brochure #2 Metal Corrosion

Q1: Does this brochure give you confidence that it is possible to assess the long-term safety of a geological disposal facility despite our uncertainties about the future regarding this particular issue?

The replies are summarised in Table 3.11.

Table 3.11. Summary of the responses to Q1 for Brochure #2.

	Yes	No
UK Respondents	8	3
CIP NSG Slovenia Respondents	7	2

Although replying with a "*Yes*", one UK respondent thought that the analogy with the Kronan cannon was weak, as the ship was only wrecked about 330 years ago.

One UK respondent who replied "*No*" said "*there's too much risk presented here, and an acceptance that the stuff is going to get out*".

It was clear from the remarks made by one UK respondent that time-lines of the processes described or referred to in the brochure need to be assigned in a clear manner.

Q2: If yes, what is it about the information we have included that gives you this confidence?

The Slovenian responses referred to the use of analogues, and one respondent made mention of multiple barriers for protection.

Most UK respondents thought the analogy with archaeological artefacts was helpful in giving confidence. The respondent who thought "*there's too much risk*" admitted to being able to relate to the durability of iron as evidenced by archaeological finds.

Q3: Do you feel that the way the uncertainties about the future regarding this issue are handled is reasonable?

The replies are summarised in Table 3.12.

Table 3.12. Summary of the responses to Q3 for Brochure #2.

	Yes	No
UK Respondents	8	3
CIP NSG Slovenia Respondents	6	3

One UK respondent offered the view that arguments by analogy "*appear ridiculous*" if you already have a suspicious mind. This person also argued that "*Most nails do not look like that and it should be made clear the circumstances of preservation were exceptional, so as not to appear biased*".

Q4: If not, how do you think this should be handled?

No responses on this were included in the summary from Slovenia.

A UK respondent wanted the brochure written in clearer language, with the second paragraph re-written and placed last, after the use of historical data, "*to show how slowly the metal could corrode*".

Q5: Did you find the way the information was presented helpful in understanding the issue?

The replies are summarised in Table 3.13.

Table 3.13. Summary of the responses to Q5 for Brochure #2.

	Yes	No
UK Respondents	8	3
CIP NSG Slovenia Respondents	8	1

A couple of the UK respondents wanted much less technical language and shorter sentences to be used in the brochure.

Q6: Is there other information you feel should be included?

One respondent in Slovenia said "*Yes*", but without any explanation.

Details of the metals, including their thicknesses, were asked for by one UK respondent.

3.2.4 Brochure #3 Human Disturbance

Q1: Does this brochure give you confidence that it is possible to assess the long-term safety of a geological disposal facility despite our uncertainties about the future regarding this particular issue?

The replies are summarised in Table 3.14.

Table 3.14. Summary of the responses to Q1 for Brochure #3.

	Yes	No
UK Respondents	8	3
CIP NSG Slovenia Respondents	2	7

Q2: If yes, what is it about the information we have included that gives you this confidence?

No clear response on this was included in the summary from Slovenia.

One UK reply said that all the things that might happen in human societies over thousands of years have been honestly addressed. Others also felt that all predictable scenarios have been considered, and locating a facility at depth and away from important resources was logical. It was reassuring to one participant that effort is being made to ensure future generations are aware of the purpose of the facility, and to another that risks of human disturbance are being minimised.

One respondent thought that the brochure was clear, concise and easy to understand.

Q3: Do you feel that the way the uncertainties about the future regarding this issue are handled is reasonable?

The replies are summarised in Table 3.15.

Table 3.15. Summary of the responses to Q3 for Brochure #3.

	Yes	No
UK Respondents	8	3
CIP NSG Slovenia Respondents	2	7

One UK respondent argued that the brochure statement that '*Going deep will protect a facility from most human activities*' was an unjustifiable assumption and not reassuring. The respondent asked "*How can we possibly guess now how deeply people will delve thousands of years hence*?" when we could not have guessed two hundred years ago that Man would walk on the Moon.

One UK respondent thought the reference to papyrus as a record tool "*almost risible*".

Q4: If not, how do you think this should be handled?

The summary response from Slovenia stated that the future is a mystery, especially for 1000 years, itself considered a long time.

One UK participant replied that the brochure was "*too academic*", whilst another suggested that we "*Can only endeavour to mark location of site as permanently as possible*."

Q5: Did you find the way the information was presented helpful in understanding the issue?

The replies are summarised in Table 3.16.

Table 3.16. Summary of the responses to Q5 for Brochure #3.

	Yes	No
UK Respondents	8	2
CIP NSG Slovenia Respondents	4	5

Two UK participants thought the diagram used in the brochure was facile and trite.

Q6: Is there other information you feel should be included?

No responses on this were present in the summary from Slovenia.

Three UK responses mentioned that terrorism should be covered, and one of these mentioned that "*a comparison could be made with material stored at the surface, which presumably would be much more vulnerable*" to theft by terrorists wishing to make a dirty bomb.

One participant wondered what effort is being made to take account of language shifts over the intervening centuries.

3.2.5 Brochure #4 Radionuclide Movement

Q1: Does this brochure give you confidence that it is possible to assess the long-term safety of a geological disposal facility despite our uncertainties about the future regarding this particular issue?

The replies are summarised in Table 3.17.

Table 3.17. Summary of the responses to Q1 for Brochure #4.

	Yes	No
UK Respondents	6 + 1 maybe	4
CIP NSG Slovenia Respondents	4	5

Q2: If yes, what is it about the information we have included that gives you this confidence?

Two of the respondents from Slovenia mentioned the "*picture*", presumably the one on the first page of brochure #4.

Three UK respondents mentioned that the argument by analogy was compelling and useful. Another thought the brochure "*indicates a good understanding of the factors involved and their possible effects*." One respondent said the table "*showing sources of radiation was very informative and reassuring*."

Q3: Do you feel that the way the uncertainties about the future regarding this issue are handled is reasonable?

The replies are summarised in Table 3.18.

Table 3.18. Summary of the responses to Q3 for Brochure #4.

	Yes	No
UK Respondents	7	4
CIP NSG Slovenia Respondents	8	1

Q4: If not, how do you think this should be handled?

One of the Slovenian respondents expressed the view that because of the huge timescale involved, "*we actually do not know what happens with waste*".

One UK respondent thought the "*smiley face to the sun*" in the diagram "*could be seen as a little patronising*". Another said that "*there needs to be some explanation about what radionuclides are, in layman's terms, is it liquid, gas, solid wastes etc.*" This same respondent thought the table should explain where Radon comes from, in the same way that we explain where the other sources of radiation originate.

Q5: Did you find the way the information was presented helpful in understanding the issue?

The replies are summarised in Table 3.19.

Table 3.19. Summary of the responses to Q5 for Brochure #4.

	Yes	No
UK Respondents	5 + 1 maybe	3
CIP NSG Slovenia Respondents	8	1

One respondent from the UK found the diagrammatic illustration unhelpful, whilst another found the table (bar chart) confusing. However, others liked the bar chart and the image of the fish. One UK respondent had not encountered the word ‘sorption’ before, and suggested that an alternative, more common term be used.

Q6: Is there other information you feel should be included?

One of the Slovenian respondents felt that information should be included on how we can prevent radionuclides from migrating, and what happens if they do migrate (the subject of brochure #5).

One UK respondent wanted to see more facts on potential doses (the subject of brochure #5). Another UK respondent wanted more information on how the release of radionuclides could affect the environment, whist another UK respondent thought that the first paragraph of brochure #5 (a summary of annual dose rates from released radionuclides) should have been presented in brochure #4.

3.2.6 Brochure #5 Assessment Results

Most respondents did not reply to these questions, Q1-Q6, but focused on the questions that were marked as being specific to brochure #5.

Q1: Does this brochure give you confidence that it is possible to assess the long-term safety of a geological disposal facility despite our uncertainties about the future regarding this particular issue?

This question was not reported on by the CIP NSG of Slovenia.

The UK replies that were received are summarised in Table 3.20.

Table 3.20. Summary of the UK responses to Q1 for Brochure #5.

	Yes	No
UK Respondents	3 + 1 maybe	2

The respondent who replied “*sort of*”, i.e. categorised as a ‘Yes maybe’, qualified their view by remarking that if the calculated risk to an individual is infinitesimal, then the detailed plots mainly serve to detract and potentially to confuse a lay person. What would be more effective is an answer to the question of "*how an escape of radionuclides (collectively perhaps rather than individually) would increase my risk compared to day to day life*."

One of the UK respondents had a viewpoint that the internationally recommended model of radiation risk is wrong, which in their view invalidated all of the results presented in the brochure.

Q2: If yes, what is it about the information we have included that gives you this confidence?

This question was not considered by the CIP NSG of Slovenia.

One UK respondent thought that "*the modelling undertaken seems to be comprehensive*". Another considered Figure 5 (the bar chart of doses) as giving confidence.

Q3: Do you feel that the way the uncertainties about the future regarding this issue are handled is reasonable?

This question was not reported on by the CIP NSG of Slovenia.

The UK replies are summarised in Table 3.21.

Table 3.21. Summary of the UK responses to Q3 for Brochure #5.

	Yes	No
UK Respondents	4	2

None of the UK respondents qualified their replies with comments worth noting.

Q4: If not, how do you think this should be handled?

This question was not reported on by the CIP NSG of Slovenia.

A UK respondent was "*completely befuddled by the presentation*", and wanted to see clarity and simplicity.

Q5: Did you find the way the information was presented helpful in understanding the issue?

This question was not reported on by the CIP NSG of Slovenia.

The UK replies are summarised in Table 3.22.

Table 3.22. Summary of the UK responses to Q5 for Brochure #5.

	Yes	No
UK Respondents	2 + 2 maybe	2

The UK respondents who indicated 'maybe' qualified their views through their answers to the specific questions on this brochure.

Q6: Is there other information you feel should be included?

This question was not reported on by the CIP NSG of Slovenia.

One UK respondent thought that without a paragraph explaining what the keys to the radionuclides meant in Figures 1 and 4, "*Joe Public will not have a clue about these symbols*."

The presentation of too much data was the criticism from at least two respondents.

Specific questions (SQ1-SQ5) for Brochure #5 Assessment Results

SQ1: Is Figure 2 easier to understand than Figure 1?

The replies are summarised in Table 3.23.

Table 3.23. Summary of the responses to SQ1 for Brochure #5.

	Yes	No
UK Respondents	9 + 3 maybe	1
CIP NSG Slovenia Respondents	3	6

The UK replies are overwhelmingly in favour of Figure 2 over Figure 1, but the Slovenian evaluation runs in the opposite direction.

SQ2: Does the bar chart in Figure 3 help in your understanding?

The replies are summarised in Table 3.24.

Table 3.24. Summary of the responses to SQ2 for Brochure #5.

	Yes	No
UK Respondents	4	9
CIP NSG Slovenia Respondents	8	-

The UK replies are mostly against the bar chart in Figure 3 being of help in understanding, whereas the Slovenian response indicates the opposite.

SQ3: Does the pie-chart representation of the calculated annual risks in Figure 4 help in your understanding?

The replies are summarised in Table 3.25.

Table 3.25. Summary of the responses to SQ3 for Brochure #5.

	Yes	**No**
UK Respondents	2 + 1 maybe	11
CIP NSG Slovenia Respondents	4	5

Although the Slovenian responses were only slightly against the use of the pie chart, the majority of the UK respondents felt that the pie chart did not help in their understanding. The respondent categorised as 'Yes maybe' wanted more explanation of the chart.

SQ4: Is it easier to view and understand calculated peak radiation *dose* shown in Figure 5 rather than the calculated peak *risks* in the other Figures?

The replies are summarised in Table 3.26.

Table 3.26. Summary of the responses to SQ4 for Brochure #5.

	Yes	**No**
UK Respondents	10 + 1 maybe	1
CIP NSG Slovenia Respondents	0	9

Again, there seems to be a contrary view from Slovenia compared to the majority UK view. Most UK respondents felt that the dose chart was easier to understand than the diagrams showing calculated risks. The reason for the diverging views between the Slovenian and UK respondents is not known, but it may be because of differences in understanding or interpretation of 'dose' and 'risk'.

Four UK respondents were uncomfortable with the inclusion in Figure 5 of the average background dose for Cornwall. Singling out a specific region with a background dose much higher than the UK average was felt to be a cause of unnecessary concern for people living in Cornwall.

SQ5: Is there any particular way of presentation that gave you a feeling of confidence about the results? Please clarify what this is.

This question was not considered by the CIP NSG of Slovenia.

Several UK respondents liked the simplicity of Figure 5, and some considered it gave a feeling of confidence by relating peak dose to other, every-day sources of radiation. One UK respondent pointed out that Figure 5 "*makes it clear that day to day risk is higher than peak dose*".

One person found "*linear scales easier to interpret*".

4 Evaluation of the Responses

The focus here is on evaluation of the UK responses rather than those from Slovenia. At times the responses from Slovenia ran counter to those from the UK respondents, perhaps a reflection of different cultural differences between the countries or differences in understanding or interpretation of the questions.

A major drawback to the evaluation of the responses is the lack of true representation of the general public by the 16 UK participants in this exercise. The UK responses were highly variable, ranging from hostile and dismissive to appreciative and constructive. Respondents who were already suspicious seemed to remain so, with the brochures apparently providing information that reinforced their sceptical views. Participants who commented on the brochures in a relatively constructive way seemed to be confident that scientists and experts were addressing uncertainties and concerns in an appropriate fashion.

When considering the responses to the general questions, the set of brochures seemed to have only a muted appeal in terms of raising feelings of confidence in the ways that uncertainties were being treated in the safety case. Some brochures (#2 and #4) were particularly considered to contain appropriate levels of detail, whereas brochure #5 was thought to contain the least appropriate level of detail.

However, when considering the responses to questions on each brochure, the information seemed to give confidence in most of the UK respondents that it is possible to assess the long-term safety of a GDF despite uncertainties about the future. Likewise, most UK respondents thought that the way that uncertainties are being handled is reasonable, and that the way the information was presented was helpful in understanding.

Some respondents would have liked shorter sentences in the text, with less technical jargon.

Feelings expressed about the diagrams used in the brochure were mixed, with some diagrams considered better than others in terms of informing the issues. The diagram in brochure #4 was well received, generally, whereas the diagram used in brochure #3 was derided by some as trivial. In addition, the diagram used to show a GDF in the Introductory Brochure was criticised by some respondents as being difficult to understand, while the image used in the climate change brochure #1 was regarded as being of little value in describing the issues.

The bar charts presented in brochure #4 and as Figure 5 in brochure #5 were a particular success in terms of presenting information on uncertainty in a simple and informative way. Comparing the regulatory dose target to different sources of radiation in the bar chart in brochure #4 seemed to work with most of the respondents, and the safety assessment results presented in the bar-chart format of Figure 5 was found helpful in understanding what the calculated peak dose actually meant to them.

The natural analogue arguments used in brochures #2 and #4 were commented on positively, in general. This finding provides support for using natural analogue information, backed up by simple images, in any communications on long-term safety that are intended for a lay audience.

Concerning the comments made on brochure #5, it is clear that safety assessment modelling results that are presented in a bar-chart format that allows easy comparison with other sources of radiation dose is a great help to understanding for a lay audience. This way of presenting results answers in a simple way the main question that a lay person might reasonably ask: "*How would an escape of radionuclides from a GDF increase the radiological impact on an individual member of the public compared to the radiological impacts received from normal activities*?"

If calculated annual individual risks are presented as a function of time, it is clear from the UK replies that the use of linear scales is preferable to using logarithmic scales. The use of annual dose curves over time for specific radionuclides seemed to be a confusing distraction that did not help, in general, the process of understanding the assessment results. Furthermore, the bar chart and pie chart (Figures 3 and 4) presented in brochure #5 did not appeal to most of the UK respondents as effective aids in understanding. Both of these charts refer to annual risks calculated for specific radionuclides. Such information seems to involve too much detail to help in understanding.

5 Conclusions

Overall, it seemed that respondents who were already suspicious of the nuclear industry before seeing the brochures remained sceptical. Participants who commented on the brochures positively seemed generally confident that scientists and experts were addressing uncertainties and concerns in an appropriate way.

Although only 16 people responded to the questionnaires in the UK and nine in Slovenia, some potentially useful findings have emerged from the evaluation, particularly of the UK responses:

- The information seemed to give confidence in most of the respondents that it is possible to assess the long-term safety of a GDF despite uncertainties about the far future.
- Most respondents thought that the way that uncertainties are being handled was reasonable.
- Most respondents felt that the way the information was presented was helpful in understanding.
- Greater store would need to be placed on the use of high-quality diagrams in the production of publicly orientated material.
- Using a bar chart to compare a regulatory dose target or calculated doses for a GDF to radiological impacts from different sources of naturally occurring radiation helped understanding for a lay person.
- Where natural analogue arguments and images have been used in the brochures, the comments were generally positive and complimentary.
- When calculated annual individual risks are presented as a function of time, the use of linear scales is preferable to using logarithmic scales.
- Presenting annual doses or risks attributable to specific radionuclides – whether over time, or as bar or pie charts at the time of peak impacts or at other times - did not help improve understanding for a lay audience.

These conclusions may be of help in projects involving communication with lay audiences that require presentations of safety assessment results for a GDF and explanation of how uncertainties are treated in the safety case.

6 Next Steps and Recommendations

Preconceptions on the issues surrounding radioactive waste disposal had probably helped to shape the various responses to the questions on the brochures. There may be a fault-line attitude that distinguishes, broadly, two camps: one side trusts the experts engaged on developing safety cases, whereas the other side does not. The brochures could either encourage a feeling of trust and, therefore, confidence in the process, or bolster feelings of mistrust. As a result of this apparent dichotomy in our relatively small sample, it would be interesting to conduct a larger-scale study of the attitudes and views of groups more representative of the general public. It is recommended that future research focuses on development and evaluation of a single brochure, to determine if this means of communication could deliver a net positive effect in lifting public confidence and, if not, why.

A first step would be to design and produce a brochure fit for evaluation by groups that represent the general public. The brochure would need to be four pages long in a folded A4-format, and would need to take account of the results from this exercise, e.g. by using simple bar charts to express safety assessment results and by presenting arguments by analogy. There would be a focus on using plain English with short sentences, avoidance of technical jargon, and as many coloured diagrams as possible. A second step would be to design a questionnaire, based, in part, on the ones used in this study. A third step would be to arrange for a number of public groups to comment on the brochure, in the UK and/or in other countries.

A question designed to discern the attitudes of respondents to scientists and experts would be important for understanding the context of other responses to the questionnaire. Equally important would be a question on whether or not respondents were in favour of a GDF (yes/no/unsure). Answers to the questionnaire could then be classified according to the pre-existing perceptions and attitudes of the respondents.

The benefits of these recommended next steps are:

- An improved understanding of the attitudes of ordinary people to the development of a safety case for a GDF.

- An improved understanding of the views of members of the general public to the treatment of uncertainties, which are inherent in all safety cases for geological disposal of waste.

Such an exercise would facilitate the continuing dialogue between a national waste management organisation and the general public on the matter of developing a safe geological disposal facility for higher-activity wastes.

7 References

Hooker, P.J. and Greulich-Smith, T. (2008). Report on the PAMINA Stakeholder Workshop: Communicating Safety Issues for a Geological Repository. PAMINA Deliverable N°: D2.1.B.1. Galson Sciences Report 0546_T2.1B-4, 9 January 2008.

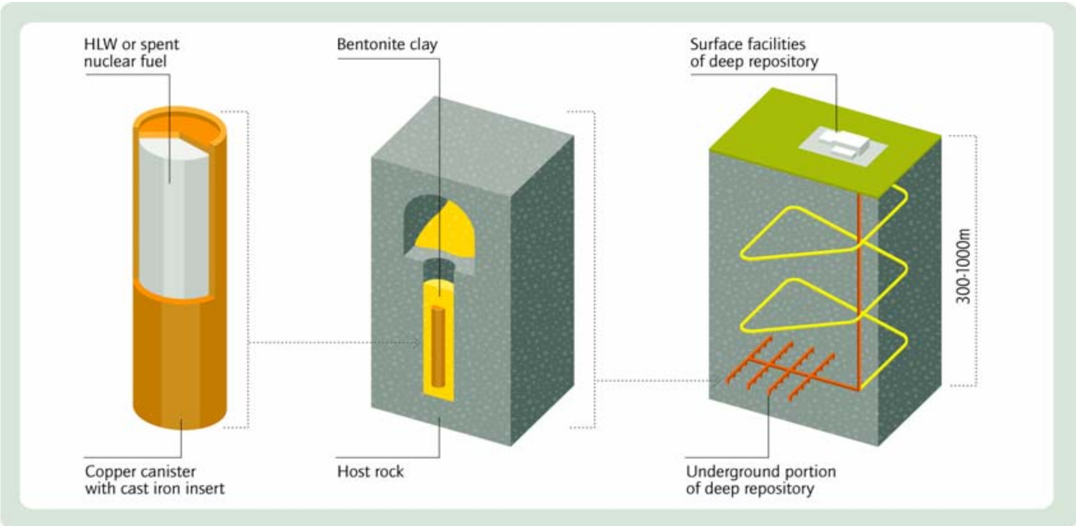
Appendix A: The Brochures

Introductory Brochure: Safety of a Geological Disposal Facility for Radioactive Wastes

A Geological Disposal Facility

What can we do with the most dangerous radioactive wastes (known as higher-activity wastes) that take many thousands of years to become safe by natural radioactive decay? Most people probably think that all that is ever proposed is to dump it in a hole in the ground and walk away, but the process of managing these wastes safely is actually highly controlled and regulated. All countries faced with the problem of managing higher-activity wastes agree that deep geological disposal offers the safest way of dealing with them, and have developed detailed designs for geological disposal facilities, often called repositories.

A typical geological disposal facility design relies on a series of physical barriers to protect people and the environment from the wastes. The barriers in the design shown in the schematic diagram below include a copper canister holding the waste package, bentonite clay to protect the canister, and the surrounding rock to protect the engineered barriers. The engineered barriers protect the wastes from any water in the rock and slow down any possible releases of radioactive elements (radionuclides), thus maximising the waste-containment period and the time for radioactive decay.



People's concerns

Surveys of public opinion have identified several worries about the safety of a geological disposal facility. Some of these concerns are:

- How safe is it? How much of the radioactive waste is likely to be returned to the surface, where people could build houses, and over what timescale?
- What happens if something goes wrong? What happens if metal containers corrode and fail more quickly than expected and radionuclides escape sooner rather than later?

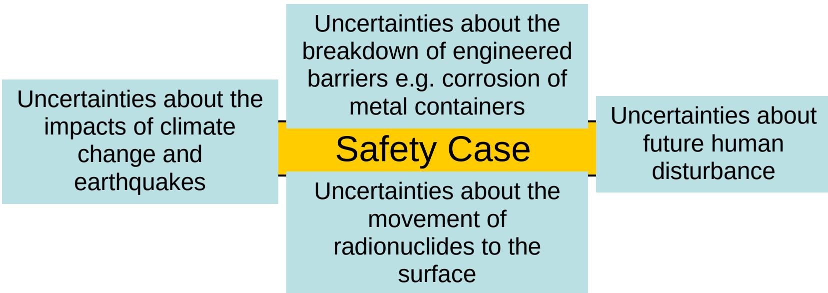
- What are the impacts of earthquakes, shifting tectonic plates, and rising sea levels from climate change?
- What happens if monitoring of a facility finds a problem? Can we go back and fix it? Without monitoring, the location of the facility might eventually be forgotten and future generations might drill or dig into it. What do we do about this possibility?

Managing concerns about safety

Public worries about safety are shared by those who design and regulate a geological disposal facility. In order to judge whether it is safe to dispose of radioactive wastes deep underground it is important to understand what the risks from doing this are. We can assess these by asking ourselves three key questions:

- What could happen to the wastes in the future?
- How likely is it that such things could happen?
- What would be the consequences to humans and the environment if they did?

The concerns are managed in a systematic way by considering all of the events and processes that could result in a release of radioactive material. The main uncertainties that affect a radiological safety case are shown here:



Different so-called ‘scenarios’ are identified to describe what, when and how all these things could happen. The scenarios are all uncertain, because of course we cannot predict exactly when earthquakes, climate change, or human disturbance might occur, or the rates of container corrosion and radionuclide migration. However, experts can anticipate what is most likely going to happen, and also how and when it might occur. Mathematical models are used to represent the geological disposal system and to simulate all the scenarios that could possibly affect it. Factors or parameters that describe the rates of breakdown of barriers and radionuclide movement are assigned values in the models. Uncertainties in these parameter values, e.g. those that can arise through experimental error, are managed by using ranges of expected parameter values in the models. By varying these parameter values, potential radiation doses and risks from the facility are calculated for comparison with the regulatory safety standards, an important way of indicating the future safety of the facility. Simplifications and assumptions in the models compensate for the uncertainty to ensure that the calculated doses and risks are over-estimates rather than under-estimates.

A set of brochures has been prepared on various issues, describing how some of the concerns and uncertainties are managed:

#1 Climate Change

#2 Metal Corrosion

#3 Human Disturbance

#4 Radionuclide Movement

We have also prepared a brochure (#5) illustrating how the results of a safety assessment are presented.

Two Questionnaires are provided to allow you to comment on both individual brochures and the combined package, to see if they have helped you understand how we cope with this lack of complete knowledge, and how we can communicate these messages better in the future.

We look forward to your comments!

#1 Climate Change Impacts on the Safety of Geological Disposal of Radioactive Wastes

Why is climate change important?

Climate change is an issue of concern that could have a bearing on the containment of radioactive wastes in a geological disposal facility. The following impacts from climate change need to be considered with respect to safety:

- Sea-level rise.
- Flooding of surface and underground facilities.
- Marine erosion at coastal sites.
- Future glaciation and erosion by ice.

The timings, magnitudes and rates of the impacts of climate change are uncertain, and they could lead to a number of changes, not least to the groundwater flow between a geological disposal facility and the surface. In theory, a change to the groundwater pattern could result in a faster return of radionuclides to the surface.

Current state of knowledge

Climate change is a natural phenomenon that has seen the Earth pass through a succession of glaciations and inter-glacial warm periods over the past million years. Climate change is therefore expected to continue to affect the Earth in the future. The last Ice Age ended about 12,000 years ago, and we are currently in a warm period before the next expected glaciation, although this may be enhanced and prolonged by the effects of global warming, a consequence of us burning coal, oil and natural gas, which results in the emission of carbon dioxide and other greenhouse gases into the atmosphere. Ultimately, however, natural cycles are expected to lead to global cooling and another Ice Age.

Current climate change models suggest that the ice sheets in Greenland (Figure 1) and West Antarctica will melt over the next few thousands of years due to global warming. Complete melting of the Greenland Ice Sheet alone could raise sea levels by about 7 m. The consequences could include flooding of low-lying land and increased coastal erosion. In addition, weather patterns could change to include a higher frequency of extreme events, for example rain storms with flash-flooding and storm surges with sea-flooding.

Importance in safety assessments of geological disposal of radioactive wastes

It appears certain that climate change will continue to occur, irrespective of the amount of greenhouse gas emissions, and will not only have global impacts, but impacts at regional and local scales. These impacts could affect the choice of site and design of a geological disposal facility, and its long-term performance. The radioactivity levels in the disposed wastes will decay with time, but could still pose potential radiation hazards after many thousands of years and numerous changes of climate.

Future climate change impacts are dealt with in some safety assessments by considering a range of climate futures to ensure that the calculated risks from possible radiation exposure are acceptably low. In contrast, a different approach is used in Sweden, where the Swedish Nuclear Fuel and Waste Management Company (SKB) has assumed that the evolution of future climate over the next 100,000 years can be based on a model reconstruction of the last Ice Age, which lasted from about 115,000 years to 12,000 years ago. This model suggests a return of global cooling about 20,000 years from now.

Potential for avoiding or reducing impacts from climate change

The most effective way to avoid or reduce potential impacts from both short-term and long-term climate change is to position a geological disposal facility at a depth that would isolate it from direct contact with the surface environment, making it largely immune from potential future effects of flood waters, marine erosion or erosion by ice sheets and glaciers. A deep facility should ensure that there will still be enough suitable overlying rock to isolate and contain the wastes for long-term protection, regardless of potential future landform and near-surface rock changes.

The process of selecting a suitable site for a geological disposal facility would also take into account potential risks from flooding, whether from sea-level rise or from flash-floods. The effects of possible marine erosion would be evaluated for coastal locations. Potential risks from water flooding into a deep facility can be much reduced by the installation of engineered seals in the access shafts and tunnels.

Figure 1. Ice-melt water on the surface of the Greenland Ice Sheet.

#2 Metal Corrosion in a Geological Disposal Facility

Metal waste containers in a geological disposal facility

All international designs of geological disposal facilities for radioactive wastes envisage the use of several physical barriers, which together provide long-term containment of the wastes. The first and potentially most important barrier is the waste container, which holds the waste package, enabling it to be transported and handled safely during temporary storage and subsequent emplacement in the disposal facility. Waste containers for high-level radioactive waste (HLW) and spent nuclear fuel are sealed, usually by welding, and are likely to be made of corrosion-resistant materials such as copper or steel. Metal containers are fabricated with walls that are thick enough to take account of any corrosion that could occur, and are constructed using best available techniques under strict quality controls. They are therefore expected to last for thousands of years, and provide containment for a sufficiently long period for much of the radioactivity in the wastes to have decayed to non-hazardous levels.

Liquid HLW is solidified into glass blocks inside a stainless steel container like that shown in this cutaway picture. The container is about 1.3 m tall.

Corrosion of metal containers in a safety assessment

The engineered barriers will gradually break down with time, allowing water to gain access to the waste. However, the surrounding rocks will continue to provide isolation and containment even when this happens. Whilst intact a metal waste container will prevent water from accessing the radioactive wastes. However, once the container has been breached by corrosion, the waste is pessimistically assumed in current models to be instantaneously saturated with water. This allows radionuclides to begin to move out of the disposal facility and back to the surface environment. This modelling approach is deliberately pessimistic so as to maximise the potential radiological consequences of metal container corrosion in the safety assessment, and to account for uncertainties in understanding of the actual saturation history.

Although we know that some of the metal waste containers will eventually break down as a result of corrosion, the actual rates at which this will take place are not known with certainty. Therefore, when assessing the impacts of corrosion on the long-term safety of a geological disposal facility, a range of possible corrosion rates is used in the mathematical models to calculate a set of possible future radiation doses and risks for comparison with the regulatory safety standards. The corrosion rates are derived from laboratory experiments and from measuring corrosion of archaeological artefacts of iron and copper.

What can we learn from nature and the past?

The durability of metal containers is known from laboratory tests, monitoring programmes, and from studying examples from nature and the past. We know from many natural examples that copper can survive as a metal in the ground for millions of years, depending on the geological environment. The conditions inside a geological disposal facility will be designed to minimise the presence of water and oxygen (both necessary for corrosion to take place) in order to protect the waste containers for as long as possible. Archaeological artefacts of copper materials have survived for thousands of years since the Bronze Age, which gives some confidence in the longevity of the copper containers that could be used in a geological disposal facility.

A copper cannon retrieved from the Kronan shipwreck in Sweden.

Despite being buried in clay sediments since the wreck of the Swedish ship, the Kronan, in the Baltic in A.D. 1676, the copper barrel of a cannon recovered in the early 1980s showed hardly any corrosion. The tiny corrosion rate of 0.15 micron or 0.00000015 m per year measured from the cannon would suggest that copper canisters used in a disposal facility could remain intact for tens of thousands of years, if they are protected by clay. A human hair has an average thickness of 80 microns.

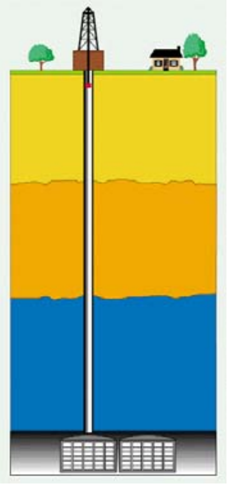
Although iron and steel rust in air, in the absence of oxygen they too can last for long periods. This can be seen from the iron nails buried by Roman soldiers in clay soil some 1,900 years ago at Inchtuthil in Scotland. Once a geological disposal facility has been sealed, there will be little or no oxygen left, and therefore, by analogy, steel waste containers will corrode very slowly.

This photograph shows a 30-cm long Roman nail from the central part of the Inchtuthil hoard. This demonstrates that iron – such as that used for waste containers – can maintain its integrity over long time-scales in an appropriate environment.

#3 Human Disturbance of a Geological Disposal Facility

Concerns over future human activities

The design of a geological disposal facility needs to protect against possible disturbance of the radioactive wastes by future human activities. Such a disturbance could be either deliberate or accidental. The diagram below indicates how a facility could, for example, be disturbed by drilling.



The main causes of possible human disturbance of a geological disposal facility would be exploration or exploitation of any natural resources present in the rocks surrounding the facility. This would not only include minerals for extraction, but also groundwater for abstraction and water supply. It is also possible that the materials present in the facility itself would be known about and some of them might be retrieved for re-use.

It is assumed in the case of deliberate disturbance that the people carrying out the necessary drilling or mining operations will know all about the location of the disposal facility and what is in it, and will therefore be technically capable of handling the radiation risks that would be associated with their work. It is also assumed that any radioactive waste material returned to the surface by drilling or mining activities will be treated in a way that will protect both the workers and the general public from radiation risks.

However, accidental disturbance by people at times perhaps far in the future when knowledge and records of the disposal facility might have been lost, presents a very different situation that needs to be carefully addressed in order to minimise the risks of unexpected exposures to radioactivity.

We also need to protect the quality of any groundwater in the vicinity of a facility so that if a well were to be sunk in the future to abstract water for drinking or irrigation by people with no knowledge of the presence of the disposal facility, any potential risks to human health and the environment from contamination of the water would not be significant.

Reducing the chances of accidental disturbance of a facility

There are several ways of reducing the likelihood of accidental disturbance of a geological disposal facility by future human activities. When deciding where to locate an underground facility, any natural resources in the rocks of the candidate sites will be identified and evaluated to see whether or not they could attract future exploration and exploitation activities that could result in disturbance of the facility. If coal, oil or gas deposits or exploitable groundwater are identified in the rocks of concern, the candidate site could be excluded from being considered further. Screening of the sub-surface in this way will greatly reduce the chances of accidental disturbance of a disposal facility.

Another way of minimising the likelihood of future human disturbance is to construct the disposal vaults or tunnels at such a depth that it removes the wastes from any near-surface activities. Going deep will protect a facility from most human activities.

In addition, ways are being developed of keeping records of where the geological disposal facility is located and what it contains. Creating durable records that can survive for many thousands of years is not as easy as it sounds. International research is considering suitable materials for holding such information. These materials include papyrus, which is paper made from reeds, and parchment made from animal skins. Archaeological examples of papyri, parchments and clay tablets have survived for thousands of years, a long time to keep reminding future generations about what is there beneath their feet, thus maximising the opportunity for a prolonged period of undisturbed radioactive decay of the wastes.

Finally, the placement of permanent markers at the surface above the underground facility is also being considered as a way of letting future generations know what is there. A marker would become an essential danger sign to warn people away if records are destroyed or lost in the future. One type of marker that has been suggested is a pyramidal structure of stone, similar to the Pyramids of Egypt, which have survived for over five thousand years. However, in attracting attention to what might be underground, a marker could lead to unwanted disturbance of a facility.

Modelling possible but unlikely exposure to radioactivity

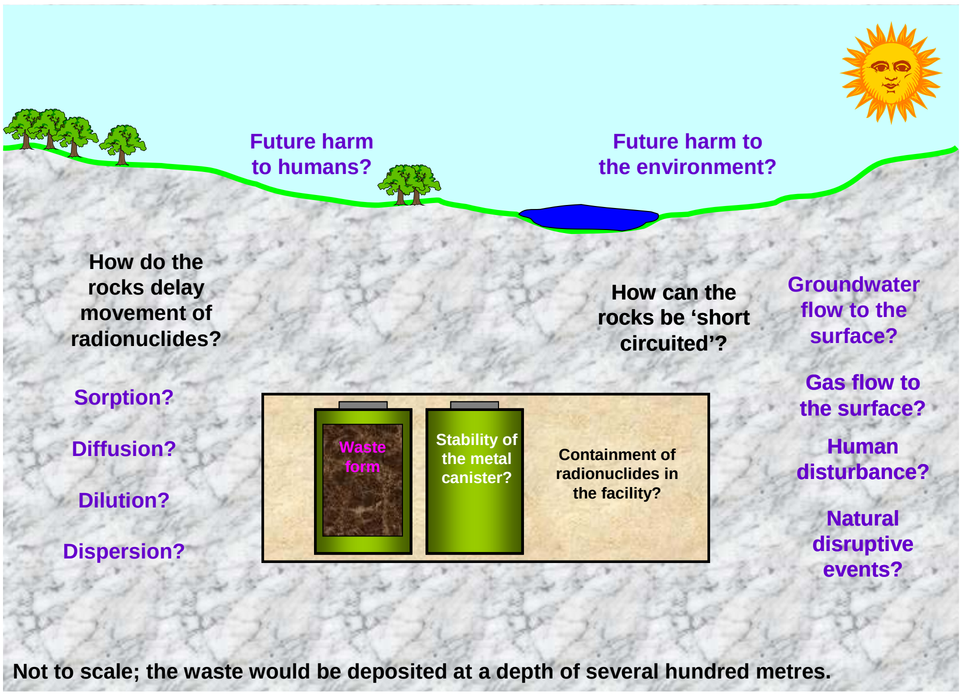
Modelling exposure to radioactivity in the unlikely event of human disturbance is carried out during the design stage of the facility in order to be sure that the radiological impacts are lower than the radiation safety standards or limits set by the regulator. To do this, expert judgement is used to identify ways in which the facility could be disturbed by future human activities, and the consequences assessed using a mathematical model. The assumptions used in the model cover the most significant exposure situations, and err on the side of caution so as to give over-estimates rather than under-estimates of dose.

In addition, a model is used to calculate radiation doses that might arise from a water supply well being unintentionally located near a facility and the water from the well becoming contaminated with radioactivity. Although screening of the sub-surface of candidate sites will take account of areas of exploitable groundwater, the modelling results are compared to radiation safety standards to be sure about the long-term safety of the facility.

#4 Radionuclide Movement from a Geological Disposal Facility and its Consequences

Modelling radionuclide migration

The design of a geological disposal facility needs to minimise the chances of water contacting the wastes and carrying radioactive elements (radionuclides) back to where people and the environment might be affected. The diagram below shows the events and processes that could lead to the movement of radionuclides back to the surface. Transport of released radionuclides could be delayed in the rocks by processes such as dilution, dispersion (spreading out over large distances) and sorption (becoming attached to minerals in the rock). The uncertainties associated with these events and processes, as shown below, are represented in the models used to assess the performance of a facility.

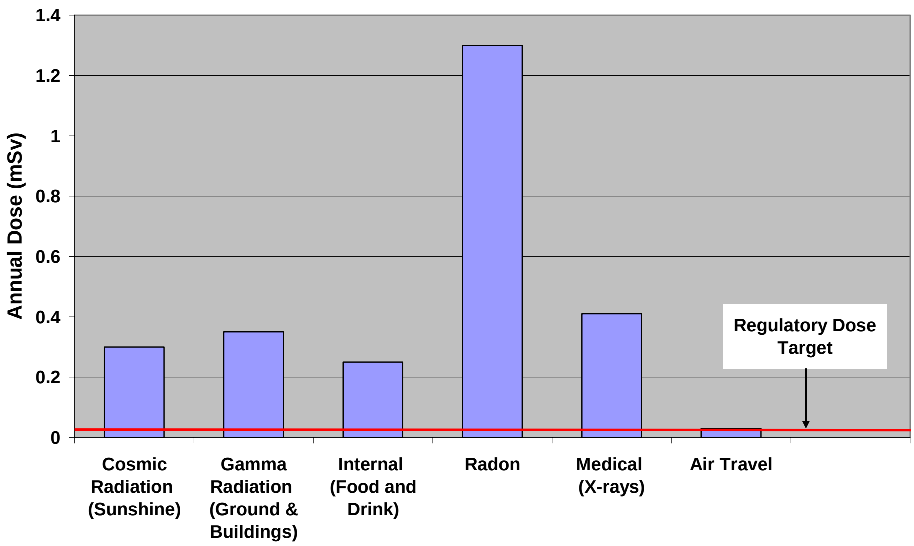


All of the different ways in which radionuclides could escape from a disposal facility and the different routes they could follow to be harmful to people or the environment, including transport in water or as a gas, are represented in a mathematical model, which describes how a facility is expected to change over time. A standard way of doing this is to consider what is most likely to happen, a so-called 'base-case scenario', in which there is a gradual breakdown of the barriers with an expected release of radionuclides in the future. Also considered are 'variant scenarios', in which less likely things might occur. The variant scenarios imagine conditions that could result in a faster release of radionuclides to the environment, thus making a facility less safe than expected. Modelling variant scenarios in this way ensures that we cover all our concerns about a facility.

For each of the factors that could affect how quickly radionuclides might reach the surface, for example the speed at which contaminated water moves through the surrounding rocks, a range of possible values is used in the model. Typically this range is based on measured values, as well as the judgement of independent experts, and takes into account available information and the suitability of any measurements.

Assessing safety - calculating radiation doses

The consequences of radionuclide migration in terms of safety are assessed by calculating possible radiation doses to hypothetical individuals living in the far future who are likely to be most exposed due to their lifestyles and where they live. These calculated doses are compared to regulatory safety standards, which are deliberately set very low. The diagram below compares the UK regulatory safety standard to the doses received annually by a typical resident of the UK from other sources of radiation.



Building confidence in the safety of the facility after closure

Another way of building confidence in long-term safety is by using arguments based on analogy. For example, we cannot test the long-term durability of the glass used to solidify high-level radioactive waste (HLW) under the expected conditions in a disposal facility as it would take hundreds or thousands of years to see any effects. Instead we can look at examples of ancient glass artefacts and natural volcanic glass, which show us by their very existence that glass is stable and extremely slow to change or dissolve over long timescales. By analogy, therefore, we can say that the glass used for HLW is likely to last for a long time, especially if other features of the facility prevent any water accessing the glass.

Photograph of a small Egyptian glass fish (3,300-3,400 years old), which has been perfectly preserved, even in the surface environment. This demonstrates that glass – such as that used to solidify HLW – can be stable over long timescales.

#5 Safety Assessment Modelling Results for a Geological Disposal Facility

The results of calculating potential radiological impacts of the extremely small quantities of radionuclides that might escape from a geological disposal facility after it has been closed are compared to regulatory safety standards, which are set well below the radiation exposure levels we receive every year in our daily lives from normal sources of radiation. Most of the average annual radiation dose in the UK is received from natural sources, with medical X-rays and air travel contributing only small proportions. The average annual UK dose is approximately 0.0026 Sieverts per year (or 2.6 mSv/yr), and this can be translated into a radiation risk of roughly one fatal cancer or serious hereditary defect in 10,000 people per year. The current regulatory risk target is about one hundred times smaller than this, and is set at one death in a million per year, equivalent to 0.020 mSv/yr.

Computer calculations of annual individual risk over time since closure of a disposal facility are carried out to help improve the final design of a facility and to ensure that the safety case complies with the regulatory risk target of one in a million or 0.000001 per year. The results of calculating annual radiation risks for an individual are usually presented to the regulators in the form of Figure 1.

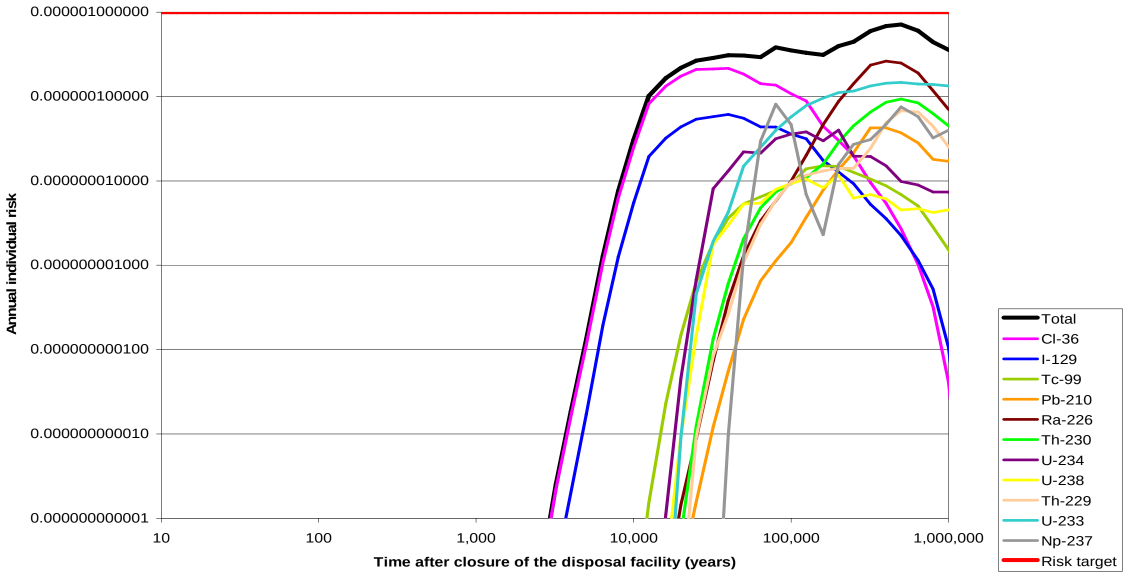


Figure 1. An exemplar of a presentation of safety assessment results to a regulator, using logarithmic scales.

The calculated total annual risk reaches a maximum value typically many thousands of years after closure of a disposal facility, in this case after about 500,000 years (Figure 1). Even then, the maximum or peak total annual individual risk (black line) is below the regulatory risk target. The black line would typically be the mean or expected risk curve for the so-called base-case scenario, which represents the anticipated changes to a disposal system. The annual risks from particular long-lived radionuclides are shown in different colours in Figure 1.

Different scenarios will give different peak total annual risks. Factors that affect how quickly radionuclides could reach the surface, for example the thickness of a metal container, can be varied in the model to produce another set of risk curves with different peak total annual risks. Comparison with the peak total annual risk in the base-case scenario can indicate how sensitive the safety assessment is to such factors. This information might be used to optimise the design of the metal containers and other engineered barriers.

The classical way of presenting the results of risk calculations can be difficult to follow. This begs the question: What is the best way to present the results so they make sense?

Figure 1 relies on logarithmic scales for the axes, whereas linear scales are used in Figure 2. Is Figure 2 easier to understand than Figure 1?

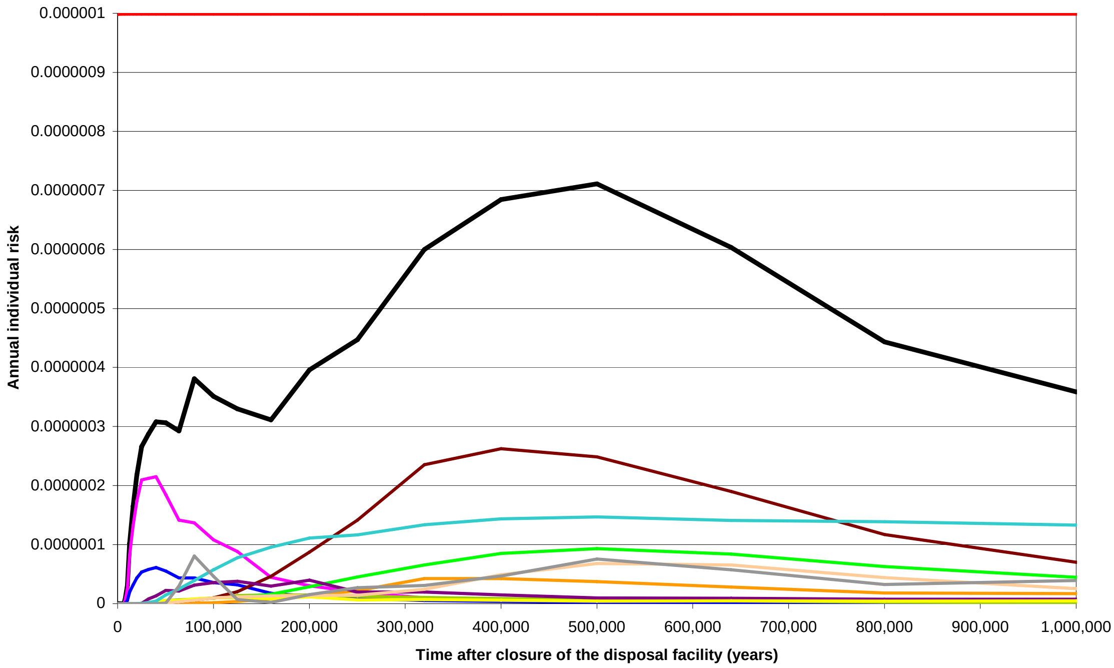


Figure 2. Another way of presenting safety assessment results using linear scales.

Does the bar chart below (Figure 3) help in understanding? In this diagram, the peak total annual individual risk is presented as a black bar on the left-hand side, again, well below the regulatory risk target (the uppermost red line).

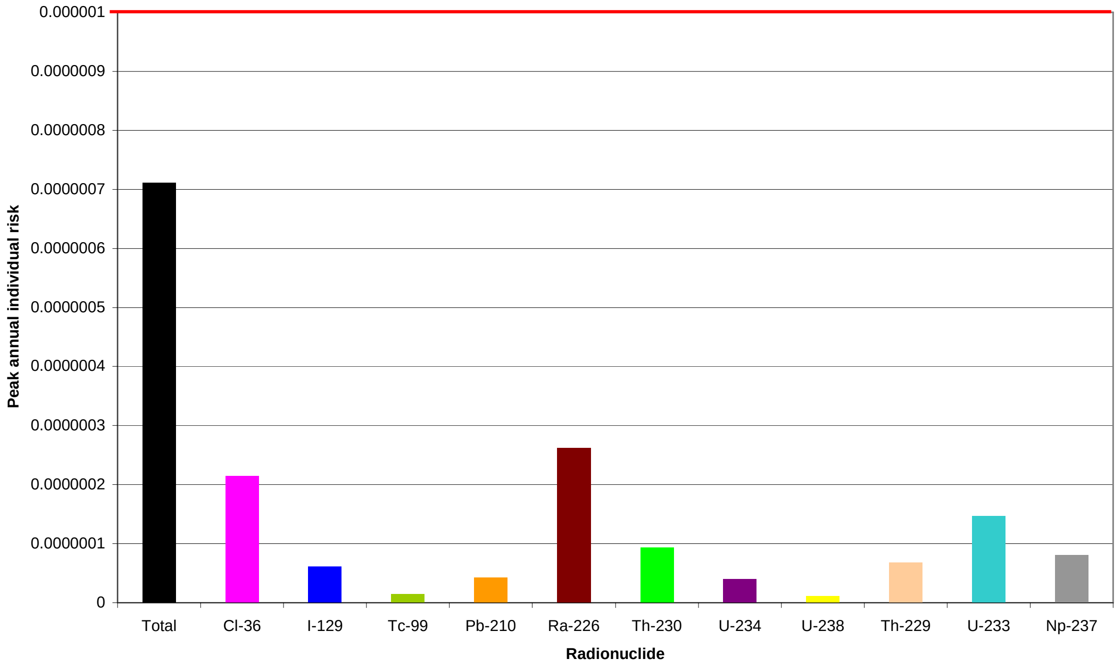


Figure 3. Peak annual individual risks from safety assessment calculations.

Also shown in Figure 3 are the peak risks from a range of particular radionuclides in the waste. Varying a parameter value in the model, for example one that describes how well Th-230 sticks to minerals in the rock, will change the migration rate of that radionuclide and the resultant peak dose in the model. This so-called 'sensitivity analysis' is useful for understanding the potential risks associated with the uncertainties about the actual future behaviour of a released radionuclide.

The peak doses from individual radionuclides may not actually coincide with the total peak risk, as can be seen in Figure 2. To account for this, Figure 4 presents the calculated annual individual risks at a point in time (100,000 years) after closure of a disposal facility, with contributions from each radionuclide of concern shown in the pie chart. The total annual risk of 0.00000035 is below the regulatory risk target of 0.000001 per year. Does this pie-chart representation of the calculated annual risks help in understanding?

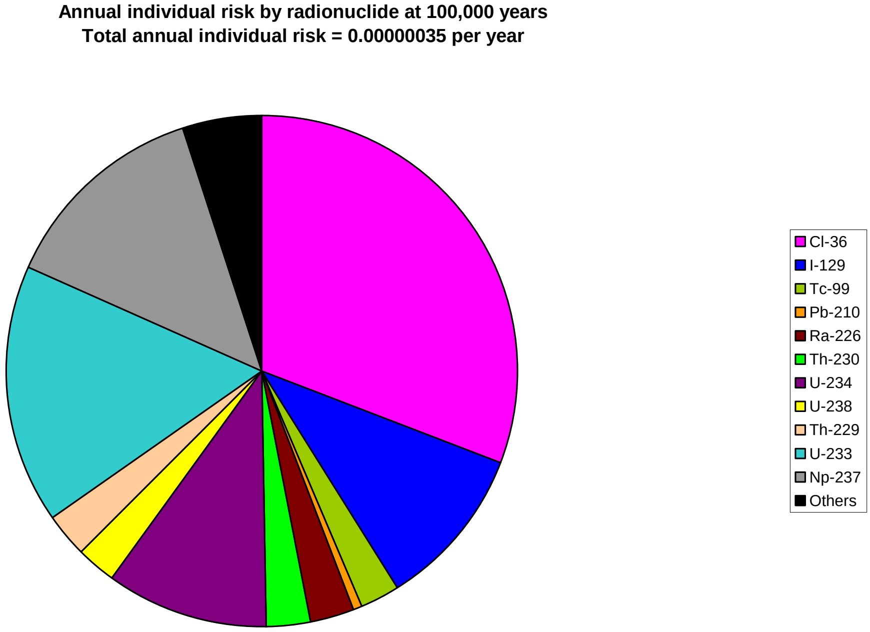


Figure 4. Annual individual risks from each radionuclide of concern at 100,000 years after closure of the disposal facility.

Is it easier to view and understand calculated peak radiation dose rather than calculated peak risks? For example, in Figure 5 below a typical calculated peak annual dose from potentially released radionuclides is compared to the regulatory dose target (0.020 mSv/yr) and to the average background annual doses for the UK and Cornwall.

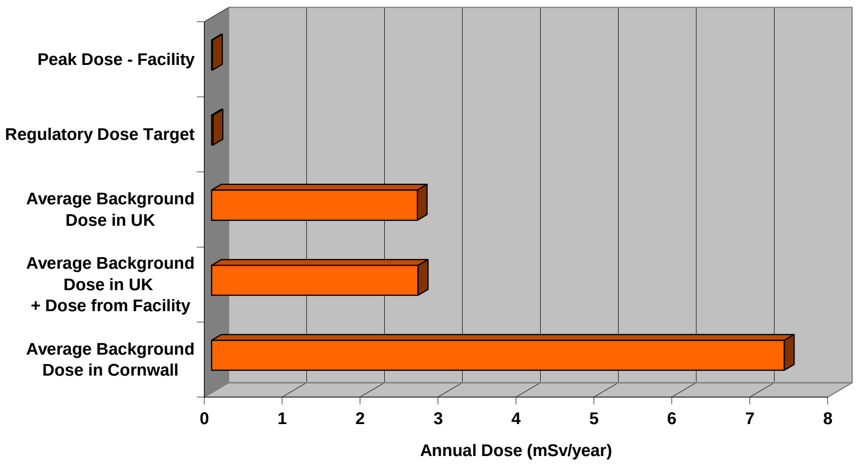


Figure 5. Peak annual dose from a disposal facility compared to the regulatory dose target and the average background annual doses in the UK and Cornwall.