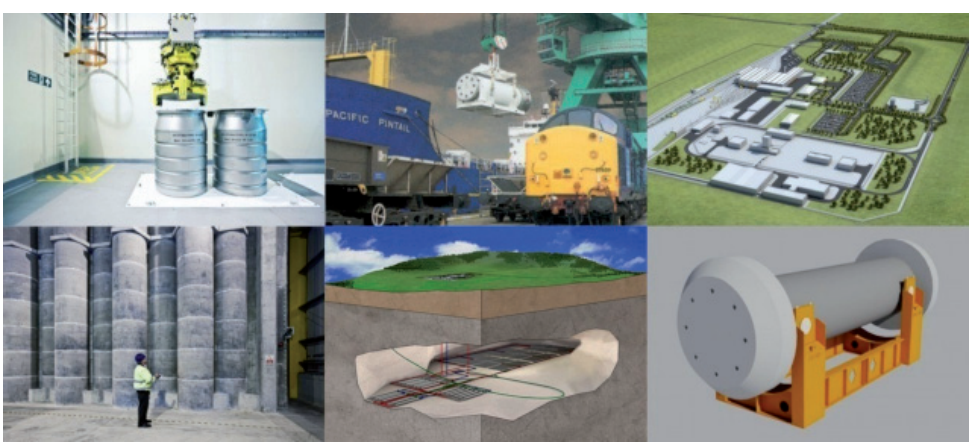
Nuclear
Decommissioning
Authority

Geological Disposal

An introduction to the generic Disposal System Safety Case

December 2010



1. Introduction

Geological disposal of higher activity radioactive waste involves constructing an engineered facility, typically between 200 and 1,000 metres underground to isolate the wastes from the environment and ensure the radioactivity is sufficiently contained so that it will not be released back to the surface in unacceptable amounts that may cause harm to people and living things.

We, the Nuclear Decommissioning Authority (NDA), have been charged with implementing the UK Government's policy for the long-term management of higher activity radioactive waste by planning, building and operating a geological disposal facility (GDF).

Before that can take place, the UK Government is leading a site selection process based on voluntarism and partnership with local communities interested in hosting such a facility, as set out in the Managing Radioactive Waste Safely (MRWS) White Paper June 2008.

Meanwhile our Radioactive Waste Management Directorate (RWMD) is in the early stages of planning for implementation. We will have to satisfy the independent regulators of the safety and security of all aspects in the development of a geological disposal facility before they issue the appropriate licences. This includes safety during construction, operation and in the long term after the facility has been closed.

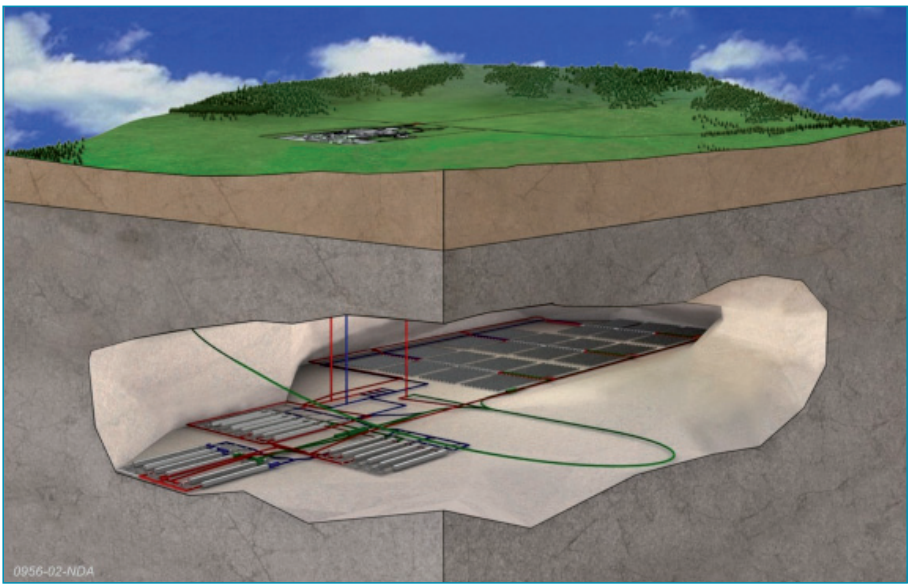
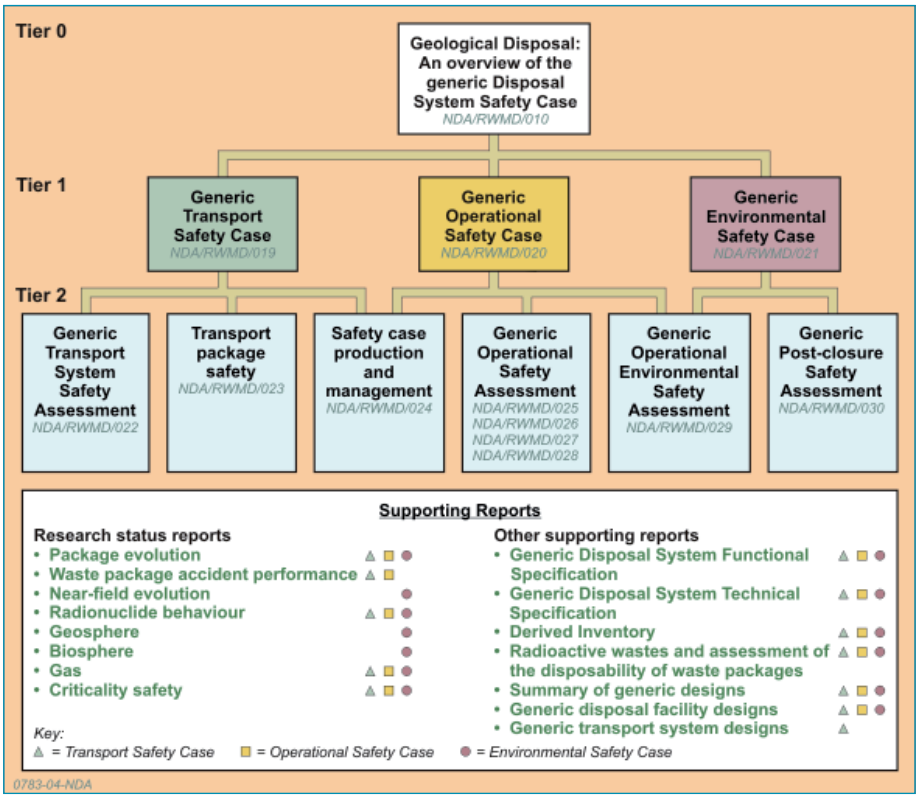


 Illustration of a geological disposal facility

The regulators' licensing process for a GDF will include their close examination of detailed safety cases produced by us covering all aspects of the disposal system. It will not be possible to produce a full safety case until we have a site and detailed design for a GDF.

At this stage our safety case is based on our understanding of the scientific and engineering principles supporting geological disposal and as it is not specific to a site or geology, we call it a "generic" safety case.

We have developed an overview report which leads a suite of more detailed documents that together form our generic Disposal System Safety Case. The other main reports are the generic Operational Safety Case, generic Transport Safety Case and the generic Environmental Safety Case. These reports are supported by research status reports and other scientific and technical reports. (See Section 6 for more details.)



Set of Generic Disposal Systems Safety Case documents

2. What are the wastes for disposal?

Low level waste

Intermediate level waste

High level waste

There are different categories of radioactive waste in the UK. They have different characteristics and need to be managed and disposed of in different ways.

- **Low level waste (LLW)**

This includes clothing, plastic, paper and metal that have become contaminated during maintenance and monitoring of nuclear operations at nuclear power plants and research facilities including hospitals and universities. The majority of LLW is disposed of at the Low Level Waste Repository near the village of Drigg in West Cumbria. Some very low level waste can be disposed of in ordinary landfill sites. However some long-lived LLW will need to go to a GDF.

- **Intermediate level waste (ILW)**

Intermediate level waste (ILW) arises from the reprocessing of spent fuel and from the operation and maintenance and decommissioning of nuclear facilities including power stations. The waste is packaged and stored on site pending a disposal facility being available.

Packaged ILW is divided into two groups based on how it can be handled in a store or disposal facility. Some of the waste packages emit sufficiently low levels of radiation that they can be handled using standard industrial warehousing methods. The remainder is too radioactive for this and needs to be handled remotely with machinery operators shielded from the waste packages.

- **High level waste (HLW)**

High level waste (HLW) arises from spent fuel reprocessing. Liquid HLW is mixed with molten glass and poured into steel containers and is then cooled and stored pending disposal. It is intensely radioactive for several hundred years and produces significant levels of heat as it undergoes radioactive decay.

- **Other radioactive materials**

Spent fuel, uranium and plutonium are not currently considered wastes and are stored pending a Government decision on whether they should be declared waste for disposal.

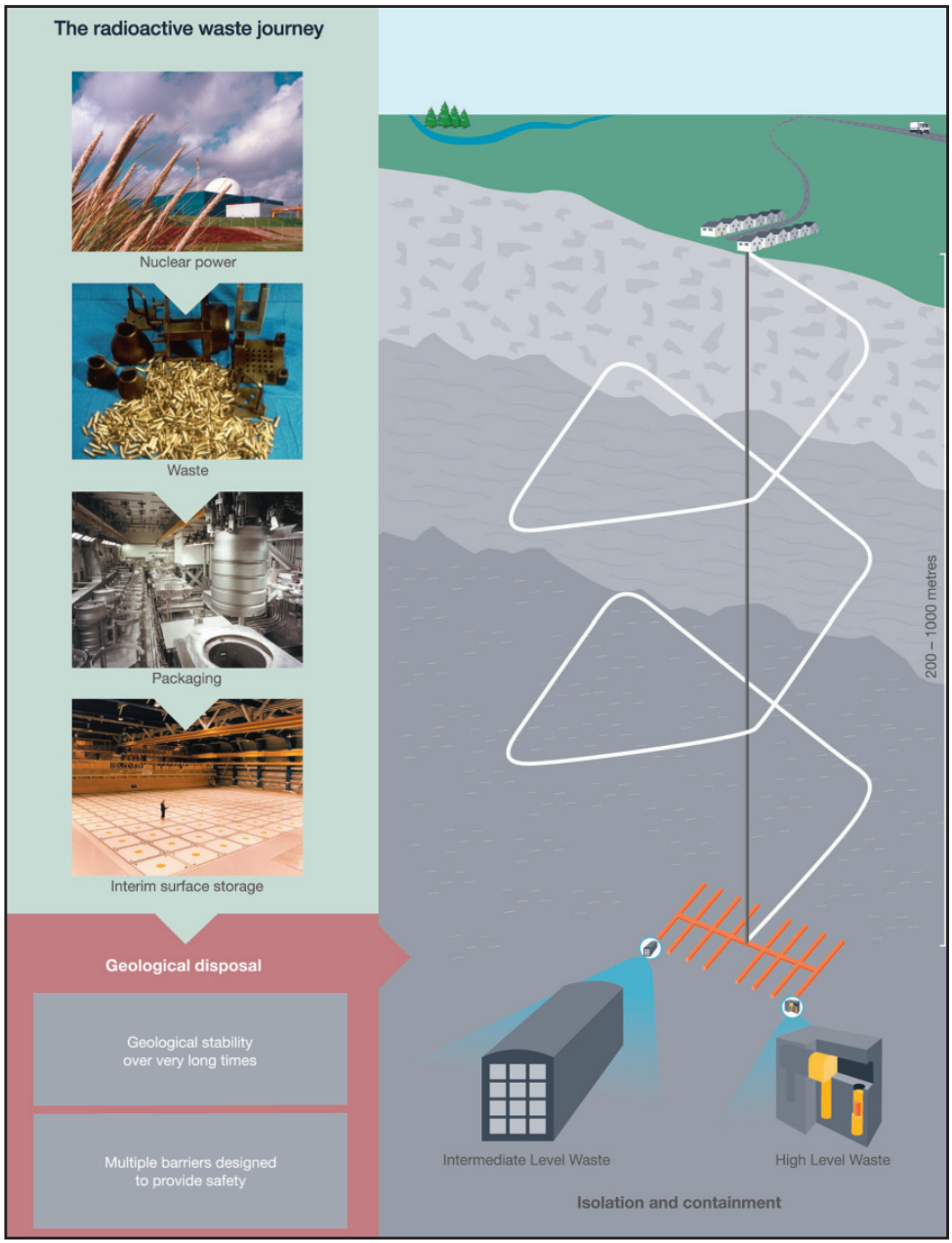
- **How much waste is there?**

The MRWS White Paper includes a baseline inventory of wastes for disposal in a GDF. Of the total of almost 480,000 cubic metres, by volume 76.3% is ILW; 3.6% LLW; 0.3% HLW and, if they are declared waste, the other materials would make up the remaining 20% of the total. The levels of radioactivity in these materials varies greatly with ILW representing only 2.5%, the remaining LLW and uranium a tiny fraction of 1%, whereas HLW represents over 40% and the other materials over 55% of the total radioactivity.

Waste from any new nuclear power stations would be in addition to this and for our safety assessment reports we have considered these wastes as part of what we term an "Upper Inventory".

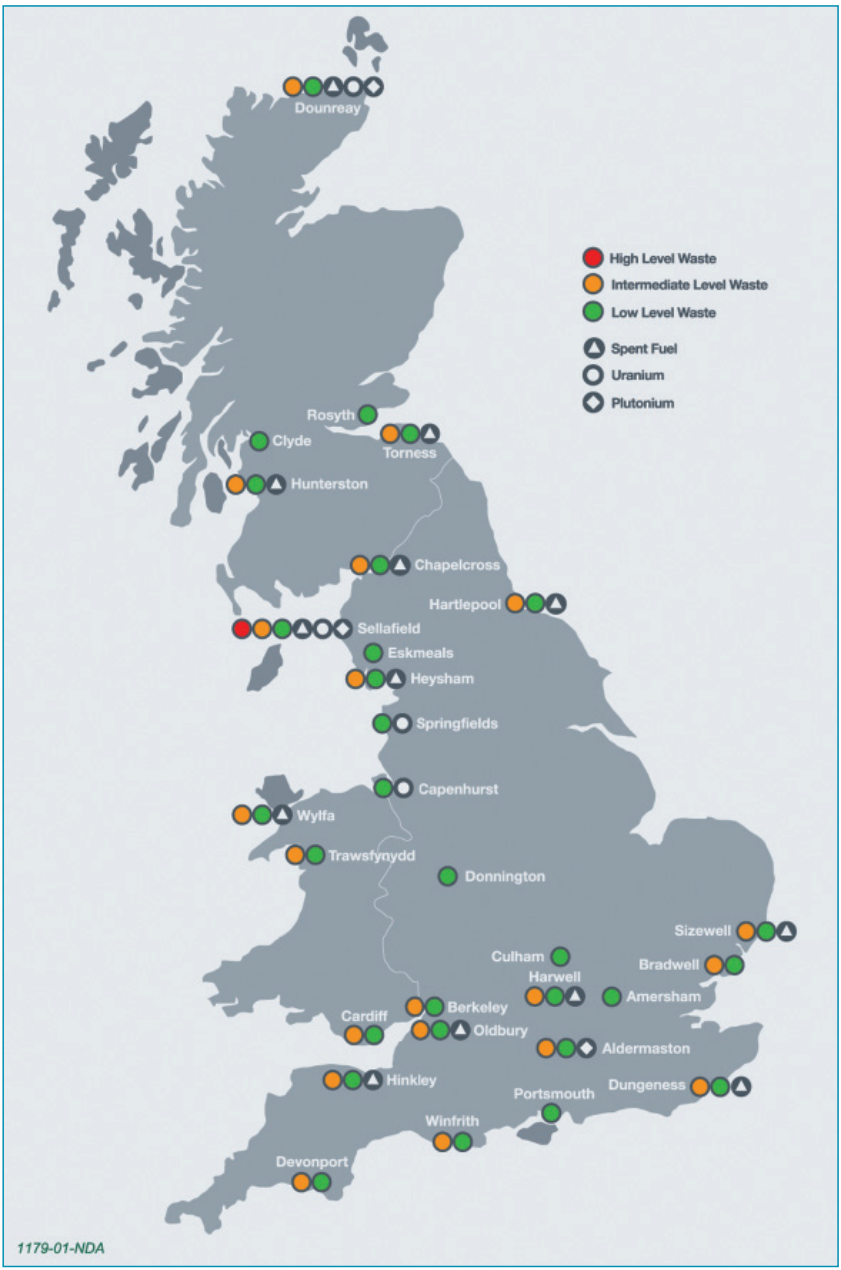
Materials	Notes	Packaged volume		Radioactivity (At 1 April 2040)	
		Cubic Metres	%	Terabequerels	%
HLW	1,2,3,5	1,400	0.3	36,000,000	41.3
ILW	1,2,5	364,000	76.3	2,200,000	2.5
LLW (not for LLWR)	1,2,5	17,000	3.6	<100	0
Spent nuclear fuel	1,4,5	11,200	2.3	45,000,000	51.6
Plutonium	1,4,5	3,300	0.7	4,000,000	4.6
Uranium	1,4,5	80,000	16.8	3,000	0
Total		**476,900**	**100**	**87,200,000**	**100**

Baseline Inventory


The radioactive waste journey
Nuclear power
Waste
Packaging
Interim surface storage
Geological disposal
Geological stability over very long times
Multiple barriers designed to provide safety
200 – 1000 metres
Intermediate Level Waste
High Level Waste
Isolation and containment

- **Where are the wastes at the moment?**

ILW and LLW are currently stored either at Sellafield in West Cumbria or at over 30 other locations around the country. Radioactive wastes need to be packaged in a "passively safe" state so that they can be stored safely. The waste producers are responsible for packaging and storage but we need to ensure that the packages are suitable for ultimate disposal in a GDF. We do this through our "Letter of Compliance" process for ILW which we have been implementing since the 1980s and a similar process is being followed to confirm the suitability of HLW and spent nuclear fuel. The process of packaging of wastes on nuclear licensed sites is overseen by the Nuclear Installations Inspectorate (NII) and the Environment Agency is a formal consultee in this process.


High Level Waste
Intermediate Level Waste
Low Level Waste
Spent Fuel
Uranium
Plutonium
Dounreay
Rosyth
Clyde
Torness
Hunterston
Chapelcross
Hartlepool
Sellafield
Eskmeals
Heysham
Springfields
Capenhurst
Wylfa
Trawsfynydd
Donnington
Sizewell
Culham
Bradwell
Harwell
Amersham
Berkeley
Cardiff
Oldbury
Aldermaston
Hinkley
Portsmouth
Dungeness
Winfrith
Devonport
1179-01-NDA

3. Assessing safety

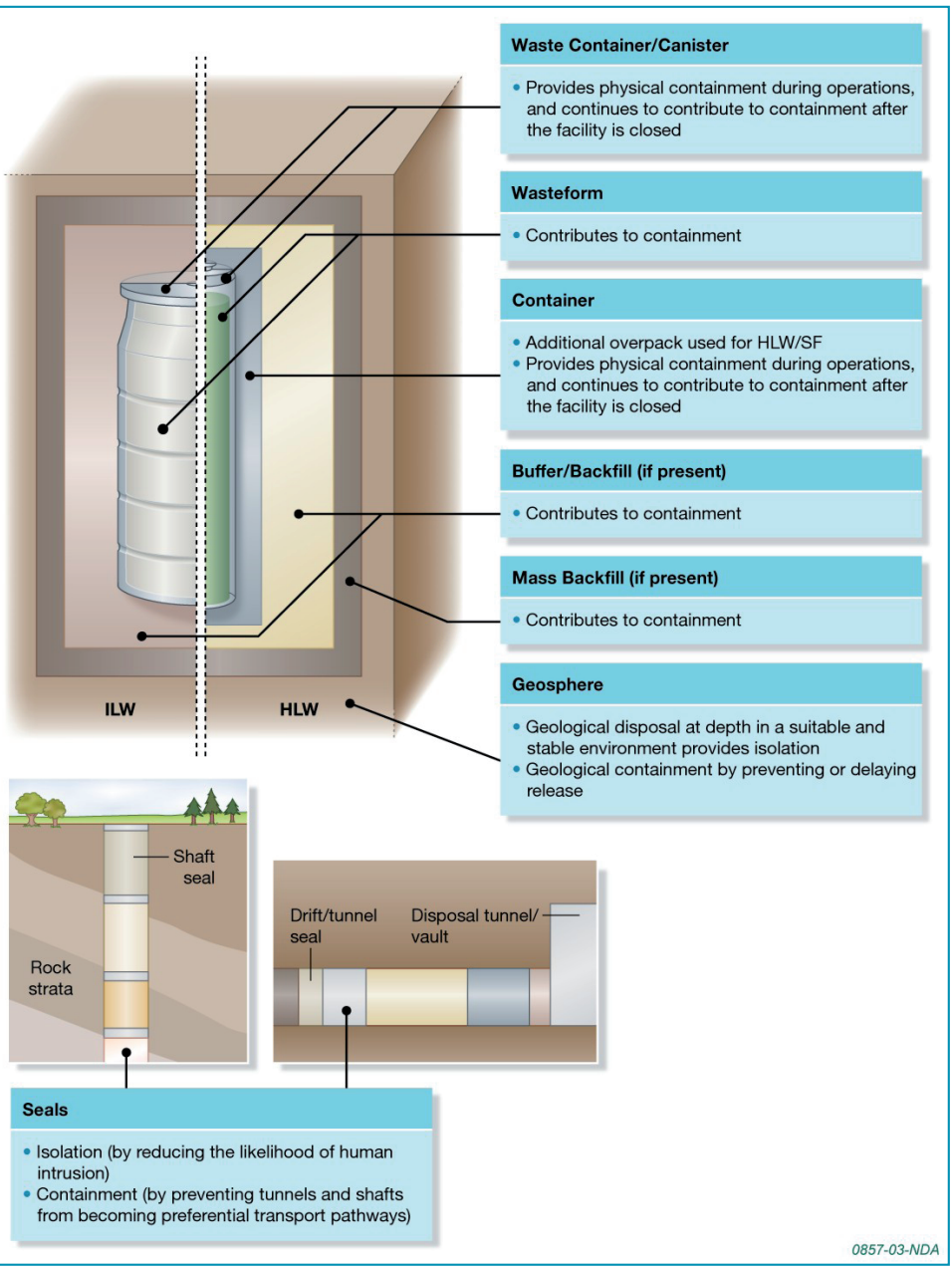
By describing something as ‘safe’, we mean there is little risk associated with it or that we can manage the situation to keep the risk to an acceptable level. Safety in the context of a geological disposal facility addresses the packaging of waste, the transport of the waste from storage to the facility as well as the construction and operation of the facility and safety in the long term after the facility has been closed.

The aim of the Disposal System Safety Case is to provide evidence to show that the geological disposal system will be safe to operate; will remain safe after it is closed and meets all applicable regulatory requirements.

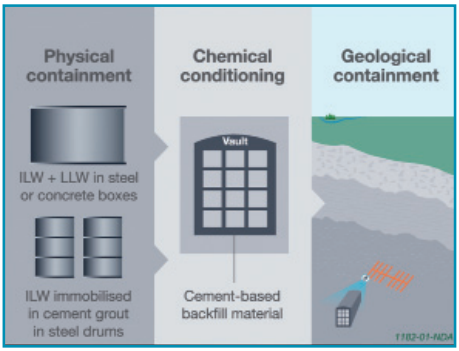
Our generic Disposal System Safety Case explains why, even at this early stage, we can have confidence in the safety of a geological disposal facility, based on our knowledge of the scientific and engineering principles that underpin geological disposal and existing experience of handling radioactive wastes, both in the UK and overseas.

Work on geological disposal has been carried out in many other countries for several decades. 25 countries have taken final decisions on geological disposal as the best solution to deal with their radioactive waste. We are actively involved through collaboration agreements with many of these countries and through international organisations such as the European Commission, Nuclear Energy Agency and International Atomic Energy Agency.

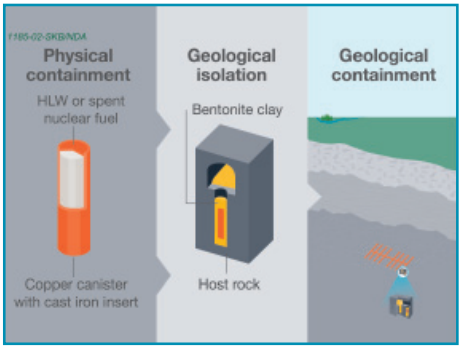
Internationally, all geological disposal facilities take a common approach in the use of a multi-barrier system to isolate the wastes from the environment and ensure the radioactivity is sufficiently contained.


Waste Container/Canister
• Provides physical containment during operations, and continues to contribute to containment after the facility is closed
Wasteform
• Contributes to containment
Container
• Additional overpack used for HLW/SF
• Provides physical containment during operations, and continues to contribute to containment after the facility is closed
Buffer/Backfill (if present)
• Contributes to containment
Mass Backfill (if present)
• Contributes to containment
Geosphere
• Geological disposal at depth in a suitable and stable environment provides isolation
• Geological containment by preventing or delaying release
ILW
HLW
Shaft seal
Rock strata
Drift/tunnel seal
Disposal tunnel/ vault
Seals
• Isolation (by reducing the likelihood of human intrusion)
• Containment (by preventing tunnels and shafts from becoming preferential transport pathways)
0857-03-NDA

4. Multi-barrier approach



Disposal system concept for ILW developed in the UK for higher strength rock



Disposal concept for HLW or spent fuel developed in Sweden for higher strength rock

A multi-barrier system for a GDF comprises a series of engineered and natural barriers working together to isolate the wastes and contain the radionuclides associated with the wastes. The typical barriers found in a multi-barrier geological disposal system include:

The waste form – This is the form into which waste is conditioned to make it suitable for disposal. ILW is typically cemented into a solid block within its waste container, for some ILW a resin is used instead of cement; HLW is turned into glass and encapsulated within a stainless steel container.

The waste container – provides a physical barrier and enables the waste to be transported and handled safely during interim storage and then for emplacement in a GDF.

The buffer or backfill – is the material that is placed immediately around the waste containers providing physical protection of the waste containers and in some cases a chemical barrier.

Mass backfill – is the material used to fill the excavated access tunnels, shafts or drifts in a disposal facility.

Sealing systems – complements the mass backfill and controls the movement of fluids along the excavated access tunnels, shafts or drifts.

The natural geological barrier – this is the host rock in which the facility is constructed and its surrounding rocks.

5. Implementing geological disposal

The detailed layout and design of the geological disposal facility, both above and below ground, will be tailored to meet the needs of the waste requiring disposal and to the specific geological characteristics of the site as well as various social factors including the views of the host community.

Although there are various options for the design of a GDF, there are some general features that would be common to all designs. These are: surface facilities; access shafts and/or drift; and, underground vaults and/or disposal tunnels.

ILW packages are likely to be stacked in vaults. Eventually it is expected (depending on the geology) that the gaps around these packages would be backfilled.

Due to the heat generated by HLW (and any spent fuel requiring disposal), these canisters would need to be placed in a separate disposal area.

Regulatory approval for implementing a disposal facility will require the necessary permissions to be obtained from the Environment Agency and a licence from the Health and Safety Executive.

- **Transport safety**

Transport of radioactive waste is subject to regulations laid down by the International Atomic Energy Agency and the UK Department for Transport. Radioactive waste has been transported within, as well as to and from, the UK for over 50 years without serious incident. The requirements for a safety case for transport to a GDF are set out in our Geological Disposal: Generic Transport Safety Case main report.

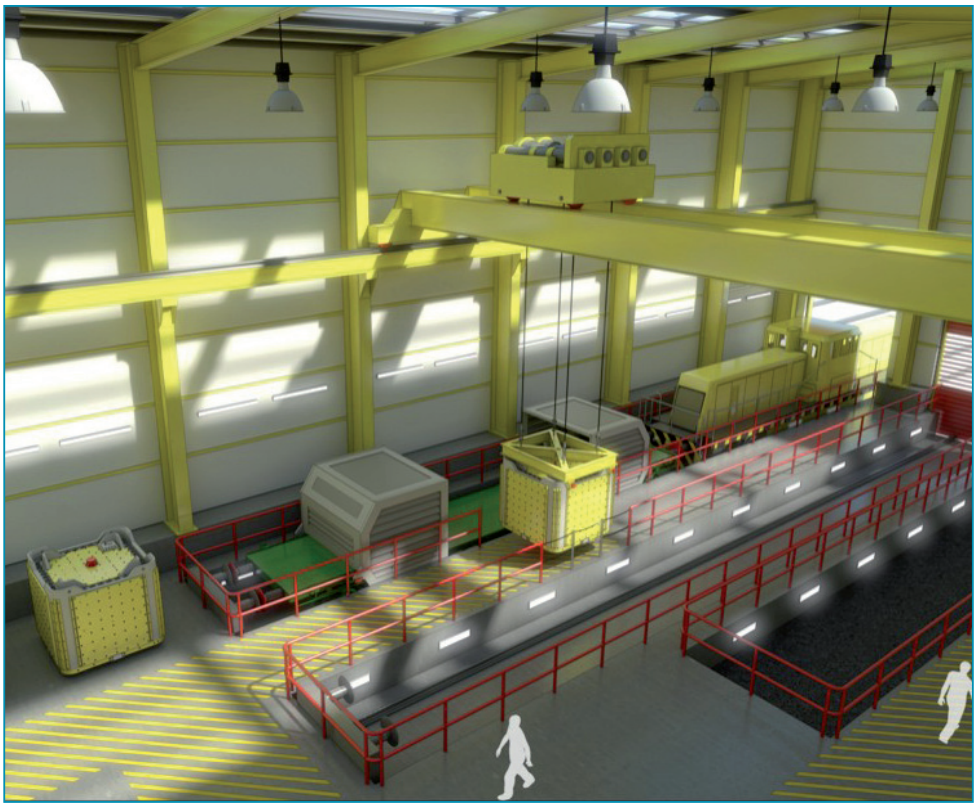
Road transport of spent nuclear fuel in the UK

- **Construction safety**

A geological disposal facility will require construction of sizeable facilities both above and below ground. Construction activities will be regulated by the HSE's Mining Inspectorate and Construction Division.

The GDF will be constructed using a combination of tried and tested techniques, such as drilling, blasting, and tunnel boring machines. The construction of a facility will take place in tandem with ongoing scientific investigations and while waste is being emplaced.

The construction safety assessment involves considering the potential hazards, identification of good engineering practice that can eliminate, reduce, isolate and control hazards and evaluating the acceptability of any remaining hazards.



Surface waste receipt and transfer facility for ILW and LLW

- **Operational Safety**

Operational safety is largely concerned with the safe handling of waste packages as they arrive at the facility and are transferred underground. Many of the packages will require remote handling once removed from their transport container. There is extensive experience in the UK and overseas of remote handling of radioactive materials.

Full details are available in our Geological Disposal: Generic Operational Safety Case main report which identifies the risks associated with hazards and assesses the consequences of them for our generic geological disposal facility designs.

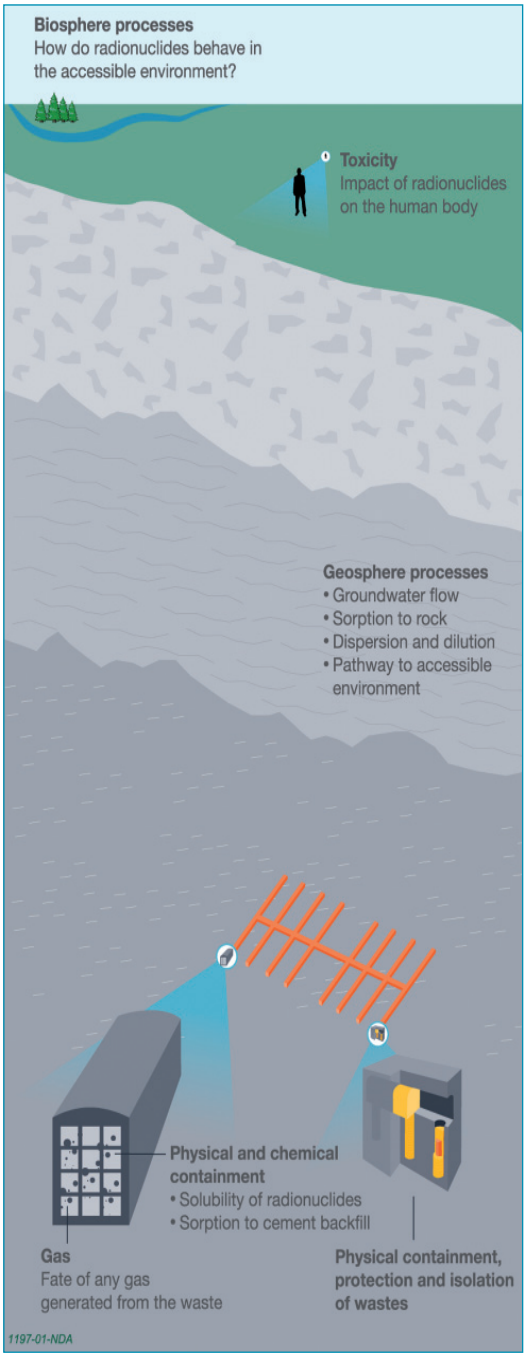
- **Post-closure safety**

Most post-closure safety assessments carried out internationally show that more than 99.9% of the radioactivity will be contained in the wastes or in the engineered barriers in a GDF until it has decayed.

In the first few hundred to thousands of years the GDF needs to provide very reliable isolation of the wastes as this is when the radioactivity and hazard is greatest. We also must consider safety over much longer periods into the future – typically up to one million years.

Full details of how we will do this are set out in our Geological Disposal: Environmental Safety Case main report.

Our approach to assessing long-term safety is to understand and illustrate the range of possible behaviours of the disposal system and to build confidence in our understanding through scientific research into the processes that affect long-term safety.



Schematic of the main processes in our geological disposal facility system model

6. Generic Disposal System Safety Case documents

The following are the key documents that comprise the generic Disposal System Safety Case suite of documents.

- **Overview**

  Geological Disposal: An overview of the generic Disposal System Safety Case
  This is a non-technical summary of the generic Disposal System Safety Case, outlining why we have confidence in the safety of a geological disposal system

- **Main reports**

  Geological Disposal: Generic Environmental Safety Case main report
  Explains in principle why we have confidence in the environmental safety of a geological disposal facility

  Geological Disposal: Generic Transport Safety Case main report
  Sets out the reasons why we have confidence that the system for transporting wastes to a geological disposal facility would be safe

  Geological Disposal: Generic Operational Safety Case main report
  Presents an illustrative safety case for normal operation and a preliminary assessment of operational and construction risk, against regulatory limits and targets

- **Safety assessment reports**

  Geological Disposal: Generic Transport System Safety Assessment
  An illustrative safety assessment of the transport of radioactive wastes to a geological disposal facility including an initial assessment of the routine radiological doses to workers involved in the transport system

  Geological Disposal: Transport package safety
  Describes the measures that are, or would be, in place to ensure the safe transport of radioactive waste packages

  Geological Disposal: Generic Operational Environmental Safety Assessment
  Outlines generic calculations for environmental discharges and radiological doses to members of the public during operation of a geological disposal facility

  Geological Disposal: Generic Operational Safety Assessment – Volume 1- Construction and non-radiological safety assessment
  This is an illustrative assessment of non-radiological safety and the safety of the construction operation

Geological Disposal: Generic Operational Safety Assessment – Volume 2- Normal operations operator dose assessment
Presents an illustrative assessment of the dose incurred by the operators undertaking various tasks during routine disposal facility operations and the direct shine doses to the public from normal operations

Geological Disposal: Generic Operational Safety Assessment – Volume 3- Accident safety assessment
Examines the safety performance of three illustrative concept designs under fault conditions

Geological Disposal: Generic Operational Safety Assessment – Volume 4- Criticality safety assessment
Presents an illustrative assessment of the risk of criticality during normal operations and under fault conditions

Geological Disposal: Generic Post-closure Safety Assessment
Explains our approach to assessing safety following closure of a GDF covering very long timescales (e.g. a million years)

Geological Disposal: Safety Case production and management
Describes how the transport and operational safety cases have been produced and the regulatory targets and legal limits that have been addressed

- **Research status reports**

Geological Disposal: Package evolution status report
Describes work supporting our position that durable waste packages have been or can be produced

Geological Disposal: Near field evolution status report
Describes our understanding of how the near field of a geological disposal facility would evolve, focussing on six illustrative concepts

Geological Disposal: Geosphere status report
Sets out our understanding of the role of the geosphere in disposal

Geological Disposal: Biosphere status report
Describes our approach to representing the biosphere in safety assessments

Geological Disposal: Gas status report
Describes our current understanding of gas generation and migration and justifies parameters used in reference gas generation calculations

Geological Disposal: Radionuclide behaviour status report
Sets out our understanding of how radionuclides would behave in a geological disposal facility, focusing on the post-closure period

- **Research status reports continued**

  Geological Disposal: Criticality safety status report
  Describes the technical studies that support a demonstration of criticality safety

  Geological Disposal: Waste package accident performance status report
  Explains our understanding of waste package performance in impact and fire accidents

- **Disposal system specification and inventory reports**

  Geological Disposal: Generic Disposal System Functional Specification
  Summarises the high-level requirements that the disposal system must satisfy

  Geological Disposal: Generic Disposal System Technical Specification
  Gives the technical requirements that must be satisfied, including the number, masses and sizes of waste packages to be assumed for the disposal system design

  Derived Inventory (contractor reports)
  Provides a detailed and enhanced description of the Baseline Inventory for use in the Disposal System Safety Case

- **Design reports**

  Geological Disposal: Summary of generic designs
  Summarises the generic transport system design and illustrative geological disposal facility designs developed for three example host rocks – higher strength rock, lower strength sedimentary rock and evaporites

  Geological Disposal: Generic disposal facility designs
  Describes illustrative geological disposal facility designs developed for the three example host rocks – higher strength rock, lower strength sedimentary rock and evaporites

  Geological Disposal: Generic transport system designs
  Outlines generic transport system designs for moving waste to a disposal facility, by road, rail and/or sea

7. Way forward

The UK Government is seeking expressions of interest from communities that may be interested in participating in a site selection process. We are confident that we can implement a geological disposal system safely, based on more than 40 years work both here in the UK and overseas.

Our initial, generic Disposal System Safety Case has further added to our confidence and also helped to highlight those areas where further research is needed and the uncertainties that would need to be resolved during a site investigation programme.

The MRWS White Paper sets out a staged site selection process that is to be followed and the criteria that will be used to assess candidate sites, following expressions of interest from local communities.

We believe that a safe geological disposal facility could be designed to suit a wide variety of UK geological settings. We will work with our stakeholders to build confidence in appropriate disposal concept designs and our safety assessments of them.

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