

# Nuclear waste disposal & transport of spent fuel

A guide to the  
transport and  
disposal of nuclear  
waste and spent fuel



## Introduction

**Radioactive waste** arises from many sources, including medical and industrial activities, as well as power stations and fuel reprocessing. The waste can be in a gaseous, liquid or solid state, but the most important factor regarding its disposal is the level of radiation emitted by it. This has implications for the temperature of the waste materials; if the level is high, then the waste will generate heat. The other important factors are the half-lives of the isotopes forming the waste and the type of radiation emitted. A highly radioactive material with a half-life of seconds only requires a minimal delay period before it can be safely discharged into the environment whereas many radioactive elements have half-lives of several thousands of years and require isolation for long periods.

There are two basic approaches to radioactive waste disposal and these have come to be known in broad terms as “concentrate and contain” and “dilute and disperse”. **Dilution and dispersion** involves discharging the waste at such a low concentration as to render it harmless. This is most clearly applicable to liquid and gaseous waste, which is generally of very large volume, but of very low activity.

Low-level liquid waste arises from water used in cooling, cleaning and other operational processes. Low-level gaseous waste comes from ventilation systems and other nuclear plant operations.

All discharges to the environment have to be in accord with limits prescribed by the Environment Agency in England and Wales, and by the Scottish Environment Protection Agency in Scotland. Authorisations for discharge are granted under the Radioactive Substances Act. Over the years, improvements in technology have allowed levels of radioactivity in gaseous and liquid discharges to be progressively and substantially reduced.

**Concentration and containment**, on the other hand, which is most applicable to solid waste, ensures that the radioactivity remains confined in the disposal facility. Thus, long-lived, highly radioactive (or high level) waste, or waste containing relatively large quantities of

radioactive elements with very long half-lives, must be isolated from the biosphere for tens of thousands of years.

## Categories of Solid Radioactive Waste

In the UK solid radioactive wastes are split into four categories:

- **Very Low Level Waste (VLLW)** - this waste contains very little radioactivity and can safely be disposed of with ordinary waste.
- **Low Level Waste (LLW)** - radioactive materials not exceeding 4GBq per tonne of alpha or 12 GBq per tonne of beta or gamma activity\*.
- **Intermediate Level Waste (ILW)** - radioactive waste exceeding the LLW boundaries but which does not require heating to be taken into account in the design of storage or disposal facilities.
- **High Level Waste (HLW)** - radioactive waste which is highly active and in which the temperatures may rise significantly as a result of its radioactivity. This has taken into account in the design of storage or disposal facilities

\* Explanation for this and other specialist terms can be found in the IET Glossary of Nuclear Terms and Phrases <http://www.theiet.org/factfiles/energy/nuc-terms-page.cfm>

## Volumes of Waste in the UK

Comparison of non-radioactive waste and solid radioactive waste shows that the total quantities of waste from nuclear power, both from fuel reprocessing and from operational power stations, are relatively small in volume. - see **Table 1**. Sources of each category of waste are shown in **Table 2**.

<b>Non-Radioactive Waste</b>	cubic metres per year	
Industrial Waste	40,000,000	
Domestic Waste	40,000,000	
Solid Toxic Waste	3,100,000	
<b>Solid Radioactive Waste<sup>1</sup></b>	Current rate of waste arising (cubic metres per year)	Predicted total packaged waste <sup>3</sup> arising to 2120 (cubic metres)
Low-Level (LLW)	<13,000	1,500,000
Intermediate-Level (ILW)	3,600	350,000
High-Level (HLW) <sup>2</sup>	60-70	1,300

**Table 1: Volume of Waste from Nuclear Power  
A comparison of waste arising in the UK**

**Sources:**

Figures for non-radioactive waste derived from "Radioactive Waste management: A Safe Solution", published by the Department of the Environment in 1993. Figures for radioactive waste derived from the 2001 UK Radioactive Wastes Inventory, UK NIREX Report N/041, published by DEFRA and NIREX in October 2002, and the Committee on Radioactive Waste Management report dated July 2006.

**Notes:**

1. Radioactive waste volumes are those after the waste has been conditioned or super-compacted for disposal.
2. This table does not include spent fuel, which is not classified as waste in the UK nor VLLW, nor plutonium or reprocessed uranium which can be used to produce reactor fuel.
3. Total waste figures include current waste stocks plus all future arisings to 2120. This assumes final stage decommissioning of all current nuclear stations is completed and all reprocessing facilities are fully decommissioned. Waste is treated and, where possible, compressed and packaged in standard size containers.

Source	Low Level (LLW)	Intermediate Level (ILW)	High Level (HLW)
Commercial Reprocessing	57%	56%	98%
Commercial Reactor Operation	29%	34%	-
Fuel Fabrication & Uranium Enrichment	<1%	-	-
Research & Development	10%	7%	2%
Ministry of Defence	2%	3%	-
Medical & Industrial	2%	<1%	-

**Table 2: Sources of each category of Radioactive Waste**

**Source:**

Figures based on NIREX report N/041, DEFRA/RAS/02.003., October 2002

## Low Level Waste (LLW)

Although LLW makes up more than 90% of the UK's waste legacy, it contains less than 0.1% of the total radioactivity.

Solid low-level waste includes clothing and paper towels and laboratory equipment, which have been used in areas where radioactive materials are present.

Low-level waste is less radioactive than some of the rocks in Cornwall where there are high levels of natural radioactivity. Hospitals, research establishments and some industries also produce low-level waste.

Reprocessing one tonne of used nuclear fuel produces about 4 cubic metres of low-level waste. This contains about 0.001% of the radioactivity in the used fuel.

Most of the solid low-level waste is disposed of in steel containers buried inside concrete lined vaults in a 300-acre purpose built shallow repository at **Drigg, near Sellafield, in Cumbria**. Before being placed in the containers, the waste in drums is "super-compacted" to minimise its volume. It is recognised that the site capacity at Drigg will be exhausted by about 2050 when a new site will be needed for LLW.

The Drigg site is regularly monitored to make sure there is no risk to people or the environment.

Solid low-level wastes arising at Dounreay in Caithness, Northern Scotland, are safely disposed of on site in pits dug in sandstone rock.



*Low level waste by kind permission of Sellafield Ltd*



## Intermediate Level Waste (ILW)

ILW comes mainly from nuclear power stations and fuel processing. Used radiation sources from hospital and industry also form ILW.

From power stations, ILW is made up of fuel element cladding, contaminated equipment and sludge from treatment processes.

Reprocessing one tonne of used nuclear fuel produces about one cubic metre of ILW.

At present, there is no permanent facility for disposing of ILW over the long term. Until there is, ILW can be safely held in licensed, shielded stores at nuclear power stations or at Sellafield.

ILW is packaged for storage by encapsulation in cement in well-engineered steel drums or concrete boxes.



*Intermediate level waste by kind permission of Sellafield Ltd*

## High Level Waste (HLW)

Only about 0.1% of nuclear waste is high level – it is produced during the reprocessing of spent fuel at Sellafield.

When spent fuel is processed to separate the unused uranium from the waste products, at least 96% of the fuel is uranium which can be recycled into new fuel, about 1% is plutonium which can also be used. The remaining 3% is HLW.

This HLW is concentrated by evaporation and stored inside double-walled high integrity stainless steel canisters inside thick concrete walls. Large cooling coils inside the tanks remove the heat the waste produces. There are several sets of coils to cover for the possibility of one failing.

To make the waste easier and safer to store, it can be converted into very dense solid-glass blocks – a process called “**vitrification**”. The

liquid is first turned into a powder and mixed with glass-making materials (1 part powder to 3 parts glass) and then the molten powder and glass is poured into stainless steel containers. By 2015, the majority of HLW will have been made ‘passively’ safe by this process. Passive safety is where no intervention is necessary to keep the waste in a condition where it poses no threat to health and safety.

The containers are transferred to stainless steel tubes in an air-cooled stack in the Vitrification Plant Product Store at Sellafield.

It is understood that the amount of HLW produced by Britain’s nuclear industry in the last 50 years would take no more space than about seven double-decker buses.

As with ILW there is no permanent facility for the disposal of HLW although it can be safely held for over 50 years in the current stores. Following this a decision can be made on whether to continue to store it or dispose of it deep underground in a secure repository.



*High level waste by kind permission of Sellafield Ltd*

## A Permanent Facility for Intermediate-Level Waste (ILW)

The responsibility for the development of disposal facilities for ILW and further disposal of LLW originally lay with UK NIREX Ltd. NIREX was established with Government backing in 1982 and as a private limited company in November 1985.

The search for a suitable site for a deep repository has proven lengthy and contentious as the following summary of key events shows:

**1989** NIREX identified 12 possible sites, potentially capable of meeting the safety requirements. From this group, Dounreay in Scotland and Sellafield were selected for initial investigation. They were chosen in part as locations which were familiar with the nuclear industry and had a measure of support for it.

**Oct 1992** NIREX proposed an underground laboratory - termed a Rock Characterisation Facility (RCF) to provide data on the rocks at the Sellafield site and on the water flow behaviour. The work envisaged two vertical 5m shafts sunk to a depth of between 650m and 900m connected at the bottom by a tunnel. The understanding of the hydrogeology was crucial as this was seen as the most likely route for radioactivity to get back to man.

**Jul 1994** NIREX submitted a planning application and an environmental impact assessment for the RCF.

**Dec 1994** Cumbria County Council refused the application.

**Mar 1997** John Gummer, Secretary of State for the Environment, rejected NIREX's appeal against the refusal of planning permission for its proposed Rock laboratory near Sellafield.

The grounds for refusal were listed as:

- Concerns about the adverse effects on visual amenity, a protected species and the natural beauty of the National Park due to the surface elements of the facility.
- Concerns about the process of selection of the site.
- Concerns about scientific uncertainties and technical deficiencies.

**Mar 1999** A report by the House of Lords Select Committee on Science and Technology on the Management of Nuclear Waste concluded that the preferred approach is phased geological disposal in which nuclear wastes are, following surface storage, placed in a repository so that they can be monitored and retrieved.

The Committee also recognised the importance of public acceptability and on openness and transparency in decision-making on the selection of sites.

They recommended a new organisation to oversee the implementation of policy, termed the Nuclear Waste Management Commission and a new organisation with a remit to design, construct and operate the repository - termed the Radioactive Waste Disposal Company - taking over the role of NIREX.

They also recommended that supporting measures such as infrastructure improvements and specific assistance for adversely affected inhabitants should be provided close to the chosen sites for repositories.



**Oct 1999** Government's initial responses to the Select Committee's recommendations promised a detailed and wide-ranging consultation document.

**Sep 2001** DEFRA produced the long awaited document "Managing Radioactive Waste Safely - Proposals for Developing a Policy". This set out an indicative staged process with approximate dates.

Stage 1 Consultation document (2001-02)

Stage 2 Research programme on feasibility of waste management options (2002-04)

Stage 3 Further consultation paper on the outcome of Stage 2 (2005)

Stage 4 Decision on the preferred waste management strategy and consultation on how to implement it (2006)

Stage 5 Legislation (if required) on implementation (2007)

**Jul 2002** Following consultation:

- DEFRA resolved to appoint an independent broadly based body to oversee the review process, examine options and make their recommendations; the Government would then publish and explain their decision.
- The process was re-designed to include 4 stages rather than 5, with Stage 3 around 2006 being a public debate on implementation including site selection criteria, and Stage 4 to mark the start of the implementation process around 2007.

**Jun 2003** Government Draft Nuclear Sites and Radioactive Substances Bill published.

This set out the intent to set up the Nuclear Decommissioning Authority (NDA) to manage the clean-up of the UK public sector civil nuclear liabilities.

The Government also announced that NIREX was to be made independent of the nuclear industry, in order to increase transparency and accountability.

**Nov 2003** The Government Energy Bill enabled the establishment of the NDA. The NDA was given complete responsibility for the decommissioning and clean-up of the UK's civil nuclear sites and for the safe and efficient management of nuclear waste.

The government also set up a new independent body, the Committee on Radioactive Waste Management (CoRWM). Its task was to review the options for managing the UK's solid radioactive waste and recommend to Government a long-term solution for protecting people and the environment. CoRWM carried out an extensive programme of consultation and assessment with a final report to Ministers in July 2006.

**Apr 2004** NDA established with responsibility for decommissioning and clean-up of 20 civil public sector nuclear sites including all Magnox nuclear power stations.

**Feb 2005** The Inventory Working Group of CoRWM 2005 published a preliminary revised inventory of radioactive waste: 478,000 cubic metres - this includes uranium, plutonium and spent fuel.

**Feb 2006** Government initiated a consultation on its Low Level Waste Policy review.



**Mar 2006** NDA published its approved strategy. Key principles include:

- Prioritising safety, security and the environment;
- Making the reduction of high hazards a key factor;
- Expediting decommissioning where it is supported by a sound business and safety case.

**Jul 2006** CoRWM reported that deep geological disposal is the optimum method for dealing with High and Intermediate Level nuclear waste.

**Jun 2008** After public consultation, Government published “Managing Radioactive Waste Safety - A Framework for Implementing Geological Disposal”. This White Paper takes forward the CoRWM report recommendations.

## Government Intent - June 2008

- UK's higher activity radioactive waste should be managed, in the long term through geological disposal: a repository deep, typically 200-1000 metres, underground
  - A robust programme of safe, secure interim storage in the meantime, 50-100 years, with the waste immobilised in passively safe forms.
  - On-going research and development programme to underpin the approach.
  - Support to explore how an approach to siting the repository based on voluntarism, willingness of communities to participate, and partnership could work in practice.
  - The Nuclear Decommissioning Authority, incorporating NIREX, to be a strong and effective implementing organisation with clear responsibilities and accountabilities for both interim storage and constructing an underground repository.
- Strong independent regulation by the statutory regulators: Health and Safety Executive – Nuclear Installations Inspectorate and Office for Civil Nuclear Security, Environment Agencies and Department of Transport.
  - Continued independent scrutiny and advice on the implementation programme by a reconstituted CoRWM.
  - Commitment to an open and transparent process throughout with full involvement of the public and stakeholders.
  - Implementation to be on a staged basis with clear decision points, allowing progress to be reviewed and costs, value for money, affordability, safety and environmental and sustainability impacts to be assessed before decisions are taken on how to move to the next stage.

Ref: White Paper June 2008



*Train transporting spent nuclear fuel by kind permission of World Nuclear Transport Institute*

## Review of Current Position

- The Government has now invited communities to express an interest in opening up discussions, without commitment, on the possibility of hosting a geological disposal facility at some point in the future.
- During 2008-2009, the NDA will undertake early planning for the implementation of a geological disposal facility with a staged implementation approach, each stage requiring Government agreement.
- The NDA has established a new Radioactive Waste Management Directorate, incorporating resources from UK NIREX Ltd, which will develop into an effective delivery organisation to implement geological disposal.
- The UK Nuclear Industry Association has backed the proposed plans, seeing a deep geological repository as in accord with international views. The UK approach is in line with countries such as Finland, Sweden, France and the USA which are pursuing geological disposal.
- Revised governance arrangements for the NDA have been set in place, establishing The Waste Management Steering Group. This will monitor the NDA's long term waste management, planning and development programmes. The Group comprises Government officials from the Treasury and other Departments with interests in this area, as well as representatives from the NDA and Devolved Administrations.
- With regards to radioactive waste arising from new planned reactors, the Government considers it technically possible and desirable to dispose of this waste and legacy waste in the same geological disposal facility. Legacy waste is that which already exists or will be produced in due course by existing plant. New reactors are being designed to minimise nuclear waste volumes.
- CoRWM plan to report to Government during 2009 on interim storage, progress on geological disposal and R&D proposals.

Overall, it can be seen that organisational arrangements have progressively been put in place to take forward geological disposal.

It will be a programme spanning many decades. A successful outcome will depend vitally on host community participation as well as consistent political momentum.

## Transport of Spent Fuel

In general terms, the UK's nuclear power stations are remote from the reprocessing and waste disposal facilities. The spent fuel from all the UK nuclear power stations is transported in specially designed flasks for re-processing at Sellafield in Cumbria.

Strict rules have been laid down by the International Atomic Energy Authority for the design of all transport containers. These set the standards for impact and fire tests to establish that the containers can withstand the most serious accident and that no radioactivity will escape.

The tests include two where a flask is dropped onto a reinforced concrete surface and onto a rigid steel bar. A third test involves a flask withstanding a fire of 800°C for 30 minutes.

Notwithstanding the stringent design and testing, the transport of spent fuel by both road and rail has given rise to considerable public anxiety. In 1984, the CEGB staged two demonstrations of the safety of transporting spent fuel by road and rail, and as part of a continuing programme of work assessing the safety of transportation flasks. The first demonstration involved a full-scale drop test and the second was a spectacular crash at 100mph of a 140-tonne train into a derailed flask (**Fig. 1**). In both cases the flasks successfully withstood the impacts with only superficial damage to their exteriors.



*Figure 1: Train Crash Demonstration 1984*



## Further Information

- **IET Energy related factfiles**  
<http://www.theiet.org/factfiles/energy/index.cfm>

## IET nuclear factfile series

- **The principles of nuclear power**  
<http://www.theiet.org/factfiles/energy/nuc-prin-page.cfm>
- **Nuclear reactor types**  
<http://www.theiet.org/factfiles/energy/nuc-reac-page.cfm>
- **Nuclear safety**  
<http://www.theiet.org/factfiles/energy/nuc-safety-page.cfm>
- **Legal framework of nuclear power in the UK**  
<http://www.theiet.org/factfiles/energy/legal-frame-nuc-page.cfm>
- **Nuclear decommissioning**  
<http://www.theiet.org/factfiles/energy/nuc-dec-page.cfm>
- **Nuclear waste disposal and transport of spent fuel**  
<http://www.theiet.org/factfiles/energy/nuc-waste-page.cfm>
- **The nuclear fuel cycle**  
<http://www.theiet.org/factfiles/energy/nuc-fuel-page.cfm>
- **The radioactive decay of uranium<sup>238</sup>**  
<http://www.theiet.org/factfiles/energy/uranium238-page.cfm>
- **Glossary of nuclear terms**  
<http://www.theiet.org/factfiles/energy/nuc-terms-page.cfm>

## Further Reading

- Wood, J. **Nuclear Power**  
IET Power and Energy Series 52  
Institution of Engineering and Technology  
(2007) ISBN 0863416683
- **Managing Radioactive Waste Safely - A Framework for Implementing Geological Disposal** White Paper by DEFRA and BERR (CM 7386) June 2008
- NDA Radioactive Waste Management Directorate - **Proposed Research and Development Strategy** - May 2008

## Useful Websites

- Committee on Radioactive Waste Management  
<http://www.corwm.org.uk>
- Defra  
<http://www.defra.gov.uk>
- Nuclear Decommissioning Authority  
<http://www.nda.gov.uk>

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