Radioactive Wastes in the UK:
A Summary of the 2001 Inventory
Introduction

An inventory of radioactive waste in the UK is compiled periodically by the Department for Environment, Food and Rural Affairs (DEFRA) and by United Kingdom Nirex Limited (Nirex) to provide up-to-date information essential for waste management policy, regulation and planning of waste treatment, packaging, storage and long term management.

This booklet summarises the 2001 UK Radioactive Waste Inventory, which is the latest public record of information on the sources, quantities and properties of radioactive waste in the UK either in store on 1 April 2001 or predicted to arise after that date. The 2001 Inventory contains details of over one thousand individual wastes totalling 1,750,000 cubic metres (m³). This represents the volume the waste would occupy after conditioning into a form suitable for long-term management.

Waste contaminated by, or incorporating, radioactivity above certain levels defined in legislation is known as radioactive waste. Radioactive waste is divided into four categories according to its radioactivity content and the heat it produces (see below). The UK Radioactive Waste Inventory includes information on LLW, ILW and HLW.

VLLW contains very little radioactivity and is disposed of by various means such as with domestic refuse at landfill sites, or by incineration. These wastes are not included in the UK Radioactive Waste Inventory.

**Very low level wastes (VLLW)**
Wastes that can be disposed of with ordinary refuse, each 0.1 cubic metre of material containing less than 400 kBq (kilobecquerels) of beta/gamma activity or single items containing less than 40 kBq.

**Low level wastes (LLW)**
Wastes other than those suitable for disposal with ordinary refuse, but not exceeding 4 GBq (gigabecquerels) per tonne of alpha, or 12 GBq per tonne of beta/gamma activity.

**Intermediate level wastes (ILW)**
Wastes exceeding the upper boundaries for LLW, but which do not need heat to be taken into account in the design of storage or disposal facilities.

**High level wastes (HLW)**
Wastes in which the temperature may rise significantly as a result of their radioactivity, so this factor has to be taken into account in the design of storage or disposal facilities.
The map shows the sites of major waste producers. Many hospitals and industrial, educational and research establishments produce small quantities of radioactive wastes; their sites are not shown. There are no major waste producer sites in Northern Ireland.

The total number of major waste producers’ sites is 34.
**Current Waste Stocks**

Of the waste in stock on 1 April 2001, 85% continues to be stored in a raw or partly treated state. A significant fraction of the current arisings are being conditioned. The process of conditioning immobilises wastes in a solid and stable form usually within stainless steel containers, suitable for long-term management. Conditioning reduces the hazard the waste presents compared with its raw form.

A particular concern is the historic wastes, largely created in the 1940s 50s and 60s. These wastes may be poorly characterised, physically and chemically degraded, and held in old facilities subject to deterioration.

The waste volumes provided in the tables include wastes which are to be conditioned and wastes which have already been conditioned.

### Volume, weight and radioactivity of wastes in stock on 1 April 2001

<table>
<thead>
<tr>
<th></th>
<th>cubic metres</th>
<th>tonnes</th>
<th>terabecquerels</th>
</tr>
</thead>
<tbody>
<tr>
<td>LLW</td>
<td>14,700</td>
<td>17,800</td>
<td>11</td>
</tr>
<tr>
<td>ILW</td>
<td>75,400</td>
<td>90,400</td>
<td>5,290,000</td>
</tr>
<tr>
<td>HLW</td>
<td>1,960</td>
<td>3,290</td>
<td>57,800,000</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>92,100</strong></td>
<td><strong>111,000</strong></td>
<td><strong>63,100,000</strong></td>
</tr>
</tbody>
</table>

**Volume in stock (m³)**

<table>
<thead>
<tr>
<th></th>
<th>Volume in stock (m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>England</td>
<td>75,700</td>
</tr>
<tr>
<td>Scotland</td>
<td>13,600</td>
</tr>
<tr>
<td>Wales</td>
<td>2,850</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>92,100</strong></td>
</tr>
</tbody>
</table>

**LLW**

On 1 April 2001 there were about 14,700 cubic metres (17,800 tonnes) of LLW in stock. Most LLW is routinely disposed of to the national disposal site at Drigg.

The total radioactivity of LLW in storage on 1 April 2001 was approximately 11 terabecquerels.
**ILW**

On 1 April 2001 there were 75,400 cubic metres (90,400 tonnes) of ILW in storage. About two-thirds (51,900 cubic metres) has arisen at the Sellafield site operated by British Nuclear Fuels plc. (BNFL). Much of the rest is held at nuclear power stations of the Magnox design, United Kingdom Atomic Energy Authority (UKAEA) sites at Dounreay and Harwell and at the Atomic Weapons Establishment Aldermaston. The volume of conditioned waste in storage is 11,200 cubic metres (21,100 tonnes, in 21,600 packages). This represents approximately 15% of the total ILW in stock. The total radioactivity of ILW in storage is approximately 5,290,000 terabecquerels.

Most ILW is being stored at the site where it is produced, some of it in original facilities. ILW is being stored in water filled concrete tanks, in a variety of steel containers or immobilised in standard packages and kept within modern stores. Centralised facilities for storing ILW from hospitals and industrial, educational and research establishments are also in operation.

**HLW**

On 1 April 2001 there were 1,960 cubic metres (3,290 tonnes) of HLW in storage. About 90% (1,770 cubic metres) are held at Sellafield. Here some of the liquid HLW is undergoing conditioning for long-term management by converting it into a glass (a process called vitrification) within stainless steel canisters. The volume of conditioned waste in storage at Sellafield was 340 cubic metres (910 tonnes in 2,280 packages).

The other 190 cubic metres of HLW are at UKAEA’s Dounreay site. This is currently stored as a liquid within stainless steel tanks.

The total radioactivity of HLW in storage at Sellafield and Dounreay on 1 April 2001 was approximately 57,800,000 terabecquerels. This is about 92% of the radioactivity in all waste in stock in the 2001 Inventory.
The total volume of future arisings is estimated to be about 1,660,000 cubic metres after conditioning. Some 85% of this volume will come from decommissioning existing nuclear facilities, particularly reprocessing plants and nuclear power stations.

The waste producers have made estimates of future waste volumes for the 2001 Inventory based on assumptions in their current plans, as shown below.

<table>
<thead>
<tr>
<th>Volume of future arisings (m³)</th>
<th>England</th>
<th>Scotland</th>
<th>Wales</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>LLW (cubic metres)</td>
<td>1,410,000</td>
<td>170,000</td>
<td>79,700</td>
<td>1,660,000</td>
</tr>
<tr>
<td>ILW (terabecquerels)</td>
<td>609</td>
<td>13,400,000</td>
<td>278,000,000</td>
<td>291,000,000</td>
</tr>
<tr>
<td>HLW (cubic metres)</td>
<td>750</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Volume and radioactivity of predicted future arisings of conditioned waste

Future Waste Arisings

These assumptions may have to be revised as plans change for technical, commercial or policy reasons. Also developments in waste management techniques and processes could lead to changes in predicted waste volumes.
**LLW**

Wastes are predicted to arise at, or close to, their current rate of between 10,000 and 13,000 cubic metres a year, in terms of conditioned waste volume, until 2020. From then until 2040 annual volumes fall as nuclear power stations shut down, spent fuel reprocessing ceases and the scale of other operations reduces. Larger volumes of LLW are predicted after 2040, principally from the decommissioning of facilities at Sellafield and from final stage decommissioning of nuclear power stations.

The volume of LLW in storage on 1 April 2001 plus predicted arisings is 1,510,000 cubic metres (expressed as if all in conditioned form).

**ILW**

Wastes are predicted to arise at their current rate of about 3,610 cubic metres a year, in terms of conditioned waste volume, until 2010. From then until 2030 annual volumes fall as most nuclear power stations shut down, spent fuel reprocessing ceases and the scale of other operations reduces. After 2030 most ILW will be from decommissioning. The increase in annual arisings around 2100 is from the final stage decommissioning of nuclear power stations.

The volume of ILW in storage on 1 April 2001 plus predicted arisings is 237,000 cubic metres (expressed as if all in conditioned form).

**HLW**

Wastes are predicted to arise at between 60 and 70 cubic metres a year, in terms of conditioned waste volume, at Sellafield until 2013 when reprocessing is assumed to cease.

The volume of HLW in storage on 1 April 2001 plus predicted arisings is 1,510 cubic metres (expressed as if all in conditioned form).
The civil nuclear power industry produces most of the UK’s radioactive waste. This includes waste from enrichment of uranium, fabrication of nuclear fuel, reactor operations and irradiated fuel reprocessing. Much of this results from reprocessing operations at Sellafield in Cumbria (57% of the total). This arises from the reprocessing of fuel from the UK’s Magnox reactors and Advanced Gas-cooled Reactors (AGR) together with fuels from overseas reactors.

The UK’s power reactors contribute 30% of the total volume of wastes. They generate about 20% of the UK’s electricity supply. Over three-quarters of this output is generated by the seven AGR stations and the one Pressurised Water Reactor (PWR) station operated by British Energy in England and Scotland. BNFL owns the Magnox stations: six remain in operation in England, Scotland and Wales, and five, which have ceased electricity production, are being decommissioned.

Research and development activities contribute about 9% of the total conditioned waste volume.

About 2% of the waste results from military activities. The main military sources are nuclear weapons production and operation of nuclear powered submarines. Smaller quantities arise from general use of radioactive materials within the armed forces and at defence establishments.

The remaining waste results from medical, industrial and fuel fabrication activities.
HLW arises from the reprocessing of irradiated fuel. Most is from reprocessing at Sellafield, the remainder has arisen from reprocessing research reactor fuel at Dounreay. HLW contains concentrated fission products created in the reactor.
Composition of Radioactive Wastes

Radioactive wastes arise from a wide range of processes. The overall compositions of LLW, ILW and HLW are subsequently very different.

**LLW**
The major components of LLW before conditioning are soil, metals, such as from ducting, piping and reinforcement, and building materials (concrete, cement and rubble). Organic materials also arise, including discarded protective clothing, paper towels and plastic wrapping. Graphite from gas-cooled reactors is also present. There are smaller quantities of glass and ceramics, and other miscellaneous inorganic materials.

[Drum of LLW]

**Material composition of LLW to be conditioned**

- Soil 46%
- Metals 22%
- Concrete, cement and rubble 21%
- Organics 7%
- Glass and ceramics <1%
- Others/ unidentified <1%
- Misc inorganics <<1%

Total weight 2,030,000 tonnes
**ILW**

The major component of ILW is metals, largely in the form of fuel cladding and fuel element debris, as well as plant items and equipment. Other major contributors are graphite from reactor cores, building materials (cement and rubble), and miscellaneous inorganic materials such as sludge and floc wastes. There are smaller quantities of organic materials, soil, glass and ceramics.

**HLW**

HLW in the form of nitric acid solutions containing fission products arises from reprocessing irradiated nuclear fuels.

High level liquid waste is concentrated by evaporation, and stored within stainless steel tanks inside thick concrete walls. Multiple water-cooling coils inside the tanks remove the heat that the waste produces.

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**Material composition of ILW to be conditioned**

- **Metals 35%**
- **Graphite 28%**
- **Misc inorganics 18%**
- **Others/unidentified 1%**
- **Organics 4%**
- **Concrete, cement and rubble 12%**
- **Soil 2%**
- **Glass and ceramics <1%**

Total weight 199,800 tonnes
Conditioning and Packaging of Radioactive Wastes

Many radioactive wastes are treated in some way after they arise, to reduce volume and so minimise requirements for storage capacity. Volume reduction techniques include compaction and incineration (for solid wastes) and evaporation, dewatering, ion exchange and flocculation (for liquid wastes).

Conditioning refers to the processes used to prepare radioactive wastes for long-term safe management.

Conditioning aims to immobilise wastes using materials which produce solid and stable forms which are typically packaged within stainless steel or concrete containers. The resulting waste packages can be disposed of in the case of most LLW or placed in purpose-built storage facilities and monitored.

In recent years all suitable LLW has been supercompacted before disposal to Drigg. In this process drums or boxes of waste are compacted under high pressure of up to 2,000 tonnes per square metre. Specifically, the Waste Monitoring and Compaction Facility at Sellafield supercompacts wastes from the site as well as wastes consigned from other sites for disposal at Drigg. Waste is placed in large metal containers, which are then filled with cement. These containers are then placed in concrete lined vaults.

Winfirth in Dorset also offers a supercompaction service, and a similar facility is operating at Dounreay to process LLW from this site.
HLW
At Sellafield HLW is being conditioned using a process called vitrification, which converts the liquid waste into borosilicate glass. It is heated to dryness leaving a fine powder, which is mixed with crushed glass in a furnace to produce a molten product incorporating the waste. This is then poured into stainless steel canisters, which hold approximately 150 litres, and a stainless steel lid is welded on. The canisters are transferred to an air-cooled store.

ILW
There are different forms of ILW. Solids from fuel cladding, slurry and ion exchange materials from the filtration and treatment of liquids may first be treated to reduce their water content to an optimum level for conditioning. Certain contaminated materials and small items of equipment can be supercompacted, while other solid wastes must be cut up to reduce their size.

For most ILW currently arising, packaging consists of conditioning in cement based materials within 500 litre stainless steel drums. Large items are conditioned in higher capacity stainless steel or concrete boxes.

There are a number of ILW packaging plants operating at Sellafield. These plants are conditioning a variety of solid and slurry wastes from reprocessing. ILW packaging plants are also operating at Dounreay, Windscale and Trawsfynydd.

When Magnox power stations come to the end of their operation, wastes that have been stored throughout operating lifetimes will be retrieved from tanks and vaults, and packaged. Similarly, wastes from the dismantling of nuclear facilities at Dounreay and at Harwell will be conditioned in cement within stainless steel containers, and further waste treatment and packaging plants are being planned.
Long-term Waste Management

Government policy and the regulatory framework aim to ensure that radioactive wastes in the UK are safely and appropriately managed for this and future generations. The regulatory authorities monitor to ensure that the policy is properly implemented. The waste producers are responsible for developing their own strategies within the policy and regulatory framework, and for bearing the costs of waste packaging and subsequent management. Nirex has responsibility to provide the UK with safe, environmentally sound and publicly acceptable options for the long-term management of some radioactive waste. This includes providing advice and endorsement on the compatibility of conditioning and packaging proposals with future management needs. The packaging advice and endorsement system is based on standards and performance specifications developed by Nirex. The continuing need for such a system has been brought into sharp focus by the Nuclear Installations Inspectorate (NII) emphasis on the early conditioning of wastes.

**LLW**

Since 1959 about 1,000,000 cubic metres of LLW from the nuclear power industry, hospitals, industrial establishments and the defence programmes have been disposed of, mainly at Dregg. The UKAEA has operated a disposal facility at Dounreay for LLW from that site and the adjacent Ministry of Defence site.

The Dregg site has a limited capacity that will become exhausted by the middle of this century. Thus, either a replacement facility or alternative means of dealing with LLW will need to be found.

**ILW**

The White Paper on radioactive waste management policy (Cm 2919) published in July 1995 stated that the Government continued to favour a policy of deep disposal rather than indefinite interim storage of ILW. This led to Nirex applying for planning permission to build a rock characterisation facility near Sellafield to investigate a potential site for a deep geological repository for disposal of ILW. The planning application was refused, and in March 1997 Nirex's appeal against this decision was rejected. This decision has led to a fresh look at radioactive waste management policy in the UK, starting with the launch in September 2001 of a Government consultation paper. Other management options are currently also being looked at by Nirex.

**HLW**

Current Government policy is that vitrified HLW should be stored for at least 50 years to allow the heat to decline so as to make long-term management less complex. Development of a research strategy for long-term management of such waste has been undertaken.

**Recent developments**

In September 2001 the UK Government launched a detailed and wide-ranging consultation on future policy for the long-term management of solid radioactive wastes. This also includes some radioactive materials – such as plutonium, uranium and irradiated fuel – which are not currently classified as wastes. The initial consultation has focussed primarily on the process for deciding policy, as opposed to specific policy choices.

The consultation exercise was the first stage in a proposed programme to develop and implement a long-term strategy for radioactive waste. The Government is proposing a major programme of research and public discussion to examine the different options.

The Government announced in November 2001 that it now intends to accept direct financial responsibility for all of the liabilities that BNFL manages except those covered by commercial contracts, in addition to liabilities on all UKAEA sites. Further information is available in the Government White Paper 'Managing the Nuclear Legacy', published in July 2002.
Materials not currently classified as wastes

Not all radioactive material is currently classified as waste. Plutonium, uranium and irradiated nuclear fuel are potential resources. Plutonium is created in nuclear reactors and separated by reprocessing. There are about 60 tonnes of UK civil separated plutonium in the UK, most of which is stored at Sellafield.

Plutonium can be utilised in Mixed Oxide (MOX) fuel, which is made up of about 95% uranium and 5% plutonium. BNFL manufactures MOX fuel at Sellafield where it processes plutonium separated by reprocessing. There are no current plans to use MOX fuel in the UK.

There are significant stocks of uranium arising from the production of nuclear fuel and irradiated fuel reprocessing.

Commercial and military irradiated fuels are not currently classified as wastes.

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Glossary

**Alpha activity**
Radioactivity associated with the emission of alpha particles.

**Becquerel**
Bq, the standard international unit of measurement of radioactivity, equivalent to one disintegration per second (see also kBq, GBq and TBq).

**Beta/gamma activity**
Radioactivity associated with the emission of beta particles and/or gamma radiation.

**Enrichment**
The process used for increasing the amount of fissionable atoms in nuclear fuel production.

**Fission Products**
see Nuclear Fuel

**Fuel Cladding**
The metal casing around the fuel.

**Fuel Debris**
Debris arising from cladding and other materials associated with nuclear fuel.

**GBq**
Gigabecquerel, one thousand million ($10^9$) becquerels.

**kBq**
Kilobecquerel, one thousand ($10^3$) becquerels.

**Nuclear Fuel**
The fuel used in a nuclear reactor. It produces heat when atoms split (fission) resulting in smaller fragments known as fission products.

**Radioactivity**
The property possessed by some atomic nuclei of disintegrating spontaneously, with loss of energy through emission of a charged particle and/or gamma radiation.

**Reprocessing**
The separation of uranium, plutonium and fission products present in fuels from nuclear reactors.

**TBq**
Terabecquerel, one million million ($10^{12}$) becquerels.
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