National Waste Programme

Strategic Guidance on the Management of LLW and ILW / LLW Cross Boundary Pond Furniture

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**Document history**

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<th>Issue</th>
<th>Date</th>
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<td>3</td>
<td>Feb 2015</td>
<td>Inventory data updated in line with published data from UKRWI 2013</td>
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Executive Summary
Pond furniture, defined as the metallic architecture used for the storage and handling of irradiated fuel in cooling ponds, which has been or is being stored under water, is a ubiquitous waste within the Nuclear Decommissioning Authority (NDA) estate. Decommissioning of fuel cooling ponds will generate (retrieve) a significant volume of this metallic waste. Despite the significance of this wastestream, historically there have been limited efforts to analyse detailed information about the characteristics of this waste and the approaches waste producers (SLCs) are using, or intend to use, for its management. The objective of this strategic guidance document is to provide a cross-NDA estate compilation of data on inventory and management approaches, as a vehicle to support the transfer of knowledge, best practice, lessons learned and innovation across the UK Nuclear Industry.

An extraction, review and refresh of data from the United Kingdom Radioactive Waste Inventory (UKRWI) 2013 estimates that the total volume of pond furniture classifiable as very low level waste (VLLW), low level waste (LLW) or intermediate level waste (ILW) in the NDA estate is 26668.7m³. This waste inventory is predominantly located at the Sellafield site (some 88% of the total volume) and consists mainly of stainless steel. The volume is dominated by LLW, albeit that much is expected to be at the upper end of activity of the LLW category. In the near term, it is expected that the majority of the waste will arise from decommissioning of the fuel ponds at the Magnox Ltd. sites (Bradwell, Chapelcross, Dungeness A, Oldbury and Sizewell A) and the legacy pond facilities at Sellafield.

Historically, waste producers have relied on disposal, either directly to the Low Level Waste Repository (LLWR) or else interim storage pending disposal to the Geological Disposal Facility (GDF) or near surface storage facility (Scotland), but there is increasing utilisation of decontamination and diversion to alternative waste routes such as metal melting. Significant efforts have been expended by waste producers (particularly Magnox Ltd.) into ongoing research and development (R&D) programmes to identify and implement new approaches for management of pond furniture. Examples of techniques trialled through these R&D programmes include foam decontamination, acid decontamination, Decontamination For Decommissioning (DFD), Decontamination For Decommissioning Electrochemical Ion Exchange (DFDX), metal milling and nitrocision.

Through review of the routinely used processes for management of pond furniture and wider discussions with waste producers, a generic decision-making process to support waste management optioneering has been developed. This illustrates the relationship between waste management decisions and outcomes (using the waste management hierarchy), demonstrating how combinations of decisions can be used to drive to waste management solutions of least environmental detriment. This is intended to inform and support the detailed optioneering processes used by waste producers.

A range of issues and opportunities have been identified and reviewed. Management of these issues, and exploitation of the opportunities, provides a mechanism to improve and optimise the efficacy of waste management practices for pond furniture.
## Acronyms and Abbreviations

<table>
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<tr>
<th>Term</th>
<th>Definition</th>
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<tr>
<td>AGR</td>
<td>Advanced Gas-Cooled Reactor</td>
</tr>
<tr>
<td>ALARP</td>
<td>As Low As Reasonably Practicable</td>
</tr>
<tr>
<td>BAT</td>
<td>Best Available Technique</td>
</tr>
<tr>
<td>BPEO</td>
<td>Best Practicable Environmental Option</td>
</tr>
<tr>
<td>CNC</td>
<td>Computer Numeric Control</td>
</tr>
<tr>
<td>DFD</td>
<td>Decontamination for Decommissioning Process</td>
</tr>
<tr>
<td>DFDX</td>
<td>Decontamination for Decommissioning, Electrochemical Ion Exchange Process</td>
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<tr>
<td>EARWG</td>
<td>Environment Agencies Requirements Working Group</td>
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<tr>
<td>EPR</td>
<td>Environmental Permitting Regulations (England and Wales) 2010 (as amended)</td>
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<tr>
<td>FGMSP</td>
<td>First Generation Magnox Storage Pond (Sellafield Ltd.)</td>
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<td>GDF</td>
<td>Geological Disposal Facility</td>
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<tr>
<td>HHISO</td>
<td>Half-height ISO container</td>
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<td>ILW</td>
<td>Intermediate Level Waste</td>
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<tr>
<td>ILW/LLW</td>
<td>Intermediate Level Waste / Low Level Waste Trans-Boundary Waste</td>
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<td>LLW</td>
<td>Low Level Waste</td>
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<td>LLWR</td>
<td>Low Level Waste Repository</td>
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<td>LWR</td>
<td>Light Water Reactor</td>
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<tr>
<td>MEB</td>
<td>Multi-Element Bottle</td>
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<td>MRF</td>
<td>Metal Recycling Facility</td>
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<tr>
<td>NDA</td>
<td>Nuclear Decommissioning Authority</td>
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<td>NOx</td>
<td>Nitrogen Oxides</td>
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### National Waste Programme

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<th>Abbreviation</th>
<th>Description</th>
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<tr>
<td>PFSP</td>
<td>Pile Fuel Storage Pond (Sellafield Ltd.)</td>
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<tr>
<td>R&amp;D</td>
<td>Research and Development</td>
</tr>
<tr>
<td>RSA93</td>
<td>Radioactive Substances Act (Scotland) 1993 [as amended]</td>
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<td>RSRL</td>
<td>Research Sites Restoration Ltd.</td>
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<td>RWM</td>
<td>Radioactive Waste Management Ltd.</td>
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<tr>
<td>SLC</td>
<td>Site Licence Company</td>
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<tr>
<td>UHP</td>
<td>Ultra High Pressure</td>
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<td>UK</td>
<td>United Kingdom</td>
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<td>UKRWI</td>
<td>United Kingdom Radioactive Waste Inventory</td>
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<td>USA</td>
<td>United States of America</td>
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<tr>
<td>WAC</td>
<td>Waste Acceptance Criteria</td>
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## Definitions

<table>
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<th>Term</th>
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<tr>
<td>Activated item</td>
<td>A solid object which has become radiologically contaminated by activation products resulting from neutron radiation.</td>
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<td>LLW / ILW cross boundary waste</td>
<td>Those wastes with radiological characteristics either side of the LLW radiological classification boundary that could practicably be managed either as LLW or else as ILW.</td>
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<td>Pond furniture</td>
<td>For the purposes of this document, this is defined as the metallic architecture used for, and associated with, the storage and handling of irradiated fuel in cooling ponds which has been or is currently stored under water, and which is classified as either low level waste (LLW) or else is intermediate level waste (ILW) where there is believed to be a practicable chance of using treatment or conditioning to render it LLW.</td>
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<tr>
<td>Surface contaminated item</td>
<td>A solid object which is not in itself radioactive but which has fixed and / or loose radioactive contamination distributed on any of its surfaces (including internal surfaces).</td>
</tr>
<tr>
<td>Volumetrically contaminated item</td>
<td>A solid object for which radioactive contamination is distributed, to some degree, throughout the volume of the object and not just contained on the surfaces of the object.</td>
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1. Introduction

Pond furniture – the metallic architecture used for the wet storage of irradiated fuel – is a ubiquitous wasteform across the Nuclear Decommissioning Authority (NDA) estate. It is a complex wasteform from a waste management perspective, due to its variability in type, physical geometry and radiological characteristics.

Despite its ubiquity and its importance as a source of a significant volume of metallic waste, pond furniture has not previously been considered in a national strategic context; for example, neither the National LLW Strategy [Ref. 1] or the Strategic Best Practicable Environmental Options (BPEO) assessment for metallic waste [Ref. 2, 3] specifically reference pond furniture, instead focussing on radioactive metals as a whole. It is acknowledged that significant work has been undertaken by waste producers and the supply chain in formulating, trialling and implementing waste management approaches for this wastestream; however, the outputs of this work has not typically been widely disseminated beyond individual organisations. This historical lack of knowledge transfer and learning from experience has contributed to duplication of effort and, in some cases, implementation of non-optimised waste management strategies.

This report intends to provide the first cross-NDA estate compilation of inventory data and waste management approaches specifically for pond furniture, with the intent of providing an effective vehicle for the transfer of knowledge – particularly good practice, lessons learned and innovation – across the NDA estate. It should be noted that this strategic guidance is not intended to supplant any existing, or developing, organisational or specific site strategies for the management of LLW, ILW / LLW cross-boundary wastes, ILW or pond furniture; but rather seeks to augment any such local strategies and to provide an additional tool to support waste practitioners in informed and underpinned decision making.

This document has been developed in collaboration with the NDA-estate Site Licence Companies (SLCs) and the supply chain. Inventory information presented in this document is extracted from UKRWI 2013, with additional validation of the data by the SLCs. The compilation of waste management approaches has been derived using information submitted by SLCs and the supply chain, supported where appropriate by literature review. Similarly, identification of cross-estate issues and opportunities relating to the management of pond furniture has been derived based on information provided by the SLCs.

It is intended that this compilation shall be periodically reviewed to take account of changes in waste inventory, strategy, management approaches and technology; so as to ensure that this document remains current and fit-for-purpose.
2. **Purpose**

This strategic guidance document intends to serve three main purposes:

- **To provide a UK-wide inventory of pond furniture detailing the types, volumes and known or assumed radiological classifications of the waste.** This will allow for identification of synergies and opportunities for consolidated waste treatment across the NDA estate, as well as providing the supply chain with better clarity on the nature of the predicted arisings of pond furniture to inform future service provision or else improvements to current service provision.

- **To provide a compilation of information on current and credible near-term future approaches being employed within the NDA estate for management of pond furniture.** This is to enable sharing of information, best practice and lessons learned; and to enable the identification of synergies and opportunities between sites. This is augmented by the inclusion of case studies on relevant wastes, where particular techniques have been employed by SLCs for management of pond furniture wastes.

- **To provide decision making logic for waste practitioners based on the current waste management practices, to complement existing waste management strategies and to support waste management decision making / optineering.**

The intended benefits of the use of this strategic guidance document for waste producers, service providers, LLW Repository Ltd. and other stakeholders are summarised in Figure 1.

**Figure 1 – Benefits matrix for pond furniture strategic guidance**

<table>
<thead>
<tr>
<th>Benefit</th>
<th>Waste producer</th>
<th>LLWR Ltd.</th>
<th>Service Providers</th>
<th>Regulators</th>
<th>Other Stakeholders</th>
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<tr>
<td>Contribute to avoidance of the need for a second UK LLWR through optimized waste management practices.</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>More cost-effective waste management of pond furniture due to knowledge transfer of best practice, lessons learned and innovations across NDA estate.</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Maximisation of opportunities for new or improved service provision from management of pond furniture through improved inventory and schedule data.</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
It should be noted that whilst this document specifies a range of potential waste management options for pond furniture (either in routine use or else in research and development), the purpose of this document is not to identify preferred options or to rank options but to facilitate the sharing of information relating to the range of options available. The selection of specific waste management options is a matter for the waste owner and should encompass a wide range of criteria (such as, but not limited to, cost, health and safety, ALARP and dose uptake, environmental impacts, trans-frontier shipment issues etc.).
3. Background

3.1 What is pond furniture?
For the purposes of this strategic guidance document, pond furniture is defined as:

Metallic architecture used for, and associated with, the storage and handling of irradiated fuel in cooling ponds which has been or is currently stored under water, and which is classified as either low level waste (LLW) or else is intermediate level waste (ILW) where there is believed to be a practicable chance of using treatment or conditioning to render it LLW.

This includes metallic waste such as (but is not limited to) storage racks, skips, frames, containers and element bottles. Transport flasks are specifically excluded from this definition.

3.2 How has radiologically contaminated pond furniture arisen?
Pond furniture has arisen as a specific category of waste owing to the wet storage of spent nuclear fuel. Spent nuclear fuel removed from nuclear reactors requires a period of interim storage pending reprocessing or disposal to allow for physical cooling of the spent fuel and a period of radioactive decay. This interim storage of spent fuel can be undertaken in wet or dry conditions. Reactor stores for spent fuel are - or were, prior to deplanting - predominantly water filled, as water is an effective radiation shield at appropriate depths, is a good heat transfer medium, allows for ready manipulation of spent fuel and allows for ready visibility of pond contents [Ref. 4]. Similarly, on transfer to Sellafield Ltd. for reprocessing, spent fuel is also stored in ponds to allow for further radioactive decay and cooling, as well as to enable buffer storage to enable arisings to be appropriately grouped into campaigns for treatment and to provide storage capacity in the event of the plant being unavailable. A range of metallic architecture is required to enable this wet storage of spent fuel such as racks, skips, frames, containers, and trolleys.

Pond furniture can become contaminated through a variety of mechanisms [Ref. 4, 5] as illustrated in Figure 2:

- Neutron emission from spent fuel can cause activation of pond furniture, producing radioactive isotopes such as Cobalt-60, Iron-55, Manganese-54 and Nickel-63. This is especially noticeable for certain wastes (e.g. fuel casks and canisters) with long campaign histories and located for storage in close proximity to sources of high neutron emission.
- During reactor operation, fuel cladding becomes activated by neutrons and the external surface of the cladding can, by adhesion, accumulate a layer of activated corrosion products from the primary cooling system. This crud can be dispersed from the cladding and become a source of loose contamination within the ponds.
- Radionuclides (fission products) can leak out of fuel rods into the pond water in the event of a pinhole leak or defect in fuel cladding. This can spread contamination to other items within the pond.
For pond furniture waste within the legacy pond facilities at the Sellafield site (FGMSP and PFSP), further contamination has occurred by contact between pond furniture items and corroded nuclear fuel and sludge resulting from the debris of fuel / metallic corrosion, wind blown debris and bio-organic wastes [Ref. 6].

Figure 2 – Key in-situ pond mechanisms for contamination of pond furniture

The extent of contamination is dependent on the physical / chemical form of the pond furniture, the degree of protective surface coatings, the concentration of radioactive isotopes present in the pond water and the contact time between the pond furniture and the contamination source in the pond. Long contact times can result in the migration or diffusion of contamination into the surface metal [Ref. 5].
3.3 Why is management of pond furniture an issue?

The retrieval and management of pond furniture is an integral part of the decommissioning process for fuel storage ponds. It poses a particular challenge to the decommissioning and waste management communities owing to the nature of the waste, the (typically) high dose environments where the waste is stored and tensions between waste management requirements and the cost / schedule of the wider decommissioning programme. Pond furniture is a complex wastestream with significant variability in chemical, physical and radiochemical characteristics as a consequence of the differences in historical usage, the types of surface coating (if any), historical / current storage regime and the multiple mechanisms for contamination as outlined in section 3.2. This variability in the characteristics and waste type of pond furniture can vary significantly within populations in a single pond, between sites within a single SLC and between SLCs. This means that there is not a “one size fits all” approach for waste management and that a combination of waste management strategies is required to manage the variability in the waste (adding to the complexity, cost and timescales for the activity).

Implementation of effective waste management strategies for this waste is thus important for ensuring that waste is retrieved and managed in a cost effective and timely manner so as to enable wider decommissioning programmes to proceed as planned, whilst enabling the waste to be managed so as to ensure that detriment (to the environment, nuclear provision and any waste disposal facilities) is minimised as far as practicable.
4. **Inventory**

Waste inventory information for the UK nuclear industry is periodically collated centrally to meet specific international reporting requirements [Ref. 7], and currently a UK Radioactive Waste Inventory (UKRWI) is generated every three years to meet these requirements. A review of the data pertaining to pond furniture, with refresh of the data by SLCs as appropriate, has been undertaken to develop a discrete inventory of pond furniture waste for the NDA estate. The inventory is described in terms of volumes, waste types, radiological classifications and timescales for waste generation in the sections below.

4.1 **Assumptions**

A number of specific assumptions have been used in the generation of this waste inventory:

- The primary data set is the UKRWI 2013. The specific assumptions used for the generation of the UKRWI 2013 apply to this inventory.

- The data reported is that which is directly attributable as pond furniture within UKRWI 2013. It is known that there is a volume of other miscellaneous pond furniture waste that will be generated by decommissioning of the fuel storage ponds at SLCs (particularly Magnox Ltd. and Sellafield Ltd.) but this is reported within UKRWI 2013 under different waste categories and is difficult to attribute as pond furniture waste. As currently the volume and categorisation of this waste cannot be quantified, this waste is excluded from this inventory.

- The information submission from Sellafield Ltd. specifically excludes Multi-Element Bottles (MEBs), a waste type which is exclusive to the Sellafield site and one for which there is a defined and ongoing waste management programme. It is recognised that the waste management approaches describes in this document will be applicable to items such as MEBs.

- Data pertaining to any pond furniture in the Sellafield Wet Inlet Facility is specifically excluded owing to commercial and security sensitivities, however it is recognised that the waste management approaches described in this document will also be applicable to Wet Inlet facility pond furniture.

- Only five Magnox Ltd. sites have been identified as possessing an inventory of pond furniture under the definition of this report (Bradwell, Chapelcross, Oldbury, Dungeness A and Sizewell A). The other Magnox Ltd. facilities do not have wet storage facilities, or are in a more advanced stage in their decommissioning programmes so pond furniture waste has already been managed, or else have assigned their small volume inventories of pond furniture to other wastestreams (e.g. Hinkley Point and Hunterston).

- It is assumed by Magnox Ltd. that all fuel skips are classifiable as ILW (based on history and provenance) and characterisation / re-classification of the waste will not be undertaken until retrieval. For this strategic guidance, the pond furniture waste for Magnox Ltd. is assumed to be ILW / LLW cross-boundary waste.
Data for Dounreay is specifically excluded from this study as the Dounreay pond furniture waste is expected to be structural waste, integral to the pond structure and fuel containers specific to the Dounreay site. DSRL does not classify this waste as pond furniture under the definition of this strategic guidance. In addition DSRL has defined waste management approaches for its waste based on disposal (or long term storage, for ILW) in its own on-site / near site facilities.

Data relating to the timescales for waste generation and decommissioning programmes in section 4.5 is based on publicly available information published in the UKRWI. It should be noted that schedules, particularly for decommissioning activities, are dependent on a range of factors including funding availability, corporate priorities and regulatory requirements. Consequently, these timescales are subject to change and are provided for indicative purposes only.

4.2 Volumes

The total volumes of pond furniture waste existing or arising within the NDA estate between 2013 and 2100 are shown in Figure 3. A total volume of around 26668 m$^3$ of pond furniture is expected to be generated during this period, which in the national context equates to 3% of the total metallic waste volume declared in the UKRWI 2013 [Ref. 8]. The most significant volume of pond furniture waste is held by Sellafield Ltd. on the Sellafield site, accounting for approximately 88% of the total volume. The Chapelcross site (operated by Magnox Ltd) holds the second largest volume of pond furniture waste, approximately 10% of the total. The Bradwell site (operated by Magnox Ltd.) has the smallest volume of waste, which reflects the fact that the majority of pond furniture waste arising at this site has already been retrieved and managed, owing to the maturity of the decommissioning programme. The remaining sites, Oldbury, Dungeness A and Sizewell A (managed by Magnox Ltd.) – have approximately 1% of the pond furniture inventory respectively.
4.3 Waste types

Pond furniture is metallic waste but consists of a variety of different types of metal. Figure 4 shows the breakdown of waste types at the different sites. The remaining waste identified at Bradwell (Magnox Ltd. site) consists entirely of stainless steel. The pond furniture at the other Magnox sites (Chapelcross, Dungeness A, Oldbury and Sizewell A) consists of other ferrous metals. At Chapelcross, this includes painted, mild steel pond skips and other large items of pond furniture. The greatest variation in waste type is seen at the Sellafield site, where the waste is a mixture of stainless steel (approximately 57% of the inventory), other ferrous metals (approximately 37% of the inventory) and other metals (4%). A proportion of the mild steel pond furniture at Sellafield is surface coated (painted).
Figure 4 – Proportions of pond furniture volume (m$^3$) by type for each relevant site in the NDA estate.

- **Chapelcross (Magnox Ltd)**: 100%
- **Sizewell A (Magnox Ltd)**: 100%
- **Sellafield (Sellafield Ltd)**: 59% Stainless Steel, 37% Other Ferrous Metals, 1% Other Metal, 1% Lead
- **Bradwell (Magnox Ltd)**: 100%
- **Dungeness (Magnox Ltd)**: 100%
- **Oldbury (Magnox Ltd)**: 100%
4.4 Radiological Classification

Although this guidance deals with the management of LLW and ILW / LLW cross boundary wastes, in the UKRWI 2013 [Ref. 9] cross boundary wastes are not identified as a separate classification. Figure 5 illustrates the breakdown of the pond furniture inventory within the NDA estate by radiological classification (VLLW, LLW or ILW), indicating that the majority of the inventory within the scope of this study is believed to be classifiable as LLW (approximately 85%). In reality, it is expected that these breakdowns may be different than stated owing to the assumption that waste classifications have predominantly been derived based on history and provenance, rather than underpinning characterisation. Although some of the ILW will be out of the scope of this study, it is important to note that some of the waste volume categorised as ILW could potentially be managed as LLW with appropriate treatment to reduce activity (LLW / ILW cross-boundary waste) [Ref. 9]. Similarly, the use of technologies may allow the classification of some LLW as VLLW following treatment. It is also important to consider that due to the nature of some LLW, a small population of these wastes is likely to be disposed of as ILW.

Figure 5 – Breakdown of pond furniture volume (m$^3$) in the NDA estate by radiological classification
4.5 Schedule for waste generation

An indicative schedule for retrieval of pond furniture waste for management for the period 2012-2100 is provided in Figure 6. Management of pond furniture and decommissioning of the pond structures for Magnox Ltd. is expected to be undertaken in the relatively near term in order to meet the corporate vision for transfer of sites into Care and Maintenance by 2028. It should be noted that there is variation in the timetable for these activities at different sites [Ref. 9-13]. All the pond furniture at Bradwell was scheduled to be retrieved during 2013. Timescales at Sellafield are more elongated, with efforts in the near term relating to retrievals from, and decommissioning of, the legacy ponds facilities (FGMSP and PFSP), as per the Sellafield Ltd strategic imperative of risk and hazard reduction [Ref. 14]. Retrievals of pond furniture associated with the fuel storage ponds for Light Water Reactor (LWR) fuel and Advanced Gas-Cooled Reactor (AGR) fuel occur over a longer period of time, to enable completion of the commercial reprocessing mission and to support ongoing decommissioning of other related facilities.

4.6 Changes since UKRWI 2010

Since the last UKRWI was published in 2010, Research Sites Restoration Ltd. (RSRL) has completed retrievals of its Pond Furniture at the Harwell site, and no pond furniture volume for this site appears in the UKRWI 2013. Data for Harwell (RSRL) is therefore absent from the inventory, however techniques used for treatment of pond furniture by RSRL are included in this report in section 5.2, to ensure that these approaches are shared with users of this document.

There has been a significant increase in the volume of pond furniture arisings reported at the Sellafield site (Sellafield Ltd.), from 13751m$^3$ in 2010 to 23498m$^3$ in the 2013 RWI, and at the Chapelcross Site (Magnox), from 199.9m$^3$ in the RWI 2010, to 2625m$^3$ in the 2013 inventory.
Figure 6 - Schedule of pond furniture waste retrievals within NDA estate 2013-2100

- Dungeness
- Sizewell A
- Oldbury
- Chapelcross
- Magnox Reprocessing Ponds
- THORP receipt and storage pond
- PFSP
- AGR Ponds
- LWR Ponds

Year:
- 2020
- 2030
- 2040
- 2050
- 2060
- 2070
- 2080
- 2090
5. Waste Management Strategies

A range of waste management strategies and approaches have been, and are currently used by the NDA estate for management of their pond furniture waste. The toolkit of approaches employed by any specific SLC reflects the overall strategic intent of that SLC and the availability of waste treatment routes, balanced against available funding and schedules for waste retrieval.

This section of the document provides summaries of the overall waste management strategies and individual waste techniques used by the NDA estate SLCs. Section 5.1 provides a high-level “state of the nation” description of the SLC or site waste management strategy applicable to pond furniture. This includes a list of the techniques in current routine use for management of this waste for each SLC. This listing is expanded in section 5.2 where technology summaries are provided for each technique. The R&D activities undertaken by NDA estate SLCs relevant to pond furniture are briefly described in section 5.3, with examples of any trials undertaken associated with the R&D. A range of techniques not used or being trialled by SLCs has been identified through literature review and these are listed in section 5.4. Case studies relating to the use of any specific technique on pond furniture or wastes analogous to pond furniture by the NDA estate SLCs are presented throughout sections 5.2 and 5.3 to illustrate the technology summaries.

5.1 NDA Estate Waste Management Strategies

Each NDA estate SLC has specific strategies relating to management of their specific waste inventories. This section identifies and briefly describes the strategy relevant to management of pond furniture, for each SLC with an inventory of this waste. This includes a list of the techniques in current and routine usage at each SLC for pond furniture management.

5.1.1 Magnox Ltd.

Magnox Ltd’s strategy for management of its sites involves undertaking preparatory work for Care and Maintenance until 2028, and then transfer of the sites into passive quiescent state until 2075 (specific timings vary for individual sites). The preparatory work for Care and Maintenance involves undertaking dismantling work to remove radiological and non-radiological plant and buildings where benefit cannot be achieved from deferring the work. Waste retrievals, decommissioning and demolition of fuel storage ponds are a key part of this preparation for Care and Maintenance [Ref. 10, 11]. The strategy for pond furniture management is to use decontamination as far as practicable to down categorise radiological waste, and then to either divert waste for re-use / recycle or to dispose of waste to an appropriate facility, where a specific waste route is demonstrated to be Best Available Technique (BAT).

The techniques previously considered, employed or under consideration by Magnox Ltd. for the management of pond furniture include:
Other techniques, and specific decontamination techniques, will be kept under watching brief by Magnox Ltd., and trials carried out as appropriate as part of the demonstration of BAT. The 2013 Integrated Waste Strategy [Ref. 15] recognises an opportunity to enhance the decontamination of pond furniture, reducing the volume requiring disposal as ILW and increasing metals recycling. This will be enabled by trials of pond skip decontamination equipment.

5.1.2 Sellafield Ltd.
Sellafield Ltd. is in the process of defining and developing a discrete strategy for decommissioning of the Sellafield site, following on from the development of Decommissioning Mandates undertaken during the latter half of 2000-2010. The situation at Sellafield is complicated by the diversity of the mission on the site, particularly with regards to fuel storage ponds, as the facilities range from those in active decommissioning (forming part of the risk / hazard reduction work ongoing on legacy facilities) through to those currently still in active use to support commercial reprocessing operations [Ref. 14]. It is expected that the strategy for management of pond furniture will continue to evolve as the mission of the site changes over time to decommissioning and site clearance. Until recently, high-level strategy employed for the management of pond furniture at Sellafield involved size reduction, packaging and disposal. Implementation of the National Strategy for LLW [Ref. 1] and other initiatives has led to consideration of greater use of decontamination and technologies enabling re-use, re-cycle and diversion from disposal. For example, trials of pond furniture decontamination have recently taken place [Ref. 16].

The techniques employed or under consideration by Sellafield Ltd. for the management of pond furniture include:
- Size reduction
- Direct disposal to LLWR
- Direct disposal to GDF
- Optimised disposal to LLWR
- Physical decontamination
- Chemical decontamination
- Metal melting
5.2 Technology summaries - waste management approaches in routine use

This section provides a compilation of the strategies and approaches employed by site licence companies and the supply chain for the management of pond furniture waste. It should be considered that these techniques can be used separately or in combination; and that, as alluded to in section 3.3, combination of these techniques is typically required to achieve an acceptable waste management outcome.

Each management strategy is presented as a separate section and provides:

- A description of the approach.
- A summary of which types of pond furniture the technique can be used on.
- A description of the outcome of the use of the approach in terms of the primary wasteform (the pond furniture) and any secondary wastes.
- Identification of any advantages and disadvantages with the use of the technique.
- Identification of which SLCs are using that specific technique.

Case studies are included for a number of techniques to illustrate where and how particular SLCs have employed the technique for management of pond furniture.

Glossary of symbols in technology summaries

<table>
<thead>
<tr>
<th>Applicability to waste classifications</th>
<th>Technology applicability</th>
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</tr>
<tr>
<td>ILW/LLW</td>
<td>Technology is potentially applicable to the specific type of waste.</td>
</tr>
<tr>
<td></td>
<td>Technology is not applicable to the specific type of waste.</td>
</tr>
<tr>
<td></td>
<td>Technology is not applicable to the specific type of waste but may be a useful precursor technology prior to use of another technique.</td>
</tr>
</tbody>
</table>

Use of technology

<table>
<thead>
<tr>
<th>Magnox Ltd.</th>
<th>Sellafield Ltd</th>
<th>Research Sites Restoration Ltd</th>
</tr>
</thead>
</table>

1 The technology summaries make reference to the Environmental Permitting Regulations 2010 (as amended) out-of-scope classification, which is applicable in England and Wales. For simplicity, this should be taken to refer to both this classification and the exempt classification used in Scotland under the Radioactive Substances Act 1993 (Scotland) [as amended] (RSA93) definition.
5.2.1 Size Reduction [Ref. 5, 17, 18]

### Usage as standalone technique

<table>
<thead>
<tr>
<th>LLW</th>
<th>ILW/LLW</th>
<th>Surface contaminated</th>
<th>Volumetrically contaminated</th>
<th>Activated</th>
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<td>Aluminium</td>
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</table>

### Description of technique

Size reduction is a set of techniques used to minimise the dimensions of an item or object. For pond furniture, if not undertaken underwater size reduction is predominantly undertaken using so-called “cold-cutting” mechanical techniques or laser cutting, to minimise the spread of contamination to atmosphere. Plasma cutting has been seen to be effective underwater as well as in dry environments and has been used successfully in size reducing fuel skips at Sellafield (Sellafield Ltd.). Examples of mechanical cold-cutting techniques used for size reduction of pond furniture include:

- Mechanical saws (e.g. reciprocating saws) for size reduction of small or medium sized pond furniture components.
- Nibblers (which use reciprocation to nibble through small amounts of metal) used for thick mild or stainless steel components.
- Diamond wire saws used for large components.

### Outcomes

- Reduction in the size of pond furniture components to facilitate further treatment or disposal.
- Secondary wastes are smaller volumes of solid metallic waste for treatment / disposal and tools / tool components.

### Advantages

- Simple.
- Applicable to wide range of metal types.
- Applicable to wide activity range.
- Minimised likelihood of contamination transfer relative to “hot-cutting” techniques.
- Simple and easy to manage secondary wastes.

### Disadvantages

- Use of manual techniques may be difficult in high dose environments.
- Can be difficult to deploy successfully for items of complex geometry.
Technique used at:

- Magnox
- Sellafield Ltd
- Research Sites Restoration Ltd
5.2.2 Surface Washing [Ref. 5, 17, 18]

Usage as standalone technique

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<td>Stainless steel (coated)</td>
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</table>

Description of technique

This is a technique which uses low pressure water (at either high or low temperature) to remove any water soluble and loose debris from the surface of contaminated items. This technique can be applied at close range, at distance or remotely (depending on the space and dose constraints of the area). The efficacy of cleaning can be improved by the addition of detergents and solvents to the water but this can make disposal of the liquid secondary waste more complex. This has been found to be most useful for the removal of bulk solids or sludges from the surfaces of metallic items.

Outcomes

- For LLW:
  - Waste metal decontaminated to EPR out-of-scope status for unrestricted release for re-use or recycle; or
  - Waste metal decontaminated to enable further processing, recycling or disposal.
- For ILW / LLW cross-boundary wastes:
  - Waste metal decontaminated to LLW classification to enable further processing, recycling or disposal.
- Secondary wastes – could potentially generate a large volume of radiologically contaminated aqueous spent washing liquors (potentially contaminated with detergents and solvents).

Advantages

- Simple.
- Applicable to wide range of metal types.
- Applicable to wide activity range.
- Can be applied remotely or at distance.

Disadvantages

- Cannot remove fixed contamination.
- Not useful for volumetrically contaminated or activated metals (unless as precursor step for further treatment).
- Generates large volume of radiologically contaminated aqueous waste requiring disposal.
- Potential for orphan secondary waste generation.
- Effectiveness limited by complex geometries or inaccessible wastes.
LLW Repository Ltd

National Waste Programme

Technique used at:

- Magnox
- Sellafield Ltd
- Research Sites Restoration Ltd
5.2.3 Surface Wiping [Ref. 5, 17, 18]

### Usage as standalone technique

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### Description of technique

This manual decontamination technique involves the physical removal of loose debris and dusts from the surface of the waste item through wiping or vacuuming. Wet wiping is used to remove debris or dusts which cannot be removed by dry wiping either through the use of a liquid soaked wipe or by spraying water / chemicals onto the surface of the item and wiping it off. The application of pressure during wiping of contaminated surfaces can remove any loosely adhering contamination.

### Outcomes

- For LLW:
  - Waste metal decontaminated to EPR out-of-scope status for unrestricted release for re-use or recycle; or
  - Waste metal decontaminated to enable further processing or disposal.
- For ILW / LLW cross-boundary wastes:
  - Waste metal decontaminated to LLW classification to enable further processing or disposal.
- Secondary wastes – high volume of radiologically contaminated solid wipes / swabbing materials (potentially contaminated with detergents or solvents) or solid dust / debris collected by vacuum.

### Advantages

- Simple.
- Applicable to wide range of metal types.
- Applicable to wide activity range.

### Disadvantages

- Cannot remove fixed contamination.
- Not useful for volumetrically contaminated or activated metals (unless as precursor step for onward transfer).
- Manual method – may not be practicable in high dose environments.
- Effectiveness limited by complex geometries or inaccessible wastes.
<table>
<thead>
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<th>Technique used at:</th>
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<tr>
<td>![Magnox Logo]</td>
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<td>![Research Sites Restoration Ltd Logo]</td>
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</table>
5.2.4 Mechanical Surface Decontamination (Ultra-High Pressure Water Jetting) [Ref. 5, 17, 18]

**Usage**

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</table>

**Description of technique**

Ultra-high pressure (UHP) water jetting is a mechanical decontamination technique which uses ultra-high pressure water to physically remove contamination from the surface of an object. The technique can be applied manually using hand-held apparatus or remotely; either in-situ or within closed boxes. UHP water jetting can be used to remove surface coatings (e.g. paint) from surfaces and can be used to remove surface deposits without damaging underlying metal surfaces. Decontamination may be improved through the use of heated water or the addition of abrasives, solvents or detergents to the water.

**Outcomes**

- For LLW:
  - Waste metal decontaminated to EPR out-of-scope status; or
  - Waste metal decontaminated to enable further processing.
- For ILW / LLW cross-boundary waste:
  - Waste metal decontaminated to EPR out-of-scope status; or
  - Waste metal decontaminated to LLW to enable further processing or disposal.
- Secondary wastes include large volume of radiologically contaminated aqueous waste (may contain abrasives, solvents or detergents if used).

**Advantages**

- Quick and relatively simple.
- Applicable to a wide range of metals.
- Applicable to a wide range of radiological activities.
- Useful for the removal of surface coatings.

**Disadvantages**

- Less useful for complex geometries where uniform coverage of the item may not be attained.
- Not useful for volumetrically contaminated or activated metals (unless as precursor step for onward transfer).
- Large volume of secondary wastes generated.
- Potential for orphan secondary waste generation.
- Can be dose-intensive if not used in automated configuration.
Case Study A – UHP Water Jetting of Pond Skips at Bradwell

Challenge

To support accelerated decommissioning of the Bradwell site, a variety of decontamination techniques were trialled on the ILW / LLW cross-boundary pond skips retrieved from the Bradwell fuel storage pond. One trial tested whether removal of the painted surface coating on a pond skip would reduce the radioactivity sufficiently to enable the waste to be classified and managed as LLW.

Solution

UHP water jetting was trialled on a skip as part of this programme. UHP water jetting was used with pressures exceeding 1700 bar using a bespoke built-for-purpose containment system. The trial successfully removed the surface paint from the fuel skip, allowing the skip to be processed as LLW. The process generated approximately 12m³ of waste water with solids including paint flakes entrained in the water. The water was allowed to settle and 0.35m³ of solids were separated and collected for disposal.
5.2.5 Mechanical Surface Decontamination (Shot-Blasting) [Ref. 5, 17-20]

### Usage

<table>
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<tr>
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</table>

### Description of technique

Shot-blasting is undertaken either using SLC infrastructure where available (e.g. the Metal Recycling Facility at Sellafield) or else within the supply chain (e.g. the Studsvik UK Metal Recycling Facility at Lillyhall, Cumbria). Metal is received at appropriate facility, inspected; size reduced as required and is subject to shot-blasting. Shot-blasting is a process by which the metallic waste is subjected to a stream of high-pressure abrasive material; and the friction of the abrasive material removes deposits from the surface of the item and a thin layer of the metal surface. This removes any surface contaminated layer from the item. It should be noted that this technique may be problematic for stainless steels, particularly where contamination is ingrained into the metal surface.

Specific restrictions exist within the Waste Acceptance Criteria (WAC) for dose rate, surface contamination levels, individual item weight and acceptability of surface coated metals. Acceptability of wastes outside the WAC specification would require assessment and decision on a case-by-case basis (for example, this has been successfully undertaken for waste management of the Sellafield MEBs).

The Sellafield Metal Recycling Facility is currently used exclusively for the Sellafield site and processes ferrous metal through shot blasting (the facility cannot accept aluminium or copper for treatment by shot-blasting). The facility can accept metal at relatively low contamination levels (<50cps $\alpha$ and <1500cps $\beta$, with a maximum dose rate of <25$\mu$Sv/hr) and in addition, there are limitations on the geometry and mass of metal which can be processed.

### Outcomes

- For LLW:
  - Waste metal decontaminated to EPR out-of-scope status; or
  - Waste metal decontaminated to enable further processing.
  - Secondary wastes – mixture of blast media and surface wastes. This is disposed of via disposition at LLWR.
- For ILW / LLW:
  - Waste metal decontaminated to LLW

### Advantages

- Applicable to wide range of metal types.
- Applicable to wide activity range.
- Reduces volume of contaminated waste requiring disposal.
- Secondary wastes are easy to manage.

### Disadvantages

- Not useful for volumetrically contaminated or activated metals (unless as precursor step for further processing).
- Generation of airborne contamination.
National Waste Programme

| status to enable for further processing or disposal.  
| Secondary wastes – mixture of blast media and surface wastes. This is disposed of via disposition at LLWR or may be returned to the customer for management if higher activity. |

- Not useful for complex geometries unless size reduced.

Technique used at:

[Sellafield Ltd logo]
5.2.6  Mechanical Surface Decontamination (Spongejet) [Ref. 5, 17, 18]

<table>
<thead>
<tr>
<th>Usage</th>
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</table>

**Description of technique**

Spongejet is a mechanical surface decontamination technique which uses a shot abrasive enclosed within sponge media. The material is jetted at high speed against the surface of the contaminated item, upon which impact the sponge structure flattens to expose the abrasive. Upon leaving the surface of the item, the sponge media expands and creates a vacuum that entraps the contamination (which would have otherwise become airborne). The media can be recycled typically up to ten times. The process is typically operated remotely, within a containment shield, to provide protection to operators. The secondary waste produced by the process is a dry solid waste - the spent spongejet media.

**Outcomes**

- For LLW:
  - Waste metal decontaminated to EPR out-of-scope status; or
  - Waste metal decontaminated to enable for further processing.
  - Secondary wastes – radiologically contaminated spent blast media.

- For ILW / LLW:
  - Waste metal decontaminated to LLW status to enable further processing or disposal.
  - Secondary wastes – radiologically contaminated spent blast media.

**Advantages**

- Applicable to wide range of metal types.
- Applicable to wide activity range.
- Reduces volume of contaminated waste requiring disposal.
- Produces secondary waste which is easy to retrieve, handle and manage.

**Disadvantages**

- Not useful for volumetrically contaminated or activated metals (unless as precursor step for onward transfer).
- Manual process.
**Case Study B – Spongejet decontamination of pond furniture at Hunterston A**

**Challenge**

Hunterston A identified a need to develop improved capabilities for the decontamination and management of surface contaminated metal, including pond furniture.

**Solution**

Spongejet technology had been used by Hunterston A since 2006 for the treatment and management of contaminated steel. A Spongejet KwietKave system was installed and commissioned at the facility to enable more contained and automated use of the process. This has been undergoing trials since 2011, and has proved to be successful with the processing of approximately 50t of contaminated metal to date.
5.2.7 Chemical Decontamination (strong mineral acids) [Ref. 5]

**Usage**

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</table>

**Description of technique**

Strong mineral acids – such as sulphuric acid, hydrochloric acid, nitric acid or phosphoric acid – are particularly useful for the removal of contamination from metals. The action of the strong mineral acid on the metal surface dissolves metal oxide films and improves the solubility of metal ions, thus removing surface contamination from the metal object. These may be applied as a solution, paste, gel or foam by a variety of application methods including jetting, swabbing, wiping or spraying. The performance of the technique is dependent on the nature of the material to be decontaminated, the type of contamination and the geometry of the object.

The technique is applicable to mild steel, stainless steel, aluminium and copper; and can be utilised for decontamination of LLW or ILW/LLW. The technique is for surface decontamination and is not useful for volumetrically contaminated or activated waste, other than a precursor to other waste treatment.

**Outcomes**

- For LLW:
  - Waste metal decontaminated to EPR out-of-scope status; or
  - Waste metal decontaminated to enable further processing.
  - Secondary wastes – acidic liquid radioactive waste.

- For ILW / LLW:
  - Waste metal decontaminated to LLW status to enable further processing or disposal.
  - Secondary wastes – acidic liquid radioactive waste.

**Advantages**

- Mature technology.
- Potentially applicable to LLW/ILW borderline wastes.

**Disadvantages**

- Generates a large volume of acidic liquid radioactive secondary wastes requiring treatment and disposal.
- Technique poses chemical hazards – e.g. corrosivity, toxicity and adverse chemical reactivity.
- Not useful for volumetrically contaminated and activated wastes (unless as precursor to other waste)
Case Study C – Nitric acid decontamination at Hunterston A

Challenge

As part of ongoing deplanting of the fuel storage pond at Hunterston A, 200 aluminium ILW pond skips were identified as requiring a waste management solution.

Solution

A chemical decontamination technique using nitric acid was identified as a solution for the Hunterston A fuel skips. The skips were retrieved from the pond and decontaminated to LLW using a warm (60°C) solution of 6% nitric acid, utilising existing equipment in the skip refurbishment plant. Following decontamination with the nitric acid, the skips were size reduced and coated to meet the acceptance criteria for LLWR. Certain components were compacted following coating to reduce the volume of the waste. The waste was packaged into half-height ISO containers and transferred to LLWR for disposal.

The process generated a significant volume (approximately 140m³) of ILW contaminated liquid secondary waste – the depleted nitric acid containing dissolved contamination and some dissolved aluminium. This has required specialist interim storage in a purpose built acid storage facility pending encapsulation.
5.2.8 Metal Melting [Ref. 5, 17-19, 21-23]

### Usage

<table>
<thead>
<tr>
<th>Material</th>
<th>LLW</th>
<th>ILW/LLW</th>
<th>Surface contaminated</th>
<th>Volumetrically contaminated</th>
<th>Activated</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aluminium</td>
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<tr>
<td>Copper</td>
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<tr>
<td>Mild steel</td>
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<tr>
<td>Mild steel (coated)</td>
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<tr>
<td>Stainless steel</td>
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<tr>
<td>Stainless steel (coated)</td>
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</tr>
</tbody>
</table>

### Description of technique

Metal melting is a technology available to SLCs via the supply chain. There are three main facilities available for the melting of radiologically contaminated metal – Studsvik, Sweden; Siempelkamp, Germany; and Bear Creek, USA.

At all facilities, the basic process is the same - the waste is received at the facility, characterised and size-reduced where required prior to melting (decontamination by shot blasting may also be applied prior to melting by Studsvik and Siempelkamp). The metal is melted in an induction furnace which results in concentration of radioisotopes into the floating slag layer. This floating layer can be collected from the bulk metal and packaged for storage and disposal. This results in a homogenised bulk metal of significantly lower activity than the feedstock metal.

For LLW, the fate of the metal is dependent on the location of treatment:

- At Studsvik the homogenised bulk metal is cast into ingots and sold for recycling. This results in a significant reduction in the volume of the radioactive waste for disposal (typically by 95-96%, although this is variable dependent on the size of the component being melted). The secondary waste (slag, filter dust, furnace lining) is returned to the customer for disposal or else is disposed of directly to LLWR via the Studsvik Metal Recycling Facility at Lillyhall.
- At Siempelkamp, the homogenised bulk metal is cast into blocks and released for recycling, or else is cast into shielding or waste containers for use in the nuclear industry. The secondary waste (slag, filter dust and furnace lining) is returned to the waste generator for disposal.
- At Bear Creek, the homogenised metal is cast into shield blocks for use in the nuclear industry. Any secondary waste arising from the process (e.g. slag, filter dust, furnace lining) is disposed of by EnergySolutions in the USA and there is no repatriation of waste to the UK.

Specific restrictions exist within the Waste Acceptance Criteria (WAC) for each facility relating to:

- Dose rate
- Surface contamination levels
- Individual item weight
- Acceptability of surface coated metals
- Metal type (EnergySolutions Bear Creek, USA facility is unable to process non-ferrous metals).
Detail on the specific restrictions is provided in the facility WAC or else on discussion with Studsvik or EnergySolutions. Acceptability of wastes outside the WAC specification would require assessment and decision on a case-by-case basis.

There is some potential for melting of higher activity metallic wastes (i.e. ILW / LLW boundary wastes) at these facilities but in this case, the partitioning of the radioactivity from the bulk metal may not be complete and so the resultant bulk metal would require either further treatment (where practicable), disposal as LLW or casting into components for use in the nuclear industry. Use of this technology / location would require an assessment of feasibility of the process on a case-by-case basis.

<table>
<thead>
<tr>
<th>Outcomes</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>For LLW (depending on treatment facility):</td>
<td></td>
<td></td>
</tr>
<tr>
<td>o Bulk metal de-classified to exempt and released for unrestricted recycling / re-use; or bulk metal classified to lower activity and recycled to shielding or waste containers for re-use in nuclear industry.</td>
<td>• Potential to recycle metal, minimising volume of radioactive waste requiring disposal.</td>
<td>• Restrictions on dose, contamination and material type may limit applicability.</td>
</tr>
<tr>
<td>o Small volume (4-5%) LLW secondary waste (slag, filter dust, furnace lining) for disposal.</td>
<td>• Mature technology.</td>
<td>• Management of LLW/ILW wastes via this process may take an extended period of time.</td>
</tr>
<tr>
<td>For LLW / ILW boundary waste:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>o Bulk metal de-classified to LLW for further treatment or disposal or recycled to shielding or waste containers for re-use in nuclear industry.</td>
<td>• Potentially applicable to LLW/ILW borderline wastes.</td>
<td></td>
</tr>
<tr>
<td>o Small volume of LLW (highly active) or ILW secondary waste (slag, filter dust, furnace lining) for disposal or storage (pending disposal to GDF) by customer.</td>
<td>• Useful for volumetrically contaminated and activated wastes.</td>
<td></td>
</tr>
</tbody>
</table>
Case Study D – Metal Melting of Sellafield Ltd. MEBs

Challenge

Sellafield Ltd. possesses a significant number of multi-element bottles (MEBs) previously used for the storage of LWR fuel assemblies in ponds pending re-processing; the waste was a mixture of LLW and ILW of varying levels of contamination. To assist hazard reduction and to optimise the waste storage capacity on-site, Sellafield Ltd. sought a waste management solution for these wastes.

Solution

In 2011/12, a project was undertaken between Sellafield Ltd. and Studsvik Ltd. (via the LLWR Ltd. Segregated Service Framework) for the treatment and disposal of 10 MEBs of higher activity (in the range of 752MBq to 3.72GBq total activity per MEB), two of which were classified as ILW. The ILW classification MEBs were decontaminated by Sellafield Ltd. to LLW classification by in-situ underwater pressure jetting. The MEBs were then transferred to the Studsvik MRF facility for size reduction prior to transfer to the Studsvik Metal Treatment and Recycling Facility in Sweden for metal melting. The use of metal melting in this project resulted in the avoidance of disposal of 5 ISO containers worth of metal at the Low Level Waste Repository, as well as significant cost savings for Sellafield Ltd. in the decontamination of ILW to LLW.

Figure 7 – MEB at Studsvik UK Metal Recycling Facility pending size reduction.
Case Study E – Metal Melting of Ferrous Fuel Skips from Hinkley Point A

Challenge

Deplanting of fuel cooling ponds at Hinkley Point A Nuclear Power Plant (Magnox Ltd.) produced 185te of ferrous metallic pond skips, previously used for the wet storage of irradiated nuclear fuel. A waste management solution was required for the treatment and disposal of this waste (classified as LLW, with average activity 5 GBq/te of predominantly Cs-137, Sr-90 and C-14).

Solution

Between 2007 and 2010, a project was undertaken in collaboration between Magnox Ltd. and Energy Solutions for the management of this waste. Magnox Ltd. undertook the partial decontamination of pond skips to facilitate their transfer off-site for treatment. The pond skips were packed into 15 half-height ISO containers (HHISO) and shipped to the Bear Creek facility in Tennessee for melting (Figure 8). Undertaking this project has diverted these 15 half-height ISO containers away from disposal at the LLWR; with 95% recycled as shield block material (Figure 9) and sold for re-use in the nuclear industry, with the remaining 5% of secondary waste disposed of at Energy Solutions Clive facility in the USA.

This project is ongoing with a number of skips awaiting treatment, owing to the high activity of the skips transferred for processing.
5.2.9 Optimised Disposal to Low Level Waste Repository (LLWR)

### Usage

<table>
<thead>
<tr>
<th></th>
<th>LLW</th>
<th>ILW/LLW</th>
<th>Surface contaminated</th>
<th>Volumetrically contaminated</th>
<th>Activated</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aluminium</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Copper</td>
<td>○</td>
<td></td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Mild steel</td>
<td>○</td>
<td></td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Mild steel (coated)</td>
<td>○</td>
<td></td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Stainless steel</td>
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<tr>
<td>Stainless steel (coated)</td>
<td>○</td>
<td></td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
</tbody>
</table>

### Description of technique

Optimised disposal is a methodology which facilitates disposal at the Low Level Waste Repository involving the disposal of two or more wastestreams in the same disposal volume, so as to maximise the use of the disposal volume capacity and minimise the use of inactive grout infill. This methodology is most useful, in the context of pond furniture, for the management of pond skips and containers for which other waste management approaches are not suitable and for which size reduction is not practicable. Optimised disposal would involve such skips or containers being transferred into an appropriate disposal container; and the voidage within the pond skips or containers filled with different radiologically contaminated wasteforms and cementitious grout. The voidage around the skips or containers, within the disposal container is similarly filled with the waste / grout mixture or different additional wastes, either from the same waste producer or from different waste producers. The disposal container is transferred to the LLWR for grouting and disposition.

It should be noted that this management approach, as it requires waste disposal at the LLWR, should be considered only where BAT (i.e. where disposal in an engineered vault is required) and would involve significant assessment by LLW Repository Ltd. The use of this approach would only be deemed acceptable where every reasonably practicable effort has been made to employ alternative conditioning, treatment and disposal routes.

This approach would be suitable for all waste types and potentially for ILW / LLW borderline wastes; but would require significant up-front dialogue with LLWR Ltd.

### Outcomes

- Waste transferred to LLWR for final disposition,
- Optimised use of disposal volume.
- Secondary wastes dependent on wasteforms included in optimised disposal model.

### Advantages

- Useful for situations where size reduction and other management approaches are not practicable.
- Optimises use of the disposal volume at LLWR.

### Disadvantages

- Requires disposal of waste at LLWR, using valuable disposal capacity.
- Removes opportunities for beneficial re-use of metal.
Technique used at:

Magnox  Sellafield Ltd
Case Study F – Optimised Disposal of Pond Skips from Bradwell (Magnox Ltd.) by EnergySolutions and Inutec²

Challenge

To support accelerated decommissioning of the Bradwell site, some 117 pond skips were removed from the Bradwell fuel cooling pond, completing during 2009. These pond skips were classified as higher activity LLW, and owing to various physical, radiological and schedule constraints it was deemed that it was not practicable for these pond skips to be decontaminated by high pressure jetting to enable recycling or for size reduction. The only option was for disposal of the skips.

Solution

A project was initiated by EnergySolutions, in collaboration with Inutec, Bradwell and LLWR Ltd, in 2011 to enable the optimised disposal of these pond skips. The pond skips had been loaded into dumpy bags, to facilitate contamination control, by Bradwell and transferred into half-height ISO containers. These were transferred in batches to the Inutec licensed site at Winfrith licensed site for processing. At Inutec, the HHISO containers were opened, subjected to Health Physics monitoring and the pond skips infilled with additional wastes. Processing of the pond skip was undertaken in stages:

- The outer voidage around the dumpy bags was infilled with cemented waste desiccant, from another waste generator.
- The dumpy bags were cut open and a contamination fixative applied.
- The skips were infilled with cemented waste desiccant (Figure 10).
- Super-compacted waste pucks were then added to the HHISO to fill additional void space (Figure 11).

This optimised disposal model facilitated disposal of these pond skips at LLWR whilst enabling a 50% reduction in the disposal volume and a 90% reduction in inactive grout infill.

² Now Tradebe Inutec
5.2.10 Direct Disposal to Low Level Waste Repository (LLWR)

Usage

<table>
<thead>
<tr>
<th>LLW</th>
<th>Surface contaminated</th>
<th>Volumetrically contaminated</th>
<th>Activated</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aluminium</td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Copper</td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Mild steel</td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Mild steel (coated)</td>
<td>●</td>
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<td>●</td>
</tr>
<tr>
<td>Stainless steel</td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Stainless steel (coated)</td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
</tbody>
</table>

Description of technique

Waste metal is characterised, size reduced (as required) and packed into appropriate ISO disposal containers. Size reduction / compaction etc. is used to ensure that inaccessible voidage within the disposal container is minimised as far as practicable. Additional LLW may be added to the containers to ensure best use of the disposal volume. These are transferred by rail or by road to the Low Level Waste Repository (LLWR) site in Cumbria, filled with cementitious grout and are then transferred into an engineered vault for disposal.

Specific restrictions relating to (but not limited to) waste type, radiological characteristics (total activity, fissile content, radiation, contamination), waste mass and voidage are specified in the waste acceptance criteria (WAC) for the facility.

Outcomes

- Waste disposed of at LLWR.
- Secondary waste – solid wastes from size reduction (e.g. diamond wire), waste grout.

Advantages

- Relatively simple.
- Applicable to wide range of metal types.
- Applicable to wide activity range (up to definition of LLW in LLWR WAC).

Disadvantages

- Uses up valuable waste disposal capacity at a national asset (LLWR).
- Reduces opportunity for re-use and re-cycle of waste.

Technique used at:

![Magnox](image1.png) ![Sellafield Ltd](image2.png) ![Research Sites Restoration Ltd](image3.png)
5.2.11 Disposal to Geological Disposal Facility (GDF) or long term storage in near-surface facility (Scotland)

### Usage

<table>
<thead>
<tr>
<th>Material</th>
<th>Surface contaminated</th>
<th>Volumetrically contaminated</th>
<th>Activated</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aluminium</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
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<tr>
<td>Copper</td>
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<tr>
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<td>Stainless steel</td>
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</tr>
<tr>
<td>Stainless steel (coated)</td>
<td>✔</td>
<td></td>
<td>✔</td>
</tr>
</tbody>
</table>

### Description of technique

Wastes are suitably size reduced, conditioned and appropriately packaged (as per specific agreements and protocols approved by the Radioactive Waste Management Ltd. (RWM). The waste packages are then interim stored by the waste generating site pending future transfer to and disposal at the GDF or long-term storage in near-surface facilities (Scotland).

### Outcomes

- For ILW / LLW cross-boundary wastes or LLW that does not meet the WAC for LLWR:
  - Waste metal conditioned and packaged, as per RWMD specifications, undergoing interim storage pending future disposal.
- Secondary wastes – any solid or liquid wastes arising from conditioning / packaging process (e.g. waste grout).

### Advantages

- Suitable option for some higher activity wastes for which other options are unavailable.
- Applicable to wide range of metal types.
- Applicable to wide activity range.

### Disadvantages

- This does not provide an early solution – GDF is not yet constructed, requiring SLCs to retain and interim store wastes pending future disposal.
- Disposal prevents any potential for re-cycle and re-use.

### Technique used at:

![Magnox](image1) ![Sellafield Ltd](image2)
5.3 Technology Summaries - pond furniture management R&D
This section provides a brief summary of the technologies that have been or are currently being investigated by NDA estate SLCs in R&D programmes.

A significant effort has been expended on research and development into waste management approaches for pond furniture and other contaminated metals, particularly with respect to decontamination techniques. Table 12 provides an overview of the key research and development (both historical and current) pertinent to pond furniture. This overview includes:
- A brief description of the technique.
- Identification of the key limitations and constraints in the use of the technique.
- Identification of any trials undertaken by SLCs into the use of the technique.

Any pertinent case study examples of this R&D – either on pond furniture or analogous wastes – are also provided to illustrate the purpose of the R&D and the outcome of the study.

5.4 Other pond furniture waste management approaches
A wide range of additional waste management practices have been developed within and outwith the NDA estate for the management of waste metals, which may have synergies or applicability to the challenges posed by pond furniture. As these waste management approaches are not in routine usage by SLCs, nor are they the subject of specific R&D for management of pond furniture, detailed information on these techniques is not provided in this document.

Such techniques include:
- Chemical decontamination – bases and alkaline salts
- Chemical decontamination – bleaching
- Chemical decontamination – organic solvents
- Electrochemical decontamination – electropolishing / electrodeplating
- Physical decontamination – dry ice crystal blasting
- Physical decontamination – ice crystal blasting
- Physical decontamination – laser ablation
- Physical decontamination – scarifying, scabbling and planing
- Physical decontamination – steam cleaning
- Physical decontamination – thermal degradation
- Physical decontamination – ultrasonic cleaning

Further detailed information about these waste management approaches is available on the Environment Agencies Requirements Working Group (EARWG) website [Ref. 17].
## Table 12 – Summary of historic and current R&D into pond furniture management

<table>
<thead>
<tr>
<th>Technique</th>
<th>Description</th>
<th>Limitations and constraints</th>
<th>Trials of process</th>
<th>Outcome of trials</th>
</tr>
</thead>
</table>
| Chemical decontamination (foam) [Ref. 17, 18] | Foam decontamination is a chemical technique used to remove loose surface contamination and grease from items. The foam is a micro-dispersion of air and gas, which typically contains acids (either inorganic or organic) and surfactants. Foams can be pumped or sprayed onto surfaces, and is suitable for either manual or remote deployment. The technique has the advantages of being relatively cheap, simple, with low residual levels of contamination and is suitable for use on items with complex geometries. | - Only applicable to surface contaminated wastes.  
- Best suited to non-porous surfaces (i.e. less useful for rusted surfaces).  
- Generates radiologically contaminated liquid secondary wastes.  
- Problems may be encountered keeping foam in-situ on vertical surfaces; this can be overcome by the use of organic additives but these may make secondary waste disposal more complex.  
- Technique potentially poses chemical hazards – e.g. corrosivity, toxicity and adverse chemical reactivity. | - Decontamination of pond skips and pipelines associated with cooling pond systems with chemical foam at Sellafield (Sellafield Ltd.). | Foam decontamination demonstrated to be technically feasible and to deliver appropriate level of decontamination of pond skips and pipework. Foam decontamination has seen some routine use for non-pond furniture wastes (e.g. transport flasks). |
### Technique | Description | Limitations and constraints | Trials of process | Outcome of trials |
|---|---|---|---|---|
| DFD [Ref. 24] | DFD is a chemical decontamination process which involves the treatment of surface contaminated metal objects with dilute fluoroboric acid with a controlled oxidation potential. This process removes the outer scale and a thin surface layer of metal, thus removing surface contamination from the metal. The fluoroboric acid is recirculated through the system and is regenerated through an ion exchange system. Use of this process enables the re-classification of metal either to EPR out-of-scope (thus allowing for unrestricted recycling and reuse) or else to a state where the metal is suitable for alternate metal treatment. The secondary waste from the process consists of the spent dilute fluoroboric acid and the spent ion exchange resin. The system can be deployed at either high or low temperature, depending on the nature of the contamination on the metallic waste and the constraints on the waste owner. High temperature processing is more aggressive and is particularly suited to situations where contamination of the item has occurred in high temperature environments. The process can be deployed either from a mobile plant at the waste owners site or else at an appropriately licensed off-site location. | - Only applicable to surface contaminated wastes, unless as a precursor to step to other waste treatment.  
- Only applicable to painted surfaces where paint is in poor condition. | - Wylfa titanium heat exchanger plates [case study G]  
- Work between Bradtec / ONET Technologies and Studsvik UK to undertake active trials of the system on items of pond furniture. | DFD demonstrated to be successful in decontamination of Wylfa heat exchanger plates to exempt levels. In the Studsvik trials, DFD was successfully used to decontaminate stainless steel under lab conditions, however this has not yet been used to develop a service offering due to limited success in metals containing boron carbide. |
<table>
<thead>
<tr>
<th>Technique</th>
<th>Description</th>
<th>Limitations and constraints</th>
<th>Trials of process</th>
<th>Outcome of trials</th>
</tr>
</thead>
</table>
| DFDX [Ref. 25] | DFDX is a variant of the DFD process, and is a chemical decontamination process which involves the treatment of surface contaminated metal objects (size reduced when required) with dilute fluoroboric acid with a controlled oxidation potential. This process removes the outer scale and a thin surface layer of metal, thus removing surface contamination from the metal. The fluoroboric acid is recirculated through the system and is regenerated through an electrochemical cell. The use of the electrochemical cell enables the metal ions in the spent fluoroboric acid to be converted to a solid metal particulate, which can be collected and removed for disposal. This reduces the volume of secondary waste requiring management by the waste owner, relative to the DFD process. Use of this process enables the re-classification of metal either to EPR out-of-scope (thus allowing for unrestricted recycling and reuse) or else to a state where the metal is suitable for alternate metal treatment (e.g. metal melting). The system can be deployed at either high or low temperature, depending on the nature of the contamination on the metallic waste and the constraints on the waste owner. The process can be deployed either from a mobile plant at the waste owners site or else at an off-site location. | - Less useful on simple geometries.  
- Only applicable to surface contaminated wastes (unless as a precursor step to other waste treatment technologies).  
- Only applicable to painted surfaces where paint is in poor condition. | Trialled at Hinkley Point A (Magnox Ltd.) to test whether DFDX could be used for paint removal and metal decontamination of a fuel skip. | DFDX observed to be successful in metal decontamination. Further trials or usage of the system for pond furniture items in UK nuclear industry has been limited. |
## Garnet Blasting

### Technique
Garnet Blasting [Ref. 17, 18]

### Description
Garnet blasting is a mechanical surface decontamination technique which uses garnet (a mixture of various silicate chemicals) as an abrasive which is propelled in a high-energy jet stream at a target area, which abrades away the contamination. This is often used in conjunction with UHP water jetting.

### Limitations and constraints
- The technique is most effective on flat surfaces – items with more complex geometries may see a reduction in efficacy.
- Only applicable to surface contaminated wastes (unless as precursor step to other waste treatment methods).
- Process generates a large volume of secondary waste, owing to the volume of abrasive media and water used.
- Garnet has a limited lifespan due to disintegration of the media.

### Trials of process
- Trialled at Bradwell (Magnox Ltd.) to test effectiveness of process on pond furniture and other contaminated metals.

### Outcome of trials
Garnet blasting observed to be effective in the surface decontamination of metal but has not been progressed to further trials or routine usage owing to the large volume of secondary waste and the limited lifespan of the media.
<table>
<thead>
<tr>
<th>Technique</th>
<th>Description</th>
<th>Limitations and constraints</th>
<th>Trials of process</th>
<th>Outcome of trials</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metal milling</td>
<td>Rotary grinders and milling machines are used to remove thin layers of the item surface in order to remove surface contamination. The secondary waste arisings are the solid metal shavings, which are easily retrieved. There is some potential for liquid secondary wastes from lubrication of the milling machine. Milling can be deployed remotely, reducing operator dose, using computer numeric control (CNC) milling machines. They operate in a dry environment, avoiding the creation of wet secondary waste, and often have an enclosure to minimise the spread of contamination.</td>
<td>• May be time-consuming, especially when changing between configurations for different geometries of items. • May leave some residual surface contamination (depending on technique). • Potential for generation of pyrophoric dust production if used on aluminium.</td>
<td>Trial undertaken at Bradwell during 2012 to test the viability of milling as a decontamination technique for contaminated metal (particularly skips). Trials of the use of computer guided milling machines, on several skips at Hinkley Point A.</td>
<td>Bradwell 2012: Milling proved to be successful in the removal of surface contamination and a small surface layer of metal. Several skips had 1.2mm of paint and metal removed, resulting in re-classification as out of scope material. Removing 20% of the skips’ mass by milling removed all detectable radioactivity</td>
</tr>
</tbody>
</table>
### Nitrocision

**[Ref. 17, 18]**

This is a cryogenic decontamination technique involving the application of liquid nitrogen at high pressure and low temperature to decontaminate the surface of items. The surface residues can be removed either through vibration, ultrasonic cleaning or the inclusion of abrasive media in the liquid nitrogen.

This technique produces minimal secondary wastes (i.e. only the actual surface material removed by the process, with evaporation of the nitrogen and release to atmosphere).

<table>
<thead>
<tr>
<th>Technique</th>
<th>Description</th>
<th>Limitations and constraints</th>
<th>Trials of process</th>
<th>Outcome of trials</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrocision</td>
<td>This is a cryogenic decontamination technique involving the application of liquid nitrogen at high pressure and low temperature to decontaminate the surface of items. The surface residues can be removed either through vibration, ultrasonic cleaning or the inclusion of abrasive media in the liquid nitrogen. This technique produces minimal secondary wastes (i.e. only the actual surface material removed by the process, with evaporation of the nitrogen and release to atmosphere).</td>
<td>• Process is undergoing development for transfer into the nuclear industry – this may present challenges in terms of scale of use. • Health and safety risks associated with the use of cryogenic materials. • Limited to use on surface contaminated items.</td>
<td>Inactive trials have been undertaken by Magnox Ltd.</td>
<td>Technique demonstrated to remove the protective coating from skip surfaces and potential for decontaminating base metal with the use of abrasive in the nitrogen stream demonstrated.</td>
</tr>
</tbody>
</table>
Case Study G – DFD decontamination of Wylfa heat exchanger plates

Challenge

Wylfa Nuclear Power Station (Magnox Ltd.) identified a contamination issue with heat exchanger plates, which require periodic refurbishment by an off-site contractor. These heat exchanger plates are used in the cooling loop on the pressure vessel to remove heat from the cooling water before it is discharged to sea. These plates are subject to mildly radioactive deposits from the precipitation of iron corroded from the carbon steel pipe work in the system. Removal of these deposits was deemed necessary to enable the transfer of the waste to an off-site contractor for refurbishment.

Solution

Bradtec worked with Wylfa to deploy the mobile DFD process rig at an appropriately licensed off-site location. The plates were subject to the DFD process which successfully removed the mildly radioactive iron deposits from the complex heat exchanger plate geometries, generating a small volume of contaminated ion exchange resin disposed of by Wylfa. This project facilitated the unrestricted release of 1500 heat exchanger plates for refurbishment and re-use on site at Wylfa.

Figure 13 – Wylfa Heat Exchanger plate prior to application of DFD process

Figure 14 – Wylfa Heat Exchanger plate post application of DFD process
6. Waste Management Decision Making Logic

As illustrated by Section 5, a wide range of waste management approaches are applied within the NDA estate for the management of pond furniture. The selection of waste management approach for a specific item of waste is undertaken by identification of BAT through assessment a range of factors including (but not limited to) cost, schedule constraints, the characteristics of the waste, dose management and ALARP, the location and accessibility of the waste, regulatory requirements etc. balanced against the defined strategic direction for that plant / site / SLC [Ref. 27]. Despite this plant / site / SLC specificity, a generic approach can be defined for the waste management decision making process using the principles of the waste management hierarchy.

This generic approach is summarised in a thought logic diagram in Figure 15. It should be noted that the purpose of this logic diagram is to provide an illustration of the relationship between specific waste management approaches and waste management outcomes mapped using the principles of the waste management hierarchy, so as to identify key areas for consideration in the decision making process, rather than to provide a rigid framework for waste practitioners to work to. Waste practitioners should use this decision making logic in conjunction with their own waste management strategies and procedures when optioneering waste management strategies for pond furniture.

A key point for consideration by waste management practitioners is the timing of the waste management decision making process. Ideally, this should be undertaken as early as possible in the lifecycle of the waste (i.e. prior to the retrieval of waste where practicable). This enables timely characterisation and decision-making, minimising the likelihood of operational and schedule constraints being realised. It is recognised that in some circumstances, this is difficult to achieve as operational reasons may require retrieval of the waste before characterisation and waste management decision-making can be undertaken. The decision making process should consider the feasibility of down classification of waste, volume reduction, disposal volume optimisation and the suitability of the waste for disposal (based on the earlier decisions) at appropriate disposal routes.

Characterisation is a fundamental and vital element of the waste management process, in that it generates a set of data describing the radiochemical, chemical and physical properties of the waste. The design and implementation of any characterisation scheme should take account of, but not limited to, history / provenance of the item, the purpose / desired output of the study, cost, schedule constraints, the ease of accessibility of the item, ALARP, and other health and safety considerations. Characterisation should ideally be undertaken as early as possible in the lifecycle of the waste, so as to ensure that waste management options are not foreclosed at an early stage. For waste management practitioners, the output of the characterisation process should provide
sufficient information on the radiochemical, chemical and physical characteristics of the waste to enable radiological classification of the waste and to enable adequate assessment of the suitability of the waste against various management options.
Figure 15 – Waste management decision making logic
Whilst it is accepted that waste management decisions are made by weighing up a variety of factors including the characteristics of the waste, cost, schedule, ALARP, technology / waste route availability, and other health / safety factors, it should be noted that waste management decisions should be directed by application of BAT and consideration of the waste hierarchy (illustrated in Figure 16), which is central to the National LLW Strategy (Ref. 1), as far as practicable.

**Figure 16 – Waste Hierarchy**

For pond furniture waste, as there are no opportunities to avoid generation of the waste as the waste is extant, the focus for waste management practitioners should be on maximising opportunities for minimising the volume of waste to be managed as LLW or ILW through the use of treatment technologies such as metal melting or surface decontamination. Reducing the radiological classification of the waste provides greater opportunity for re-use and re-cycle, and greater opportunities for diversion away from disposal at LLWR or the future GDF, as well as providing a range of waste management solutions which are available in the nearer term than disposal facilities for higher activity wastes. This enables waste management practitioners to achieve earlier solutions for final disposal and discharge of liabilities. Only where re-use, recycle and down-classification of waste through treatment have been assessed and discounted as not being BAT should disposal be considered as a viable waste management option.

It should be considered that the application of waste treatment technologies often result in the generation of secondary wastes. The type, volume, radiological classification and ease of disposal of any such secondary wastes should be assessed in the waste
management optioneering process. In particular, careful consideration should be given to the feasibility of generation of orphan wastes (either as secondary waste or as primary waste). The management of orphan waste can be complex and costly for SLCs, and as such the potential for the generation of orphan wastes through the application of any given technology should be assessed during the waste management optioneering process. All practicable steps should be taken so as to minimise the generation of orphan wastes.

For higher activity wastes (highly active LLW or ILW), the feasibility of decay storage should be assessed as a mechanism to reduce the radiological classification of the waste. Assessment of the feasibility of decay storage is likely to include assessment of the characteristics of the waste and the probability of radioactive decay within an acceptable timescale producing a waste of a lower radiological classification. This will also include assessment of acceptable timescales, programme schedule, cost, storage capacity, interim or final site end-states, regulatory requirements and stakeholder concerns.

Disposal of waste should be considered as the last resort and should only be sought where it is justified as being BAT; although it is accepted that it may be the only acceptable waste management option in some cases. Given the demands that disposal can pose – in terms of challenge to the finite disposal capacity for LLW disposal and in terms of cost for ILW disposal – waste managers should take every practicable step to minimise the volume requiring disposal (for example, through the use of size reduction) or to optimise the use of the disposal volume (for example, through the use of co-disposal of metallic waste with other waste types).
7. **Issues and Opportunities**

During development of this strategic guidance document, a number of generic issues have been identified. These issues pose barriers and challenges to the effective management of pond furniture.

The generic issues and barriers associated with management of pond furniture include:

- A lack of centralised approach, leading to inconsistencies in the level of maturity of decontamination planning and implementation across the NDA estate. This contributes to duplication of effort (particularly with respect to R&D) or the perception of the duplication of effort.

- The challenge of obtaining changes to environmental permits, for example in the circumstances where an increase in discharge limits is required to support decontamination. There may be a tension in timescales and ideals between pond furniture management programmes and the regulators.

- Characterisation of pond furniture, whilst critical to waste management, is challenging as a consequence of the high-dose environments where the waste is located and limited alternative buffer storage in lower-dose environments.

- Operational difficulties in packaging and transport of pond furniture, particularly ILW / LLW cross-boundary wastes, impact the ability of SLCs to transfer waste into the supply chain for treatment.

- There is a requirement for R&D, as there is no “one size fits all” waste management solution owing to the significant variance in total activity and dose rate in the inventory of pond furniture. Such R&D is costly and time consuming, and can create tension with the programme for waste retrievals and decommissioning of fuel ponds.

- There are limited facilities currently available on SLC sites with the capability to handle higher activity (ILW / LLW cross boundary waste and ILW) pond furniture which impacts on the waste management approaches which can be employed.

- There is a lack of centralised facilities, requiring each site to develop its own capability. This can adversely impact on the waste management approach which can be employed, owing to limitations on economies of scale and constraints on individual site funding, schedule and end states.

Allied to the issues and barriers associated with the management of pond furniture, there are a number of opportunities to support improved efficacy of management of this waste within the NDA estate. These opportunities include:
• Improved and more formalised linkages between SLCs to support the transfer of knowledge and lessons learned, particularly with respect to R&D. It is recognised that there is communication between SLCs but this could be further augmented, as could opportunities for collaborative working between SLCs.

• The commercial viability of centralised facilities for the management of pond furniture should be investigated. This could be encouraged through engagement with the supply chain. Centralising approaches and facilities is likely to improved value through centralised R&D / technology transfer and better economies of scale.
8. Conclusions

This strategic guidance document has compiled a baseline for the management of LLW and ILW / LLW cross-boundary pond furniture in terms of waste inventory, routinely implemented waste management approaches and historic / current R&D. This document provides the first comprehensive review of the management of lower activity pond furniture within the NDA estate and provides waste practitioners (and indeed other stakeholders) with a toolkit of information to support and guide decision making with respect to management of this waste type.

The key conclusions from this strategic guidance document are:

- Compilation and review of the UKRWI shows that (at best estimate) the total volume of LLW and ILW / LLW cross-boundary pond furniture within the NDA estate is approximately 26668m$^3$. Approximately 88% of this waste is located at the Sellafield site. This waste inventory is predominantly stainless steel, with a smaller proportion of other ferrous metals and significantly smaller volumes of other metals. This waste inventory is dominated by LLW. In the near term (i.e. in period up to 2030), it is anticipated that the majority of the waste will be generated from retrievals at Magnox Ltd. sites and the high hazard pond facilities (FGMSP and PFSP) at Sellafield.

- A range of approaches are currently used for the waste management of pond furniture. These include size reduction, mechanical decontamination (surface washing, surface wiping, UHP water jetting, shot-blasting and sponge-jet), chemical decontamination, metal melting and disposal (either direct / optimised disposal to LLWR or else interim storage pending disposal to GDF). Historically, there has been a reliance on disposal as the main management approach but there is increasing usage of routes better aligned with the waste management hierarchy allowing for reuse and recycle, and diversion from disposal.

- Significant efforts have been made in research and development allied to the management of pond furniture, particularly by Magnox Ltd. Examples of techniques which have been trialled on pond furniture (or analogous wastes) include chemical decontamination with foam, DFD, DFDX, garnet blasting, metal milling and nitrocision. It is anticipated that successful R&D will transfer, over time, into routine usage where successful and appropriate to the waste.

- Pond furniture is a complex waste type and is highly variable in physical, chemical and radiochemical characteristics within individual populations (i.e. within the same pond) and between sites / SLCs. Whilst a range of waste management approaches for pond furniture have been identified, it should be noted that management of this waste type is challenging for SLCs as a consequence of this variability.
A generic waste management decision making approach, utilising the principles of the waste management hierarchy, has been defined for pond furniture. Early planning and optioneering prior to retrievals is identified as good practice, to mitigate against foreclosing options, and enabling collection and use of characterisation data. The value of characterisation as a mechanism to facilitate the underpinning of waste classifications and optioneering decisions is highlighted. Opportunities to down-classify waste, re-use and recycle should be sought and exploited where practicable. Disposal should be considered to be a worst case approach, and should only be pursued where other options have been exhausted and where demonstrated to be BAT. Careful consideration should be given to the nature and management strategy for any secondary wastes generated through the use of a treatment approach. In particular, generation of orphan wastes should be avoided.

A number of generic issues and barriers have been identified which make effective management of pond furniture more challenging for SLCs. These include the nature of the waste (i.e. the variability in the radiochemical characteristics of the waste within the inventory), the environment where the waste is stored (e.g. high dose environments making characterisation and waste management more dose intensive to operators, so requiring more automated and remote systems for waste management), tensions with the regulatory permitting regime and limited facilities, particularly for higher activity wastes. Opportunities have been identified to improve transfer of knowledge and to investigate the viability of centralised facilities for management of pond furniture.
9. References

1. UK Strategy for the Management of Solid Low Level Radioactive Waste from the Nuclear Industry, NDA, August 2010


5. Spent fuel storage and transport cask decontamination and modification: An overview of management requirements and applications based on practical experience, IAEA-TECDOC-1081, IAEA, 1999


9. UK 2013 Radioactive Waste Inventory Main Report

10. Magnox Plan Summary: Magnox Lifetime Plan 2012, Magnox Ltd., Issue 1, 2012


14. Sellafield Plan, Sellafield Ltd., Issue 1, August 2011


17. EARWG Waste Minimisation Good Practice Technology Database
   (http://www.rwbestpractice.co.uk/Main.aspx) worksheets:
   a. Foam Decontamination, Version 1, 2008
   b. Cryo-Cleaning, Version 1, 2007
   c. Mechanical Cutting (Hands On and Remote), Version 1, 2008
   e. Wiping / Scrubbing, Version 1, 2006
   f. Water flushing, Version 1, 2005
   g. Use of strong mineral acids, Version 1, 2008
   h. Melting, Version 1, 2004
   i. Use of abrasive cleaning, Version 1, 2008
   j. Metal milling, Version 1, 2005


19. UK Management of Solid Low Level Radioactive Waste from the Nuclear Industry: Metal Decontamination Study, LLW Repository Ltd., Issue 1, 2009


23. Innovative water treatment and conditioning technologies at nuclear power plants, IAEA-TECDOC-1504, IAEA, 2006


27. Policies and strategies for radioactive waste management, NW-G-1.1, IAEA, 2009