Nuclear Decommissioning Authority

Improved Management of Problematic Radioactive Waste

Credible Options (Gate A)

September 2016

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Executive Summary

The Nuclear Decommissioning Authority (NDA) is committed to considering opportunities to reduce the overall costs, environmental impacts, and timescales for nuclear decommissioning and site restoration by optimising waste management. Radioactive Waste Management Limited (RWM) and Low Level Waste Repository Limited (LLWR) have undertaken several studies on the management of problematic radioactive wastes, addressing Higher Activity Waste (HAW) and Lower Activity Waste (LAW), respectively. The findings of these studies have been used to identify the potential strategic options described in this report.

The strategic focus of this document is primarily the NDA estate however; the scope of our work addresses strategic options that could apply to the management of problematic radioactive wastes generally, including NDA and non-NDA wastes, lower activity and higher activity wastes. Whilst the NDA is only accountable for the waste at NDA sites, managed by its Site Licence Companies (SLCs), there are also a number of non-NDA sites generating volumes of HAW and LAW. The non-NDA HAW is within the scope of wastes that are considered for disposal by RWM, which is a waste management organisation and wholly owned subsidiary of the NDA. For LAW, in addition to NDA estate LLW producers, there are a number of LLW producers that are not part of the NDA-estate, but which are part of the LLW National Waste Programme led by LLWR (which is the UK LLW management organisation and an SLC).

NDA sites have wastes which are not suitable for treatment in existing processing plants (or those currently planned at a detailed level). These wastes can be referred to as ‘problematic wastes’. They may also be known as ‘orphan waste’ or ‘waste requiring additional treatment’ (WRAT).

There are several reasons that wastes may be considered problematic, for example the waste may:

- Have an unknown provenance or inventory (e.g. concrete lined drums originally destined for sea disposal).
- Have a specific hazard (e.g. pyrophoric material).
- Be unsuitable for a standard treatment process (e.g. reactive metals which are unsuitable for encapsulation by standard cementitious grout).
- Pose issues to the disposability of a waste package (e.g. particulates).
- Pose operational or interim storage issues (e.g. radon emanating waste).

Previous work conducted by RWM and LLWR has collated UK wide inventories for problematic radioactive waste.

The work has also stated potential treatment options and defined knowledge gaps and research needs. Generic categories of problematic radioactive waste have been defined to enable analysis of the inventory. Appendix 1 of this document shows each category and states which sites have the problematic radioactive waste. The total volume of problematic radioactive waste in the UK is estimated[1] to be ~38,000m^3, however, it is acknowledged that waste which is problematic at one site may not be problematic at another site, as capabilities, infrastructure and Lifetime Plans vary.

Currently, all nuclear SLCs and non-NDA estate radioactive waste generating organisations (collectively referred to as 'waste producers') manage their own problematic radioactive wastes to fit with their own Lifetime Plans and business plans. Under their permits, waste producers are responsible for managing all the waste (including problematic radioactive waste) at their site(s).

Collaboration between waste producers, on technical issues, has improved in recent years, but there may be a potential to introduce further efficiencies when considering waste management across the nuclear industry as a whole.

There are many assumptions in the current plans for the treatment of problematic radioactive waste at waste producing sites. As well as some unknowns in the treatment techniques that may be employed in the future, inventories of problematic radioactive wastes are subject to uncertainty. Many uncertainties around the properties of the waste are only likely to become clearer at the time of retrieval and characterisation. This leads to risks with currently projected costs and timescales for treatment of problematic radioactive wastes as they are based on assumptions.

The management of most problematic radioactive waste is not currently planned in detail, for HAW it is likely most processing will not occur in the near term as priority is often given to bulk wastes and legacy facilities. For some sites, the treatment of problematic radioactive waste is, however, a critical path activity for decommissioning and site restoration. In the case of LAW, it is anticipated that near-term solutions will be required. If an estate wide strategy for problematic radioactive waste is developed in the near-term, there is a potential to not only save time and money on the treatment of these wastes, there is also a potential to remove these activities from the site critical path, bringing further savings and earlier solutions. Even if these

[1] This is based on the inventory analyses undertaken in the RWM and LLWR studies. It is noted that the waste is often not well characterised and there is the potential for uncertainty on categorisation to lead to duplication between the two inventories.

activities cannot be removed from the critical path, NDA risks and uncertainties could be reduced.

For some categories of problematic radioactive waste, the majority of waste producers have a fairly small volume (e.g. batteries, solvents and pyrochemical waste), which would make the development of treatment capability at each site disproportionately expensive per unit volume. Individual projects at sites may not be able to afford a solution, but an estate wide approach could potentially be utilised to develop a cost effective process. If the development, or the provision, of a treatment facility occurs at an estate wide level rather than at a project or site level, then the opportunity and therefore the incentive is likely to be greater for the supply chain. By taking a strategic overview of problematic radioactive wastes, decommissioning programmes can be de-risked if waste management does not become a critical path project. Non-NDA estate waste volumes and commercial drivers can contribute to economies of scale and development of timely solutions. The strategic overview allows us to make best use of current and future facilities. By sharing information and learning, the NDA can minimise the number of new facilities required and move from problematic radioactive wastes to 'business as usual'.

17 potential options for the improved management of problematic radioactive waste have been identified and are described in this document. The options are not mutually exclusive, and have different insertion points along the waste lifecycle, but all options could potentially help to improve the current situation. From this initial long list of options, potential options have been combined and 5 potential options have been ruled out as not appropriate to pursue at an estate wide strategic level, although some may be beneficial at a site specific level.

12 options have been identified as being credible. Some credible options are very similar from a strategic point of view, but the commercial case, financial case and management case are likely to be very different, so they have been described separately. These options are not mutually exclusive and it is likely that some combination of these options may be required to enable a transformation in the management of problematic radioactive waste in the UK. These credible strategic options align with the waste management principles set out in our Strategy.

This Gate A paper concludes that the options shown in the table below are considered to be credible, and will be taken forward for analysis in a Gate B paper.

TABLE ES1 - CREDIBLE STRATEGIC OPTIONS FOR IMPROVED MANAGEMENT OF PROBLEMATIC RADIOACTIVE WASTE

Credible Strategic Options
No change to current strategy
Promoting timely characterisation of waste
Knowledge transfer between waste producers
Early and collaborative engagement between waste producers and LLWR/RWM as integrators
Transfer waste to an existing waste processing facility
Use mobile characterisation plant
Use mobile treatment plant
Make better use of the supply chain to treat waste in the UK
Provision of a problematic radioactive waste treatment service
Utilise one or more new centralised treatment facilities
International coordination (overseas treatment)
Design a standard treatment plant that can be built on multiple sites

1 Introduction

The Nuclear Decommissioning Authority (NDA) is committed to considering opportunities to reduce the overall costs, environmental impacts, and timescales for nuclear decommissioning and site restoration by optimising waste management. Radioactive Waste Management Limited (RWM) and Low Level Waste Repository Limited (LLWR) have undertaken several studies on the management of problematic radioactive wastes, addressing Higher Activity Wastes (HAW) and Lower Activity Wastes (LAW), respectively [1, 2, 3 & 4]. Findings of these studies have been used to identify the potential strategic options described in this report.

The strategic focus of this document is primarily the NDA estate however; the scope of our work addresses strategic options that could apply to the management of problematic radioactive wastes generally, including NDA and non-NDA wastes, lower activity and higher activity wastes. Whilst the NDA is only accountable for the waste at NDA sites, managed by its Site Licence Companies (SLCs), there are also a number of non-NDA sites generating volumes of HAW and LAW. The non-NDA HAW is within the scope of wastes that are considered for disposal by RWM, which is a waste management organisation and wholly owned subsidiary of the NDA. For LAW, in addition to NDA estate LLW producers, there are a number of LLW producers that are not part of the NDA-estate, but which are part of the LLW National Waste Programme led by LLWR (which is the UK LLW management organisation and an SLC).

All waste producers have wastes which are not suitable for treatment or disposal in existing processing plant or through existing routes (or those currently planned at a detailed level). These wastes can be referred to as ‘problematic radioactive waste’. They may also be known as ‘orphan waste’ or ‘waste requiring additional treatment’ (WRATs). Both terms are commonly used, sometimes interchangeably and therefore our work has not applied any strict definition and the scope does not differentiate between the two.

Some sites have used the term ‘orphan’ to describe waste with an unknown provenance or incomplete characterisation. A lack of information can cause difficulties with sentencing the waste to a route, as there is uncertainty that the conditions for acceptance will be met.

The term ‘WRAT’ is used by some sites when they know waste will require additional treatment steps to ensure it is compliant with plant safety cases or disposability requirements. The additional treatment needed is often not completely technically underpinned, and is subject to uncertainty.

There are several reasons that wastes may be considered problematic, for example the waste may:

- Have an unknown provenance or inventory (e.g. concrete lined drums originally destined for sea disposal).
- Have a specific hazard (e.g. pyrophoric material).

- Be unsuitable for a standard treatment process (e.g. reactive metals which are unsuitable for encapsulation by standard cementitious grout).
- Pose issues to the disposability of a waste package (e.g. particulates).
- Pose operational or interim storage issues (e.g. radon emanating waste).

An RWM Upstream Optioneering project, conducted in 2013 [1], developed a UK inventory of HAW problematic radioactive waste which has subsequently been developed by LLWR to produce an inventory for low level problematic waste data. These projects also looked into potential treatment solutions for each type of problematic radioactive waste and detailed future work needed to enable the treatment of all waste. Many potential strategies to improve the management of problematic radioactive waste are drawn from conclusions and recommendations in these studies.

The projects categorised all problematic radioactive waste into generic categories. Appendix 1 shows a table with details of why each category is considered problematic, and shows the sites known to have that type of waste.

Through each of the studies gathering information about problematic radioactive waste, each waste producer has been directly engaged with, so that the most realistic picture could be gained. The detail of problematic radioactive waste, especially for historical waste, is often held by key individuals at site and is based on their plant knowledge rather than a formal record. Therefore information gained anecdotally was often more relevant and representative than information gained by looking at collated inventories such as the United Kingdom Radioactive Waste Inventory (UKRWI). This is one of the key reasons for developing strategy in this area.

Problematic radioactive waste often occurs as a small fraction of a larger waste stream, so specific properties are not obvious from an overview. Several individuals at sites have very good knowledge and experience of developing treatment solutions for some problematic radioactive waste, so were a good source of information to understand specific complications with some wastes.

2 The Strategic Case

2.1 Existing situation

Currently, all waste producers manage their own problematic radioactive wastes to fit with their own Lifetime Plan and business plans. Under the terms of their permits, waste producers are responsible for managing all the waste (including problematic radioactive waste) at their site(s).

Collaboration between waste producers on technical issues has improved in recent years, but there may be a potential to introduce further efficiencies when considering waste management across the NDA estate and the nuclear industry as a whole.

Some waste producers have made significant steps in treating problematic radioactive wastes, and many technical solutions have been found. Through recent projects [1, 2, 3, & 4], further technical solutions have been found and a number of research needs have been identified.

Some wastes are currently considered to be problematic because insufficient characterisation has been undertaken to be able to demonstrate compliance with acceptance criteria for treatment or disposal. Gaining a better understanding of the characteristics of the waste may enable them to be managed using existing routes.

There are many assumptions in the current plans for the treatment of problematic radioactive waste at each site. As well as some unknowns in the treatment techniques that may be employed in the future, inventories of problematic radioactive wastes have large uncertainties. Many uncertainties are only likely to become clearer at the time of retrieval and characterisation. This leads to risks with currently projected costs and timescales for treatment of problematic radioactive wastes.

2.2 The case for change

The management of most problematic radioactive waste is not currently planned in detail. For HAW it is likely most processing will not occur in the near term as priority is often given to bulk wastes and legacy facilities. For some sites, the treatment of problematic radioactive waste is, however, a critical path activity for decommissioning and site clearance. In the case of LAW, it is anticipated that predominantly near-term solutions will be required and will be available. If an estate wide strategy for problematic radioactive waste is developed in the near-term, there is a potential to not only save time and money on the treatment of these wastes, but also to remove these activities from the site critical path, bringing further savings. Even if these activities cannot be removed from the critical path, NDA risks and uncertainties could be reduced.

Significant technical information on the management of problematic radioactive waste had been developed by waste producers, RWM and LLWR. Without a holistic strategic approach there is a danger that this information will not be shared and implemented effectively at each site, potentially leading to duplicated effort.

For some categories of problematic radioactive waste, the majority of waste producers have a fairly small volume (e.g. batteries, solvents and pyrochemical waste), which would make the development of treatment capability at each site disproportionately expensive per unit volume. Individual project budgets at sites may not be able to afford a solution, but an estate wide budget could potentially be utilised to develop a cost effective process. If the supply chain was involved with the development, or the provision, of a treatment facility, the incentive is likely to be greater at an estate wide level rather than at a project or site level. By taking a strategic overview of problematic radioactive wastes, decommissioning programmes can be de-risked by ensuring waste management does not become a critical path project. Non-NDA estate waste volumes and commercial drivers can contribute to economies of scale and development of timely solutions.

2.3 Assumptions, risks, constraints and dependencies

2.3.1 Assumptions:

The following assumptions have been made during the development of this paper:

- If no change was made to waste producers' plans they would continue to treat their problematic radioactive waste in a technically acceptable, safe and secure manner.
- In order for waste to be moved and managed safely, a certain level of characterisation will be needed to ensure that site specific safety limits, and transport limits are not breached. It is assumed that waste characterisation can be achieved so that waste can be sent offsite for management where appropriate.
- Raw waste can be retrieved and transported off site safely, securely and relatively easily and cost effectively.
- No policy will exist in the medium to long term that will stop waste being moved to different countries for treatment.

2.3.2 Risks

The following risks have been noted:

- National policies for England, Scotland and Wales may evolve which may not enable a UK strategy to be implemented.
- Transport containers will be needed to transport raw waste off sites. There is a risk that a sufficient number of suitable containers cannot be made available. This is particularly significant for containers suitable to transport mobile waste, such as liquid.
- As time goes on, waste producers may spend more time and money developing and implementing their own approaches for managing problematic radioactive waste if coordinated solutions are not implemented.
- If coordinated solutions are implemented, programmes become dependent such that delay at one site may interfere with the programme at another site. It may be possible for a critical path activity to be delayed at one site due to delays at another site. This may cause an unacceptable business risk to a waste producer's programme.

2.3.3 Constraints

To maximise efficiencies, a strategy for the coordinated management of problematic radioactive waste should be implemented within the near term.

If sites start to receive and treat waste from other sites, environmental permits may need to be amended. This has the potential to lead to stakeholder concerns.

2.3.4 Dependencies

To manage problematic radioactive waste efficiently at a UK level, a detailed inventory would be beneficial. To date, a UK inventory of problematic radioactive waste has been compiled using the best available information. However, it is known that current inventory information for problematic radioactive waste at waste producer sites is subject to uncertainty. Generally, the UK Radioactive Waste Inventory (UKRWI) provides some indicators of problematic radioactive waste, but does not provide detail. Although desirable and likely to be needed in the future, a more accurate inventory is not necessary for this stage of strategy development.

For subsequent more detailed stages of strategy development, a greater understanding of the inventory including the timing of arising of the problematic radioactive waste will need to be known. For example, if problematic radioactive waste at one site only arises 50 years after arising at another site, a common management process is unlikely. At this stage of strategy development we will not screen out options which may later be screened out due to a big difference in time of arising.

Plans for sites will be dependent on assumptions made for the treatment of problematic radioactive waste. If an existing or future site facility is used to treat waste from a different waste producer, the current plan may need to be extended, and costs reallocated.

2.4 Stakeholder engagement

This credible options paper has been developed through engagement with:

- Department for Business Energy & Industrial and Strategy (BEIS).
- Environment Agency (EA).
- International Nuclear Services (INS).
- LLW Repository Ltd (LLWR).
- Nuclear Legacy Advisory Forum (NuLeAF).
- Office for Nuclear Regulation (ONR).
- Radioactive Waste Management Ltd (RWM)
- Scottish Environment Protection Agency (SEPA).
- Waste Strategy Managers representing several waste producers.

It is acknowledged that stakeholder engagement will continue during the development of subsequent NDA business cases for the improved management of problematic radioactive waste.

As well as engagement with the stakeholders listed above, the views of the following organisations will be considered during the development of a preferred option position (Gate B):

- All waste producers.
- Waste treatment providers in the supply chain.

3 The Economic Case

In this Gate A paper, the Economic Case is not developed in detail beyond the identification and evaluation of a list of credible options which have the potential to enable improved management of problematic radioactive waste.

3.1 Definition of credible options

Credible options should meet the minimum requirements in respect of the key Value Framework [5] attributes. These requirements include the following:

- **Safety/Environment:** The option should involve activities and processes that comply with statutory dose limits and constraints, as well as dose/risk targets for post-closure safety at a disposal facility, effluent discharge, transport and groundwater protection. The option should be consistent with As Low as is Reasonably Practicable (ALARP) and Best Available Technique (BAT) requirements.

- **Technical:** The Technology Readiness Level (TRL) must be high enough that the option can be deployed on the required timescale. For technologies that would only be needed in the far future, a lower TRL may be acceptable, but proof of concept is required.

- **Management:** The option must be legal in the broadest sense (e.g. comply with international policy and transboundary limits), and must be compatible with existing UK and Scottish Government policy. It must be capable of implementation at NDA sites.

- **Cost:** Evaluation of costs should consider affordability, lifecycle cost savings or evaluate if the cost is otherwise “proportionate” to the benefit.

3.2 Long List of Options

The following list is derived from the outputs of the RWM and LLWR studies and engagement described above.

1. No change to current strategy.
2. Avoid the creation of problematic radioactive wastes.
3. Promote timely characterisation of waste.
4. Knowledge transfer between waste producers
5. Early and collaborative engagement between SLCs and RWM / LLWR as integrators.
6. Sort and segregation of problematic radioactive waste from bulk waste, to minimise volume of problematic radioactive waste.
7. Transfer waste to an existing NDA waste processing facility.
8. Use mobile characterisation plant.
9. Use mobile treatment plant.
10. Make better use of the supply chain to treat waste in the UK.
11. Provision of a problematic radioactive HAW treatment service (similar to LLWR framework contract with SLCs).
12. Utilise one or more new centralised treatment facilities.
13. Use of robust containers.
14. Create flexible treatment and packaging solutions (e.g. shredding, sorting and segregating processes).
15. International coordination (overseas treatment)
16. Segregate and store until treatment technology is developed.
17. Design a standard treatment plant that can be built on multiple sites

It is noted that no single option would provide a full solution for the lifecycle management of problematic radioactive wastes, as it is recognised that management covers retrieval, characterisation, transport, treatment and interim storage. Some options may however prove to be useful enablers for another solution, or may form part of an optimal solution. Although different options have different insertion points, making direct comparisons difficult, all options could improve the management of problematic radioactive waste, so are considered at this stage. The options are not mutually exclusive, so several options could be implemented.

It is also noted that there may be potential for some options to be implemented at different levels. For example, some may be implemented at a UK level, some at a country, regional or local level. This level of detail is not assessed at this stage of the business case, but is likely to be needed at a later stage.

It should be acknowledged that the use of some options at a tactical level may give significant benefit, and should not be discouraged, even if the option is evaluated as not appropriate to pursue at a strategic, or estate wide, level.

3.3 Screening methodology

The following qualitative criteria were used to evaluate the options and screen out those options considered not appropriate to pursue at a strategic, estate wide, level:

- Implementation is not considered feasible without significant change to existing national policies and regulations.
- The option is considered tactical, rather than strategic. It is waste stream or site specific. Decisions are best made at a waste producer level.
- The option only offers a detailed technical treatment solution rather than generic management benefits.

It is acknowledged that some options would require significant investment. At this stage of the business case, no attempt to quantify the cost or benefit has been attempted, so options have not been screened out on the basis of cost. This will be done at a later stage of business case development.

Each option is described and evaluated against the screening criteria below.

Option 1 – No change to current strategy

Each waste producer could feasibly continue using their own resources or the existing supply chain to manage their own waste, or to be individually responsible for developing a coordinated approach with another waste producer, on a case by case basis. This is likely to be technically acceptable, safe and achievable, but overall has the potential to be suboptimal, taking longer and costing more.

It is probable that efficiencies throughout the nuclear industry will not be optimal, which could result in, for example, the construction of duplicate treatment facilities.

This option is **credible**.

Option 2 – Avoid the creation of problematic radioactive wastes

Historical problematic radioactive waste is already in existence, in storage and needs to be treated. Good practice and the application of the waste hierarchy mean that creation of problematic radioactive waste from future activities should be minimised, although it is not always practical and beneficial to entirely avoid the creation of new problematic radioactive waste. For example particulates are often considered to be a problematic radioactive waste, and these will be created during any standard cutting process.

It should also be noted that the generation of waste that may be regarded as problematic can sometimes give an overall benefit. For example a bulk waste stream may be amenable to treatment via more optimal routes if specific components of the waste can be segregated, which may then become problematic. For example removing fuel fragments from fuel element debris (FED) may enable the majority of

waste to be packaged in a different type of container (IP-2 instead of Type B), and may enable the security category of most containers to be reduced, leading to lower costs for interim storage. A small volume of fuel fragments then, however, potentially become problematic, whereas if they were not separated, they would not be problematic.

Waste processing plants are often designed to treat and package the majority of wastes in a wastestream, and not necessarily to cater for all constituents of the waste, meaning some waste outside of the feed envelope becomes problematic. This is an effective strategy to start reducing the on-site hazard as soon as possible, to use proven technology to treat 'standard' waste and to gain operational experience of waste treatment before more complex processes are needed. It can be considered a safe, well planned and cost effective strategy which fits in well with current NDA strategy [6]. If all plants were initially built to process all wastes, including problematic radioactive wastes, initial costs could be hugely increased, timescales to start waste processing could be pushed back, and efficiency of treating the majority of 'standard' waste may be decreased. If a processing plant was initially built to treat all components of the wastestream, including allowance for uncertainties, the facility could be over-engineered and may cost significantly more than was necessary.

The minimisation (but not avoidance) of creating problematic radioactive waste is already encouraged and incentivised, and is taking place. Waste producers manage waste in accordance with the waste hierarchy, which should lead to the minimisation of all wastes. SLCs also have an Integrated Waste Strategy (IWS) which details the management of all waste. The process of developing the IWS will ensure consideration of problematic radioactive waste.

The implementation of this option is best performed at a tactical level. If implemented at a strategic level there is a potential for hazard reduction to be delayed and costs to be increased, therefore this option is **not being pursued** at a strategic level**.**

Option 3 – Promote timely characterisation of waste

Characterising waste robustly is a standard practice, but doing it at the right time is often an enabler to robust decision making. It would decrease uncertainties, and may result in some wastes, which were deemed problematic due to lack of characterisation, no longer being considered problematic. This option would not provide a complete solution for the treatment of the majority of problematic radioactive waste, but could act as an enabler to improve the current situation of some waste with an unknown provenance or inventory.

It is acknowledged that the characterisation of waste is not a simple task, and robust characterisation generally involves a direct measurement or taking physical samples, which often requires the waste to be handled. This handling often requires specialist plant, equipment and safety cases to be made, so is time consuming and expensive. Double handling of waste is not optimal from a safety or operational efficiency view. The benefit achieved through characterisation alone is minimal, but an acceptable

ALARP justification should take into consideration the full lifecycle impact of this important enabling step.

Prioritising the characterisation of problematic radioactive waste may contradict with existing strategic objectives of hazard reduction at sites, as it would divert resources. This potential conflict would need more understanding and consideration.

Uncertainties in a waste inventory can sometimes be significantly reduced by using desk based techniques, such as looking at the history of a facility. This technique however is only likely to adequately reduce uncertainties for a fraction of problematic radioactive wastes.

This option is **credible.**

Option 4 – Knowledge transfer between waste producers

Knowledge transfer is good practice, and many mechanisms are already in place to enable information sharing between waste producers. For example, information is transferred through NDA site facing teams, through the Nuclear Waste and Decommissioning Research Forum (NWDRF) and its subgroups, through Theme Overview Groups (TOGs) and through regular interactions between SLCs and RWM/LLWR. Waste Packager Liaison (WPL) meetings are also held between RWM and SLCs. Integrated Project Teams (IPTs) have been commissioned by NDA to advance the collective knowledge in some areas such as interim storage and the disposal of uranium. There are however no regular forums specifically for discussion on problematic radioactive waste.

It is noted that information sharing regarding problematic radioactive waste could be improved. Specific interactions could be focused on problematic radioactive waste, and proactively sharing information at a technical level and development of solutions which would benefit other sites.

There is a potential to involve LLWR and RWM in this knowledge sharing with waste producers, and to facilitate the creation of thematic guidance. Discussions regarding problematic radioactive waste do not need to be limited to a single waste category as the same factors apply to HAW and Lower Activity Waste (LAW) for some waste groups. This cross category (LAW and HAW) technical information sharing is likely to maximise benefit. The improved sharing of disposability information, e.g. Letter of Compliance (LoC) assessments could also be advantageous. This work should also take into account the need for appropriate waste package records to support waste management.

This option is **credible**.

Option 5 – Early and collaborative engagement between waste producers and RWM/LLWR.

RWM and LLWR regularly engage with waste producers to help develop waste management solutions which result in a disposable product. Both organisations have

developed expertise in the development of waste management plans across the UK. They could be used as a point of contact for waste producers to establish the processing solutions available or those that have previously been developed.

LLWR have set up a framework to provide treatment solutions for waste producers. They have significant experience in developing and implementing waste treatment routes for LLW. Waste producers have contracts in place with RWM and LLWR, so collaboration between waste producers and the waste management organisations is routine.

RWM Upstream Optioneering project has collaborated with LLWR during several projects, including studies on problematic radioactive waste, and the collaboration is ongoing.

This option is **credible.** It could be considered as business as usual or further development and extension of existing good practice. It is noted that there is currently no formal mechanism for discussions between one waste producer and RWM to be shared with other waste producers, so there is potential for engagement to improve. Information may be commercially sensitive and therefore, must be managed appropriately. A specific problematic radioactive waste forum could help to solve these issues and there is potential to review confidentiality clauses in contracts.

Option 6 – Sort and segregation of problematic radioactive waste from bulk waste

Sorting and segregating could allow the majority of waste to be processed in a standard manner, while minimising the volume of problematic radioactive waste. This strategy is being implemented by some waste producers, but it is recognised that a sort/segregation facility may not be available at all sites, so may need to be purpose built.

Although this strategy does not solve the problem of treating problematic radioactive waste, it has the potential to provide a partial solution, so should be considered.

It is acknowledged that sorting and segregating could in fact lead to the creation of problematic radioactive waste where it did not previously exist. It may be possible for the entire waste stream to be acceptable for processing, but if, for example, pieces of fuel, or very highly active material were removed and concentrated, a problematic stream could be created. This could be of benefit if segregation enables the majority of waste to be treated and packaged more cost effectively, for example as contact handleable waste rather than remote handled waste. The benefits and disbenefits of segregation should be clearly understood for each waste stream.

It is noted that the segregation of problematic radioactive waste is not always practicable, it may not be ALARP or BAT, but could be implemented where practicable.

For many situations, this strategy is likely to be considered business as usual, and a strategy may not significantly change behaviour. However, if the strategy was implemented across all sites it could give rise to disbenefits.

The implementation of this option is best performed at a tactical level. If implemented at an estate wide level there is a potential for hazard reduction to be delayed and costs to be increased, therefore this option is **not being pursued** at a strategic level.

Option 7 – Transfer waste to an existing waste processing facility

This option would involve transferring raw, untreated waste off one site, to another site which has existing capability of processing a particular type of waste. This strategy could lead to the avoidance of building some processing plants, or simplify planned facilities, as they would not have to cope with such a diverse range of waste.

There may be benefit in segregating waste at the site of origin to minimise the volume transported off site, but in some circumstances it may not be beneficial. This is likely to depend on the segregation capability available at the site of origin, and the timescales required to achieve overall decommissioning plans at both sites.

Once treated, the waste could be returned to the site of origin for final packaging and interim storage or sent for disposal. However, if beneficial, the HAW could be packaged at the site of treatment, or placed in an interim store at the site of treatment. Consolidated interim storage is dependent on planning and stakeholder considerations. 'Trading' of waste on volume may be a possibility which would ensure the overall liability at each site remained similar, if that was a local concern.

Variants of the option to treat waste at a different site exist at a national, regional and local level.

This option is likely to have significant stakeholder engagement requirements. For example members of the public may have concerns about waste from a different site being imported to their local site. Planning constraints may restrict the ability to import waste for treatment.

Suitable transport containers would be needed to facilitate this option. New, purpose built containers may be required depending on the characteristics of the waste. The availability of containers may constrain the rate of transferring waste.

This option is **credible**.

Option 8 – Use mobile characterisation plant

Moving characterisation equipment on and between sites is generally safer, more secure and more cost effective than moving raw waste to a characterisation facility. For small quantities of waste which need specialised characterisation equipment (or expertise in analysing results), characterising the waste can be prohibitively expensive. There is a potential for waste producing sites to share characterisation

equipment, which would spread the cost across the industry, rather than relying on a specific site or project to pay.

As an example, some pyrochemical waste, typically contaminated fluorides and chloride salts can cause severe characterisation challenges, so are classed as problematic radioactive waste. The quantification of fissile material is generally performed using neutron counting techniques, but neutrons produced by alpha particles colliding with fluoride or chloride can lead to inaccurate results. There is a possibility that specialist equipment (or expertise) could be shared between sites to help with challenges like these. However, each waste producer is generally responsible for their own procurement, deployment, calibration, maintenance and use of characterisation equipment.

Several supply chain organisations successfully offer a characterisation service, where equipment is moved to the waste. LLWR also offer a characterisation service as part of the framework agreement with waste producers. This service has worked effectively for LLW in standard 200l drums, or large individual items of LLW, as waste can be handled and moved simply, without the need for significant shielding or radiological protective equipment. Characterising HAW can pose significant issues, especially the issue of gaining proximity to the waste. For example dose rates from HAW mean that remote handling facilities are often needed. The deployment and removal of characterisation equipment from HAW facilities is a significant issue to be considered.

A feasibility study on the use of mobile characterisation equipment for HAW [2] shows that although technically feasible, the use of mobile non-destructive assay equipment for HAW may be limited. Assay systems are generally integrated into a processing facility, and are used to measure small volumes of waste (up to 200l) before it is packaged into a final disposable container.

Mobile characterisation equipment for small samples of waste (destructive, lab based equipment) is technically feasible, and could have the advantage of not needing to send many samples away to a laboratory. Although they exist in other countries, to date no mobile radiological characterisation laboratory for HAW has been operated in the UK.

If equipment is shared between sites, there is a risk that delays on one site could cause delays in the programme at another site.

This option is **credible**. However, the use of mobile characterisation equipment has benefits which stretch much further than the management of problematic radioactive waste. Mobile equipment could be used to characterise many types of waste which are not considered problematic. The business case to use mobile characterisation plant is likely to be much stronger if it is considered separately from the strategy of managing problematic radioactive waste. It is therefore recommended to consider the use of mobile characterisation at a higher strategic level.

Option 9 – Use mobile treatment plant

Many problematic radioactive wastes only occur in small volumes (a few m^3) at each site. A mobile plant could mean that multiple sites could share a plant and therefore reduce the potential for duplication of design, development and construction, making treatment of the waste more cost effective overall.

Mobile plants are likely to have low throughput rates when compared to fixed plants, but this may not prove to be a significant disadvantage if the volumes of waste to be treated were small, as would be the case for several types of problematic radioactive waste.

This option gives the potential for problematic radioactive waste to be treated at the same time as other waste is treated in a different plant. If treatment of problematic radioactive waste was a critical path activity to a facility, there is a potential to reduce overall timescales.

Several mobile treatment processes have been shown to be technically feasible [2]. There are several examples of where mobile plant has successfully been used in the UK to treat LLW. For example the LLW Solidification Plant was used for nearly two decades across 14 different sites. A mobile supercompactor has been used across a number of different sites and compacted over 30,000te of drummed LLW. There are however technical challenges associated with the use of mobile plant for treatment of HAW, which would need to be overcome. Implementation of this option is likely to need significant effort. Several mobile plants for HAW have been built and trialed, but there are no examples of plants successfully treating waste at more than one site in the UK. The operability and maintainability of mobile HAW plants is an important consideration. Dose to operations and maintenance staff has the potential to be higher than for a fixed plant. Since the equipment will be more spatially constrained, operations and maintenance staff could be closer to the waste than they would need to be for a bigger, fixed plant. Heavy shielding may be required, and the extra size and weight is an important consideration for transportation.

For most waste treatment process techniques it is feasible to remove the radioactive contamination to such a level that would meet transport constraints. However, ensuring operational safety and achieving transportability are often conflicting issues, and both need to be met if a mobile plant is to be successfully deployed.

For maximum benefit to be achieved, a schedule of operation at each site would need to be planned in advance and implemented. Any delays at one site could impact on another site, which may cause significant risk to achieving key targets.

For any mobile plant the provision of suitably qualified and experienced operations and maintenance staff would need to be carefully considered. A team of dedicated staff who have a thorough understanding of the equipment may be best placed to run the plant, but the interface with existing site safety arrangements would need to be managed.

The physical interfaces with existing site plant would also need consideration, and may vary between sites. For example if a liquid was transferred into a mobile plant, the interface may need to be purpose built at each site to ensure compatibility between the mobile plant and the site capabilities.

This option is **credible**, but significant implementation issues are noted.

Option 10 – Make better use of the supply chain to treat waste in the UK

There is a potential to improve the links between SLCs and the supply chain, to incentivise the supply chain to provide effective treatment solutions for problematic radioactive waste.

Facilities are already in place within the supply chain for the treatment of some waste, which can mean that some sites do not need to develop and operate their own solutions. For example, contaminated metal is melted by supply chain organisations and contaminated mercury is cleaned. Incineration of material such as oils, plastics, paper and wood is also already commercially available and utilised by SLCs. It is acknowledged that most current routes are however only available to LAW, and are not suited to HAW.

If individual SLCs engaged with the supply chain in isolation, the financial incentive to the supply chain may not exist, or the cost to individual SLCs may be prohibitive. However, at an estate level, optimisation is more likely, and economies of scale may mean that treatment routes became commercially viable.

The time of arising for problematic radioactive waste at each site will need to be understood and shared with the supply chain to ensure capability would match demand. A study into the timing of arising of problematic radioactive waste is currently being conducted through an NDA Direct Research Portfolio project.

The transportation of waste may provide challenges which would need to be overcome. For example transporting liquid HAW offsite is likely to prove onerous. The interfaces between existing plants and supply chain facilities would also need to be compatible. Some facilities may only be able to handle certain containers safely, and may not have the capability to export the waste in a package which could be handled by the recipient.

This option is **credible**.

Option 11 – Provision of a problematic radioactive waste treatment service

This option is similar to option 10 (making better use of the supply chain), but would require more active, sustained involvement from the NDA, or another management company. As well as utilising the supply chain, there is potential for existing NDA assets to be used for the treatment of waste. For example an integrating waste management organisation could facilitate the treatment of waste from one site at another site, which could accelerate the decision making process.

Decisions such as the best available technique (BAT) could be made at a generic estate wide level, which could improve the overall environmental performance of the estate.

This option is **credible**, however it is noted that at a strategic level it is very similar to option 10. The commercial and management cases are likely to be significantly different for a future stage of the business case, so the options are treated separately at this point.

Option 12 – Utilise one or more new centralised treatment facilities

One, or more purpose designed waste treatment facilities could be built to treat waste from different sites. The facilities could be established to treat a wide variety of problematic radioactive waste, so several processes could be available.

The option could enable the treatment of problematic radioactive waste to be removed from the critical path of hazard reduction at sites. This could allow the treatment facility to concentrate on flexibility and development of niche solutions, rather than on standardisation and maximised throughput of waste.

The facilities would need to be on a permitted site, but may not need to be on a nuclear licensed site. This could give extra flexibility in location and operation.

As with the option of sending waste between waste producers, the transport of raw waste would need to be considered.

This option is **credible.**

Option 13 – Use of Robust Containers

Several types of problematic radioactive waste may be suitable for packaging in a bespoke robust container that can meet performance requirements for storage and disposal while reducing reliance on the properties of the waste itself. For example, a fine particulate waste that is not sufficiently compatible with a standard grout to allow a cementitious encapsulation process to be used may be considered immobile if the waste is unencapsulated inside an appropriately designed robust container. Using a robust container has also been highlighted as a potential solution for filters and ion exchange resins.

The use of a robust container does not offer a complete solution for many problematic radioactive waste categories. For example it many not provide a solution for oil, physically awkward waste, mercury, or waste of unknown provenance. Some waste may also need conditioning (for example, drying) to enable use of robust containers.

SLCs are responsible, and are best placed, to make the decision on what type of waste package to use. Many factors, such as existing infrastructure and compatibility with other site processes will need to be considered. If the baseline plans involve

using a different type of container and stores and handling equipment are designed for those containers, using robust containers may not be cost effective.

This option is site specific and tactical, rather than strategic. This option is **not being pursued** at a strategic estate wide level. NDA will consider the need for small volume robust containers and guidance on waste packaging as part of the broader programme of work.

Option 14 – Create flexible treatment and packaging solutions

Some processes are technically suitable for treating several categories of problematic radioactive wastes. Encouraging more use of these techniques may help to standardise the treatment of problematic radioactive waste. Previous studies [1] have shown that theoretically, there are technologies available for treating each problematic radioactive waste category.

The study also shows that there is no single technique suitable for the treatment of all problematic radioactive waste. Cementation, compaction and the use of polymers have been shown to be the most flexible treatment solutions, and they are the techniques already used most widely by SLCs.

It is worth noting that absence of treatment technology is not the issue for some types of problematic radioactive waste, where the reason for being considered problematic is not due to treatment. For example, lead is often classed as problematic as a decision on whether to recycle or dispose of has not yet been made. Significant extra work, such as decontamination followed by robust characterisation, would often be needed to reduce uncertainties to enable recycling to be a possibility. The BAT assessment and ALARP justification are often complex, as the amount of work needed and therefore the dose involved may not be known in advance.

Radium contaminated waste can lead to significant environmental discharges of radon if not managed appropriately. The operational management technique is therefore as important as the treatment process for this waste. For example, simple management techniques such as keeping a lid on a container for as long as possible can have a significant overall impact. However, that requirement is not likely to be compatible with operation of a flexible waste treatment process.

The technical decision on the process to use to treat the problematic radioactive waste is best made by the SLC, in accordance with a robust options assessment which justifies the selection of BAT.

In isolation, this option is not considered strategic, as it is waste stream specific, and site specific. It may however be combined with other options, such as option 12 (centralised treatment facilities), or option 10 (making better use of the supply chain).

Solutions developed by sites could be shared with other SLCs, but this is considered in option 4 (transfer of knowledge).

This option is **not credible**, as it is considered tactical rather than strategic.

Option 15 – International coordination (overseas treatment)

Some treatment processes have already been developed, and are already being used in other countries. There may be a potential to send UK waste to these facilities for treatment, rather than constructing a new facility in the UK. For example some incinerators overseas have higher discharge limits which lend themselves to the combustion of a wider range of waste.

COVRA, in the Netherlands, has a small purpose built incinerator for contaminated organic waste, and a separate incinerator for contaminated liquid waste. It also has a liquid cleaning process, a shredder and a compactor. Belgoprocess, in Belgium, is a privately owned organisation which runs purpose built waste processing facilities. Many other international facilities also exist. More details on acceptance criteria as well as costs would be needed as the business case is developed.

There is a potential to explore the possibility of return of equivalent radioactivity but not the waste, if disposal routes exist outside the country of origin but not within the country of origin.

It is also worth considering the potential that waste from abroad could be sent to the UK for treatment, if capacity was created. This could potentially generate revenue.

This option is **credible**, but could be combined with option 10 (making better use of the supply chain) as it is a very similar strategy. It is described here as a separate strategy as the commercial, financial and management cases are likely to be very different.

Option 16 – Segregate and store until treatment technology is developed

New treatment techniques are developed over time, so there is a potential for innovation and advanced treatment techniques, which are suitable for problematic waste, to be available in the future. Delaying the treatment now may lead to a more efficient process in the future.

As discussed for option 14 (create flexible treatment solutions), the technical treatment is only a part of the issue for problematic radioactive wastes. Many wastes are problematic for other reasons, such as they have an unknown provenance, or problems are likely during interim storage. For example radium, thorium and actinium contaminated waste can cause a significant gaseous discharge issue unless they are stored appropriately.

This option will not be suitable for all types of problematic radioactive waste, so will be waste and site specific. It is considered that the SLC is best placed to make this decision after a robust options assessment which justifies the selection of BAT. Impacts on individual LTPs will need to be considered by SLCs.

A strategy to deliberately delay the treatment of problematic waste generally, to be able to utilise possible future technological advances is not commensurate with existing NDA strategy [6] and regulatory joint guidance [7]. The option may also involve double handling which would bring inefficiencies and increase risk. The waste may need to be retrieved for temporary packing and interim storage, then again to retrieve from storage in order to treat it.

This option is **not credible** at a strategic level, as this approach is contrary to policy and strategy aims of timely management of wastes. This approach might be considered suitable at a tactical or wastestream specific level, in which case it becomes a decision for the waste generator.

Option 17 – Design a standard treatment plant that can be built on multiple sites

One treatment plant could be developed for the treatment of problematic radioactive waste, designing a standard plant that could be built where needed by waste producers. As well as the design, other significant requirements could be made available in generic form such as safety case, and LoC documentation. This would reduce the amount of duplication in design effort, but would require duplication in construction effort.

Site specific compatibility issues would need to be addressed, such as the handling of waste containers. Different sites use different historical waste containers to transfer waste around site. Any new facility would need to be able to accept existing waste containers.

This option could be combined with option 4 (knowledge transfer), at this stage. Detailed methods of knowledge transfer can be discussed at a later stage of the business case.

This is **credible** but will be combined with option 4 (knowledge transfer) as it is a very similar strategy. It is described here as a separate strategy as the commercial, financial and management cases are likely to be different.

3.4 List of credible options

From the long list of 17 original options, 5 options have been deemed to be **not credible** at this stage. These 5 options will not be evaluated at future stages of a business case for the improved management of problematic radioactive waste although many of them are appropriate for consideration at a tactical level.

The 5 options deemed as **not credible** at an estate wide, strategic level are:

- Option 2 – Avoid the creation of problematic radioactive waste
- Option 6 – Sort and segregation of problematic radioactive waste from bulk waste, to minimise volume of problematic radioactive waste
- Option 13 – Use of robust containers

- Option 14 – Create flexible treatment and packaging solutions
- Option 16 – Segregate and store until treatment technology is developed

12 options remain **credible** at this stage. Some of the options are very similar at a strategic level, but are likely to be viewed differently during the commercial, financial and management cases, so have been described separately. The following table shows the credible options. These credible options align with the waste management principles set out in our Strategy [6].

TABLE 1 – CREDIBLE STRATEGIC OPTIONS FOR IMPROVED MANAGEMENT OF PROBLEMATIC RADIOACTIVE WASTE

Credible Strategic Options
1. No change to current strategy
3. Promoting timely characterisation of waste
4. Knowledge transfer between waste producers
5. Early and collaborative engagement between waste producers and LLWR/RWM as integrators
7. Transfer waste to an existing waste processing facility
8. Use mobile characterisation plant
9. Use mobile treatment plant
10. Make better use of the supply chain to treat waste in the UK
11. Provision of a problematic radioactive waste treatment service
12. Utilise one or more new centralised treatment facilities
15. International coordination (overseas treatment)
17. Design a standard treatment plant that can be built on multiple sites

It is noted that the credible options are not mutually exclusive, and are not directly comparable in terms of end points. It is possible, owing to the diversity of problematic wastes and the issues associated with their management, that a combination of the options will be necessary to drive a successful transformation in the management of problematic radioactive wastes.

4 The Commercial, Financial and Management Cases

This Gate A paper has concentrated on the strategic case and the economic case, as required in the NDA Strategy Management System (SMS/GEN/018).

The commercial, financial and management cases have not been considered in this document and will be developed at a later stage.

5 Forward Programme

- NDA will share its findings with SLCs and other stakeholders to gather feedback on the suggested credible options.

- An Integrated Project Team has been established and is progressing the development of strategic options for the management of problematic radioactive waste

- Gate B papers will be developed to unpack and prioritise the credible options in more detail.

- The scale of, and issues around, problematic radioactive waste at SLCs are not formally reported as updates to the UKRWI are made. This lack of transparency at an estate level potentially causes risk to both programme and cost for NDA. The UKRWI does not recognise problematic radioactive waste as it often forms a very small proportion of a waste stream. The existing HAW and LAW inventories of problematic radioactive waste will be subject to ongoing review and improvement. It is intended that, at an appropriate time when data is sufficiently well developed, it can be made more visible, and changes reported routinely as the UKRWI is updated.

- The options of using mobile characterisation plant and mobile treatment plant to improve the management of problematic radioactive waste have been discussed in this document. These options are considered credible at this stage. However, it is noted that the use of mobile characterisation plant and mobile treatment plant could be beneficial for waste which is not considered problematic. Any business case for mobile plant should be developed separately, rather than for the sole purpose of improving the management of problematic radioactive waste. If this is done, the business case for mobile plant is likely to be stronger.

- There are perceived benefits in future collaboration with waste producers outside the NDA estate when developing strategy for the improved management of problematic radioactive waste. Non NDA sites, such as Atomic Weapons Establishment (AWE), Ministry of Defence (MoD), EdF and GE Healthcare own significant volumes of problematic radioactive waste.

5.1 Guide to scoring criteria for Gate B business case

This Gate A paper has stated the credible options for the improved management of problematic radioactive wastes. After further engagement with stakeholders, these credible options should be assessed by a Gate B paper to find the preferred option(s). The Gate B business case will evaluate the options and define the preferred option(s) to implement. This should be done in the near term so that strategies can be implemented in a timely manner.

To determine the preferred option(s), the NDA value framework will be used. It is considered that the following criteria will be relevant to discriminate between the options:

- Ease of implementation
- Stakeholder support
- Capital cost of implementation
- Ongoing management cost (outside PBO contracts)
- Benefit / effectiveness of implementation (e.g. number of sites positively / negatively affected)
- Acceleration of hazard reduction
- Programme risk
- Technical risk

6 Way Forward

A Gate B paper for near term opportunities is planned for development in 2017.

A Gate B paper for longer term opportunities is planned for development in 2017.

References

1 Optimised Management of Orphan Wastes, ASSIST, R12 – 152 (A), Jan 2013.

2 Technical feasibility of Mobile Plant for HAW, ASSIST, NDA/RWMD/118, September 2014.

3 Application of Thermal Treatment within the NDA estate, Credible Options (Gate A), SMS/TS/D1-HAW/002/A v1.0, February 2013

4 LLWR, LLW Problematic Waste Technology Optioneering Summary Report NWP/REP/130 – Issue 1 – August 2016

5 The NDA Value Framework, Version 1.2, January 2016.

6 Nuclear Decommissioning Authority, Strategy, April 2016.

7 The management of higher activity radioactive waste on nuclear licensed sites, Joint guidance from the Health and Safety Executive, the Environment Agency and the Scottish Environment Protection Agency to nuclear licensees, February, 2010

Appendix 1 - Summary of the generic problematic radioactive waste groups

The following table shows the generic categories of problematic radioactive wastes that have been identified. It gives a brief description of the waste and states the main justification for its classification as a problematic radioactive waste. It should be noted that the list is not exhaustive and that not all waste in these categories can be considered to be problematic, some components within these categories will have existing treatment routes available.

ID	Problematic radioactive waste category	Description	Reason waste is problematic‡
1	Bulk Fines or Particulates	Fines, particulate, vacuum cleaner bag contents, filings, sawdust, sand.	Material may not become fully immobilised using standard large scale immobilisation processes.
2	Reactive Metals	Highly reactive metals which can react with water e.g. lithium, sodium, potassium, NaK (sodium and potassium alloy), and metals that can react with cementitious grout to form hydrogen. E.g aluminium, Magnox. This group also includes zinc which retards grout setting.	Not compliant with standard grout encapsulation, due to the potential for hydrogen generation.
3	Pyrophoric Material	Can ignite spontaneously on contact with air (e.g., uranium hydride (UH_3)).	There is a potential fire risk during standard processing methods.
4	Organic Ion Exchange Materials	Organic ion exchange resins, i.e., those composed of high-molecular-weight polyelectrolytes such as DeAcidite FF (A400).	Material may not become fully immobilised using a standard large scale immobilisation process.
5	Inorganic Ion Exchange Material	Inorganic based ion exchange media such as zeolites, Ionsiv®, clays etc.	
6	Radium/Thorium Contaminated Waste	Radium and thorium contaminated wastes emanate radioactive gas (radon and thoron).	Gaseous discharge can cause problems during operations and storage.

ID	Problematic radioactive waste category	Description	Reason waste is problematic‡
7	ILW Fuel	Fuel not suitable (or planned) for reprocessing. Also excludes bulk irradiated fuel streams. This group includes fuel fragments, thorium, enriched uranium, natural uranium and depleted uranium.	May not be designated as waste. Not always compliant with standard conditioning and packaging approaches. Criticality issues.
8	Tritium Contaminated Waste	Tritium contaminated solid or liquid waste. The discharge of tritium during processing or storage must be minimised. Excludes tritiated oil.	Cross contamination and gaseous discharges during processing means standard operations may not be suitable. Various alternative management routes possible (decay store, near-surface, GDF disposal).
9	Pyrochemical Wastes	Waste salts and slags from pyrochemical processes. These are typically contaminated fluorides and chloride salts).	Material is difficult to assay. Neutrons produced by (alpha-n) reactions make accurate quantification of fissile material difficult.
10	Halide-Based Fire Suppressant Powders	e.g., Ternary Eutectic Chloride (TEC) powder, glove box fire extinguisher powder wastes.	Particulate material not suitable for treatment using larger scale immobilisation processes.
11	Mercury Wastes	Mercury contaminated with radioactivity, or other radioactive waste contaminated with mercury.	Only one UK treatment route exists at present and it is likely that HAW mercury may not meet WAC at that facility. Segregation of mercury from other waste can often be difficult due to dispersion as fine droplets. Toxicity and volatility also limit treatment options.
12	Contaminated Bulk Oil	Oil contaminated with radioactive material (excludes tritiated oil).	May not meet WAC for incineration. Not compliant with standard conditioning and packaging approach.
13	Material Contaminated with Oil	Radioactive material contaminated with oil.	
14	Tritiated Oil	Oil contaminated with tritium, where tritium has replaced hydrogen within the hydrocarbon chain of the oil.	

ID	Problematic radioactive waste category	Description	Reason waste is problematic‡
15	Ventilation Filters	High Efficiency Particulate Air (HEPA) and charcoal filters.	Filters may be loaded with significant quantities of fine particulate that must be immobilised for packaging.
16	Solvents	Contaminated solvents, non-halogenated or halogenated.	Requires specialised treatment processes to separate radionuclides from organic liquids.
17	Zinc Bromide	Zinc bromide solution used in shielding windows, or radioactive material contaminated with zinc bromide solution.	May not meet WAC for standard treatment route.
18	Sludge	Bulk, residuals and heels.	May not be compliant with standard conditioning and packaging approach.
19	Putrescible and Cellulose Waste	Putrescibles (materials which rot and produce gas), e.g. wood, paper, animals.	May be excluded from Waste Package Specification.
20	Batteries	All types of batteries. Batteries used in monitoring equipment, plutonium batteries.	Batteries need to be electrically isolated before packaging.
21	Lead	Lead shot, sheets and bricks.	Disposal is often not the best option for dealing with lead, but reuse or recycling may not be simple.
22	Isotope Cartridges	Isotope Cartridges are mainly present at Sellafield legacy facilities and include materials such as lithium, magnesium, bismuth oxide, aluminium nitride, potassium chloride, thulium, thallium, lead, stainless steel and cobalt clad in aluminium.	Difficult to manage due to high dose rates, chemical reactivity, toxicity, may be physically awkward, or contain materials not suitable for standard packaging techniques.
23	MAC	Miscellaneous Activated Components (MAC).	Often very high dose rates, may be physically awkward.

ID	Problematic radioactive waste category	Description	Reason waste is problematic‡
24	Sealed Sources	Includes neutron sources such as Cf-252, Am/Be, Am/Li and Ra/Be. National Disposal Service sources, other sealed/closed sources. Leaking sources that were previously sealed.	Often very high dose rates (gamma or neutron), may be physically awkward, or may contain gas.
25	Graphite	Waste of which the majority is graphite.	Packaging and disposal route still to be determined.
26	Asbestos	Contaminated or activated asbestos wastes.	Adds an extra hazard to packaging/treatment processes. Future arisings may lack disposal route at LLWR.
27	Concrete Lined Drums	Formerly known as Sea Disposal Drums. These were created before 1983 and were originally destined to be disposed of at sea. The inner waste may have been encapsulated.	Original disposal route unavailable. Characterisation often needs improvement, but is challenging due to the concrete shielding. May contain mobile waste requiring encapsulation.
28	Containerised Waste	Waste already in drums, cans, or paint tins, but was not packaged in accordance with a LoC. Often very little inventory data, as waste was packaged many years ago.	Perceived to require an unpacking, sorting and segregation facility.
29	High Fissile/Moderator/ Heat Waste	High Fissile content, moderator content or heat output exceeds packaging limits for container. Includes Be waste. Also includes Jabroc (a non-impregnated, densified wood laminate) due to its neutron moderating and absorbing properties.	Waste exceeds current package limits. Potential criticality issues.
30	Pressurised Waste	Aerosols, fire extinguishers, gas cylinders.	Waste must be made passively safe before it is packaged.
31	Aqueous Liquids including Bottles of Liquid	Aqueous liquids; bottles of liquid found in otherwise solid, dry waste.	Liquids are often not compatible with existing solid waste processes.

ID	Problematic radioactive waste category	Description	Reason waste is problematic‡
32	Physically Awkward Waste	Material with enclosed voidage, large objects. Also includes large plastic sheets which could contain trapped particulate.	May need size reduction and characterisation. Operational difficulties, requiring extra equipment or facilities.
33	Undefined Waste	Possibly needs segregation, but cannot fit into any other category. Often many unknowns, and poorly characterised.	May require sorting and segregation. Often further characterisation is needed.
34	Absorbent Material	Cloths, pads, swabs and desiccants.	Material is not compatible with a standard large scale immobilisation processes.
35	Other	Chemicals that do not fit in another category.	May require sorting and segregation. Often further characterisation is needed.