Optimisation of the Management of Higher Activity Waste in the UK – 13537

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ABSTRACT

The Upstream Optioneering project was created in the Nuclear Decommissioning Authority (UK) to support the development and implementation of significant opportunities to optimise activities across all the phases of the Higher Activity Waste management lifecycle (i.e. retrieval, characterisation, conditioning, packaging, storage, transport and disposal). The objective of the Upstream Optioneering project is to work in conjunction with other functions within NDA and the waste producers to identify and deliver solutions to optimise the management of higher activity waste. Historically, optimisation may have occurred on aspects of the waste lifecycle (considered here to include retrieval, conditioning, treatment, packaging, interim storage, transport to final end state, which may be geological disposal). By considering the waste lifecycle as a whole, critical analysis of assumed constraints may lead to cost savings for the UK Tax Payer. For example, it may be possible to challenge the requirements for packaging wastes for disposal to deliver an optimised waste lifecycle. It is likely that the challenges faced in the UK are shared in other countries. It is therefore likely that the opportunities identified may also apply elsewhere, with the potential for sharing information to enable value to be shared.

INTRODUCTION

The mission of the UK Nuclear Decommissioning Authority (NDA) is “to deliver safe, sustainable and publically acceptable solutions to the challenge of managing the UK’s civil nuclear liability, driving changes to improve delivery by enhancing innovation and improving the process of clean-up” [1]. The Radioactive Waste Management Directorate (RWMD) of the NDA has responsibility for planning and implementing a geological disposal facility (GDF), whose mission is to deliver geological disposal and provide radioactive waste management solutions.

The Upstream Optioneering project was created in the Radioactive Waste Management Directorate to support the development and implementation of significant opportunities to optimise activities across all the phases of the Higher Activity Waste (HAW) management lifecycle (i.e. retrieval, characterisation, conditioning, packaging, storage, transport and disposal). The objective of the Upstream Optioneering project is to work in conjunction with other functions within NDA and the waste producers to identify and deliver solutions to optimise the management of HAW.

Historically, optimisation may have occurred on aspects of the waste lifecycle (considered here to include retrieval, conditioning, treatment, packaging, interim storage, transport to final end state, which may be geological disposal). By considering the waste lifecycle as a whole, critical analysis of assumed constraints may lead to cost savings for the UK Tax Payer. For example, it may be possible to challenge the specific requirements associated with packaging wastes for disposal to deliver an optimised waste lifecycle.

In addition to cost, the project considers other aspects such as the speed of hazard reduction, safety issues and environmental detriment. For example, the speed of retrieval from existing waste storage facilities is strongly influenced by the final end state being pursued. Activities related to segregation of wastes, size reduction etc required to create disposable packages is strongly influenced by the specifications defined for disposable waste packages. Consideration of lifecycle benefits of these activities are considered to hold significant potential for influencing the speed of hazard reduction.

APPROACH

Phase 1: Collation of opportunities from across the estate

During the course of development work undertaken across the NDA estate over recent years a number of opportunities have been recognised that could offer significant advantages from a waste management perspective. Some may offer overall cost savings through increased operational efficiency, while others may hold promise for reducing the risks of waste retrieval substantially (but possibly at some cost). Yet others may offer novel technical approaches to solving a range of challenges but would require some investment in Research and Development (R&D) before their true value can be appraised satisfactorily.

The opportunities which form the basis of this work were collated from a number of documents supplied by the waste producers (such as opportunity registers, integrated waste strategies etc). Opportunities were also collated through workshops with the waste producers. The process was designed to relate the potential benefits of each opportunity to factors that would be relevant to their possible implementation to form an overall measure of value to NDA.

Phase 2: Consolidation, analysis and prioritization of opportunities

In total, 130 opportunities were identified in Phase 1. In Phase 2, opportunities were consolidated where relevant, links between opportunities were established and the opportunities were assessed in more detail to support prioritization of the work. Following this exercise, a total of 69 opportunities remained, and this total was further reduced to 51 by excluding those where there was already work ongoing outside the project.

In order to assesses the value that may be accrued, the following measures were used.

- Hazard Reduction, Environmental or Safety Benefit: How much does the opportunity reduce hazard resulting from the physical form or chemical properties of the stored waste, including public and worker safety and security aspects, but also provide environmental benefits, such as reduction of radiological and non-radiological discharges? This criterion considers the overall benefit going from the present situation to full implementation of the opportunity. Consideration of any temporary increase in hazard during implementation of an opportunity is captured under Ease of Implementation.

- Undiscounted Cost/Savings of Implementation: Undiscounted full lifecycle cost of opportunity implementation in comparison to the current baseline.

- Discounted Cost/Savings of Implementation: Discounted full lifecycle cost of opportunity implementation in comparison to the current baseline.

- Ease of Implementation: How difficult would it be to implement the opportunity? What is its level of technical maturity, inherent complexity, or Technical Readiness Level in comparison to the baseline? Are there significant regulatory issues to overcome? Would there be a significant, albeit temporary, increase in hazard or risk? The focus is on technical difficulties and any potential delays (e.g., for technology development) are captured under Timescale to Implement.

Three criteria related to Affordability and Time are evaluated separately because it is not possible to relate them to the current baseline:

- Affordability – Short-Term Investment Requirement: What up-front investment will be required in order to realise the opportunity in the next 1-2 years (i.e. to deliver a programme level business case to support a change in strategy for well-defined opportunities, or to complete an enabling study, or a scoping study that would allow a less well-defined or more far-reaching strategic opportunity to be taken forward)?

- Timescale to Implement: How long will it take to implement the opportunity? This criterion differentiates opportunities in terms of the timescale needed to implement them, so that it is possible to distinguish "urgent opportunities" (opportunities that could be implemented relatively easily and quickly) from those where considerable work over a longer timescale would be necessary to implement them. However, this criterion is not directly related to priority and may not necessarily be used to decide which opportunities to implement first.

- Time Sensitivity: How time-sensitive is the opportunity? A further aspect related to time is the urgency, or time sensitivity, of the opportunity. If a time-sensitive opportunity is implemented immediately, the cost savings may be greater than if implemented in a few years, and there may be a point in the future at which the opportunity is not worth implementing. Other opportunities may not be time sensitive at all and may offer benefit whenever they are implemented.

The output from Phase 2 is a three year programme to explore each opportunity through standalone or linked studies.

Phase 3: Delivery/implementation of opportunities

The project is currently delivering phase 3, which is the three year programme. At this stage, most studies are planned, or are currently underway. The following are the results and interim findings from two of the studies underway.

- Use of Neutron Absorbing Materials in ILW and Spent Fuel Packages for Criticality Safety Control

The use of neutron-absorbing materials (neutron poisons) as an additive to waste packages that contain fissile material has been identified as a potential upstream opportunity for the safe packaging and disposal of intermediate level waste and spent fuel. While the use of poisons for the packaging of spent fuel has been the subject of many studies, there has been very few studies identified which consider using neutron poisons for intermediate level waste, particularly for heterogeneous legacy wastes. One of the main drivers for the use of neutron poisons is to facilitate higher fissile material limits for radioactive waste disposal packages than might otherwise be possible. This has relevance for some of the UK waste streams. The use of neutron poisons is potentially one way to enable waste producers to increase the leading per disposal package, leading to benefits such as fewer packages, reductions in waste handling, cost etc.

The work considered a range of poison materials and three approaches for incorporating the poison in the package:

  - Blending with fissile material.

This would most readily apply to direct blending are liquor waste streams, such as raffinates, that could be mixed with a poison prior to encapsulation. Spent fuels and solid ILW would need to be processed into a form that could be blended with the neutron absorbing medium. Credit could be taken for the poison during transport and operational phases, and potentially in assessments of long-term post-closure criticality scenarios because close association of the poison with the fissile material (in a similar chemical form) may allow credit to be taken for the absorbing effect of the poison material. It is important that the effects of differential mixing, non-homogenous

/non-uniform mixing and sub-specification mixing are understood and their criticality safety impacts assessed. However, direct blending of absorber material with the waste would most likely be expensive and in the case of solid intermediate level waste or spent fuel would involve many processing steps. This will likely require the installation of bespoke waste processing facilities. This particular concept is still at the research and development stage and there is still considerable work required in order to apply it to a particular wastestream.

- Use as a package filling material

The basic premise for this approach is that the poison or a poison-bearing matrix is added to the waste as part of an immobilisation matrix, such as a grout, or in order to fill any void space within the package. In theory this concept could be applied to any waste stream where void space exists within the waste form and an encapsulation matrix is used. For example, a poison-bearing grout matrix could be used to encapsulate supercompacted drums of plutonium-bearing wastes in 500 litre drums as an additional criticality control measure. In general, for compactable wastes, it may be preferable to incorporate the neutron poison into the encapsulation grout rather than the waste to avoid reducing the level of compaction that could be achieved. The addition of a neutron absorbing medium directly to the package is likely to be a less onerous and costly process than blending with the waste.

A criticality assessment would need to determine an appropriate and measurable level of credit that could be taken for the presence of a poison. Given that the configuration within the container and the mass of poison material packaged could vary significantly between packages, the determination of a bounding case may be difficult. For example supercompacted plutonium contaminated waste may benefit very little from poison materials within the package unless they are present in between the supercompacted pucks themselves. This may require physically engineered mechanisms such as spacers between the pucks to ensure they could be credited in a criticality assessment. Without such measures, then this may lead to adoption of a level of pessimism that limits the criticality safety benefit that can be assumed or alternatively to challenging compliance assurance requirements for waste producers.

Given that little research appears to have been undertaken on this concept, its feasibility in application to waste packages is uncertain. Research into the effect of the addition of a poison material to an encapsulant would need to be understood from the perspective of chemical stability as well as from the perspective of criticality safety.

- Use as a package construction material

This concept involves the use of a neutron absorbing material within part of the fabric of the package itself. This could be achieved by blending the poison materials with the construction materials used for the package or by incorporating the poison materials as standalone features within the design of the package. This concept could be applied to any packaged fissile-bearing waste stream. However, the criticality safety benefits realised could be highly dependent on the type of package used and the nature of the waste matrix itself. A greater benefit may be obtained for waste packages for which neutronic interaction is significant, either between fissile elements within the package or between adjacent packages, than for those in which neutron interaction is not significant.

The use of a poison within the fabric of the container material would probably be a lot less onerous and costly than incorporating it into the matrix by direct blending. In addition, the substantiation of the presence of the material is likely to be simpler because the fabrication of the container is a more consistent process than the inclusion of poisons in waste streams that have varying properties, such as plutonium contaminated materials. In addition, the process of poison introduction is separate from the process of waste packaging. Therefore, the use of poisons in this way is less likely to introduce additional radiological hazards during waste packaging.

Where the reactivity of an array of packages in a store or disposal vault is only weakly dependent on neutron interaction between the neighbouring packages, the addition of a poison to the container material may have little or no effect on the overall reactivity of the system. Also the potential degradation of the container over the long term under disposal conditions may lead to a loss of effectiveness of the absorber as it is dispersed, which may present long-term criticality safety concerns.

The technologies utilised in this concept are well developed and have been applied to several spent fuel packages as described above. However, no examples have been identified of the application of this concept to waste packages.

As a result of this scoping study, it is considered that waste producers should only consider the use of poisons in very specific situations, and that little can be gained at the moment by trying to pursue a more holistic approach, such as the incorporation of poisons into the reusable transport container which will transport most waste packages to the disposal facility.

While the study has in effect demonstrated that no wide scale opportunity exists, it is hoped that it has indicated to waste producer’s specific applications which may be of benefit for bespoke solutions, and also where significant technical challenges and uncertainties exist for the use of poisons for some streams.

- Optimum management of orphan wastes

An 'orphan' waste is defined as a waste for which there is no treatment process and / or disposal route identified. An orphan waste on one site may not be considered an orphan waste on another site- many orphans are designated as such because the treatment route is not currently available on the site where the waste is stored and managed. Orphans may also be known as 'wastes requiring additional treatment', i.e. wastes that could be managed using existing routes if pre-treated such that the waste was compatible with the existing route.

Orphan waste streams typically include ion-exchange resins, sources, filters, mercury, oil, solvents and other mobile wastes. Although these can exist in small amounts, their processing is often on the critical path to placing a facility / site into Care and Maintenance. Orphans or wastes requiring additional treatment are inevitably more commonly found on research and development legacy nuclear sites rather than commercial power stations sites.

In the first task of this study, a database of all orphans/wastes requiring additional treatment was collated (as declared by the waste producers). The database includes hundreds of waste streams (some with only m^3 quantities). The wastes were grouped into wastes with common features- e.g. pyrophoric wastes, oil contaminated wastes, particulate wastes), and the use of a database also enables searching and custom reporting. The database also holds details of potential technical solutions.

For clarity and balance, the orphan waste groups considered under the following headings:

- High Hazard (potentially mobile) Waste - Fines and Particulates; Oils; and Solvents;
- High Volume / High Hazard Waste – Sludges;
- Multi-Site Wastes - Tritium Contaminated Wastes; High Fissile Content Wastes; and Ventilation Filters;
- Opportunities to apply the Waste Hierarchy – Lead; and Mercury;
- Radium / Thorium wastes; and Sealed Sources; and
- Unpacking, Sort and Segregate - Containerised Waste; Concrete Lined Drums; Undefined Waste; Miscellaneous Activated Components; and Physically Awkward Items.

A key conclusion is that (on the basis of the information available in this high level study) there are technologies available that are potentially applicable for the treatment of most of the 35 generic orphan types identified within this study.

As many research facilities in the UK have been, or are being, decommissioned, several technical solutions have already been developed and implemented for some wastes on those sites. Many of those technical solutions have been assessed through the RWMD disposability assessment process [2] and have been assessed to be disposable. Due to the historic practices in the UK industry, there has been little sharing of research and development.

In addition to identifying treatment approaches that have been previously applied to similar wastes in the past (or are being pursued at present), the study has highlighted wastes that are perceived to be very challenging but which may be manageable with relatively simple techniques. These include sealed sources, mercury wastes and physically awkward wastes (such as pressure vessels, as the perception has been that the vessels must be size reduced to enable the void to be filled). The study has recommended that management approaches be investigated for several waste items (particularly where small volumes exist at several sites), including assessing the waste product for disposability.

This study has identified:

- Where one site might be able to provide a solution to orphan wastes currently located at other sites / facilities.
- Where there are orphan waste streams from several sites that could employ a common waste treatment strategy and potentially share waste treatment / packaging facilities / existing processes.
- Future treatment / disposal routes in development which might be applied to those orphans that this study has not identified current treatment / disposal routes. This includes a discussion of what development activities (needs, risks and opportunities) are required to fully develop that route. These treatment solutions might reside within the broader supply chain.
- Those orphan waste streams (including quantities and radiological challenge) that might benefit from a centralised approach to their management on a particular site (or sites).
- Where existing disposability assessments could be amended to include new waste streams or where a new disposability assessment is required

CONCLUSIONS

The upstream optioneering project has moved beyond the preparation phase to the delivery phase and some tasks are starting to deliver results. Engagement across the nuclear industry on opportunities related to the management of higher activity wastes has been positive and has enabled the project to prioritise efforts and resources to those which have high impact, and which offers opportunities across the industry.

REFERENCES

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