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Life Cycle Costing in Radioactive Waste Packaging: Reducing Costs Whilst Accelerating Clean-Up

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Abstract

The original strategy for managing intermediate level waste (ILW) in the UK involved retrieving, sorting and encapsulation in cement based grout within thin walled stainless steel containers. These would then be transferred to a purpose-built shielded ILW store on site, where they would be stored until transport within heavily shielded Type B transport containers to the planned geological disposal facility.

In recognition of the high up-front costs of such a strategy, which requires remote facilities for the encapsulation and storage coupled with the long programme duration for the design, construction and commissioning of these facilities, then in recent years organisations responsible for managing legacy facilities within the UK have sought innovative solutions to accelerate clean-up and hazard reduction and offer a lower overall life cycle cost.

Recent innovative packaging solutions have looked to a new family of packaging designs known as robust shielded containers (RSCs). These are self shielded containers manufactured from materials such as ductile cast iron. These containers offer the potential to package wastes for storage, transport and disposal; mimicking the multipurpose container MPC systems used for spent fuel management. Such a strategy removes the need to encapsulate the wastes and for highly engineered remote handled shielded stores. This offers the opportunity to accelerate hazard reduction and site clean-up by reducing programmes of work and costs.

Underpinning the cost benefits of such a strategy using Life Cycle Cost (LCC) assessment can assist in strategic planning and decision making. These decision making processes are often guided by legislative requirements which look to ensure that risks from nuclear operations are As Low As Reasonably Practicable (ALARP), and as such the balance of cost and affordability must be considered against safety and security. In this respect RSCs are play a critical role in alleviating public concerns over safety issues during interim storage and transport.

The paper presents a balanced view of the application of LCC assessment process, utilising a number of waste ILW packaging LCC scenarios, covering waste management including public transportation. The paper is intended to promote discussion and consideration of the benefits of undertaking a holistic assessment of the investment decision as part of an overall waste management strategy.

Introduction

A thorough Life Cycle Cost assessment can help strategic planning and decision making for packaging radioactive wastes and can more thoroughly and rigorously demonstrate the most cost effective waste packaging strategy. Decisions are often guided by legislative requirements that are aimed primarily at ensuring risks from nuclear operations are as low as reasonably practicable and that the best practicable environmental option is offered; these decisions balance the benefits of acceptable cost against the benefit to be delivered.

In looking at the optimum waste management strategy an organisation should look to quantify the costs of acquisition, operation and disposal – the life cycle cost - of the complete waste packaging process, which will often drive the most cost effective solution, rather than drive a particular strategy around the cost advantage of a single element within a process.

When evaluating waste packaging options, whilst individual elements (e.g. container costs) may appear to offer a cost benefit by comparison with alternatives, the programme as a whole may not be the most cost effective solution when life cycle costs are taken into account and when other benefits (e.g. safety, technical performance with practicability and feasibility, social and ethical and security) offered by alternative strategies are considered.

Packaging Options for Intermediate Level Waste in the UK

Historically in the UK there have been two generic types of waste packages for packaging ILW; these are unshielded and shielded waste packages. Standard unshielded ILW containers [1] are shown in Figure 1. These are typically thin walled stainless steel containers and the radioactive waste is encapsulated in a cement matrix.

Figure 1. Unshielded Waste Packages (500 litre drum and 3 cubic metre box)

Standard shielded ILW containers which are also transport packages [1] are shown in Figure 2. Traditionally, shielded waste packages have been used for low dispersible materials (Low Specific Activity Materials – LSA – and Surface Contaminated Objects – SCO [2]). The shielding in these containers is traditionally provided by concrete; the shielding reduces radiation levels allowing the waste packages to be transported in the public domain with no additional shielding (other containment and performance requirements must also be met for transporting waste packages in the public domain [2] and [3]). Earlier designs of these shielded waste packages were an all concrete fabrication with steel collars added to improve impact performance (furthest left image in Figure 2) but more recent designs (such as the 4 metre ILW and 2 metre ILW boxes) included a stainless steel containment vessel (encompassing the concrete shielding) with a verifiable sealing arrangement. These designs were introduced to overcome some of the technical issues with an all concrete fabrication.

Figure 2. Shielded Waste Packages
(6 cubic metre concrete box, 4m ILW box and 2m ILW box)

As unshielded waste containers contain no shielding they require remote handling facilities for processing the waste, due to the high radiation levels, and they also require heavily shielded stores and shielded containers for transport. Shielded waste packages allow the use of much simpler handling and storage facilities although to package the waste into these boxes will still require remote handling facilities.

To meet UK disposability requirements, waste packages must prevent or minimise the release of activity from the waste package in impact or fire accidents [3]. Traditionally this is achieved by a combination of the waste container and waste form; with immobilisation of the waste by encapsulation. Preparing wastes for encapsulation typically requires: a pre-treatment plant (e.g. sorting, segregation), an encapsulation plant to immobilise the waste, a capping station to ‘seal’ the encapsulated wastes in the container and a shielded store for unshielded waste packages. In addition there will be ancillary plant to feed materials to the plant for encapsulating and capping the waste and process systems to manage secondary wastes. The process for encapsulating waste either in an unshielded or concrete shielded container is illustrated schematically, in the left hand block, in Figure 4. For wastes encapsulated in concrete shielded packages the main difference would be the removal of the requirement for heavily shielded transport flasks and store.

More recently a new generation of waste containers has been introduced [4] to the UK; Robust Self-shielded Containers (RSCs). These are typically manufactured in ductile cast iron (DCI) and are called Ductile Cast Iron Containers (DCICs); examples are shown in Figure 3. The containers are robust and meet impact and thermal performance requirements for disposal without reliance on the wasteform.

**Figure 3. Ductile Cast Iron Containers
(Croft MINIBOX and Croft 3m3 Safstore)**

The main process steps for the use of DCICs for packaging ILW is illustrated in the right hand block of Figure 4. Comparing this against traditional packaging options (left hand block) of cement encapsulation it is evident that DCICs offer a potentially much simpler process for packaging wastes than traditional encapsulation processes. The use of these containers also offers opportunities to package ILW into DCICs that had traditionally been packaged in unshielded containers (i.e. materials requiring Type B transport packaging); presenting another innovation in waste packaging strategy. The benefits of considering DCICs compared to traditional approaches of unshielded containers or concrete shielded containers, are:

- reduction in capital plant requirements thus presenting savings in reduced programme duration and cost to implement through the; e.g. eliminates need for encapsulation plant;
- relative to unshielded containers, savings in shielded stores, shielded transport container infrastructure and remote operations;
- elimination of lengthy and costly research and development programmes required to establish waste and encapsulants behaviour;
- negating need to design, build, construct, operate and ultimately decommission secondary waste treatment facilities;
- achieving rapid hazard reduction through early retrieval and packaging of legacy wastes;
- overall reduction in waste produced as decommissioning of encapsulation plant and heavily shielded store not required;
- offering the ability for future retrieval and processing of materials; they do not foreclose future options;
- versatility to accommodating mixed wastes;
- packaging of some problematic wastes that are not compatible with cement encapsulation techniques;
- use of DCIC leading to fewer total shielded waste packages as DCI is a more efficient shield material than concrete.

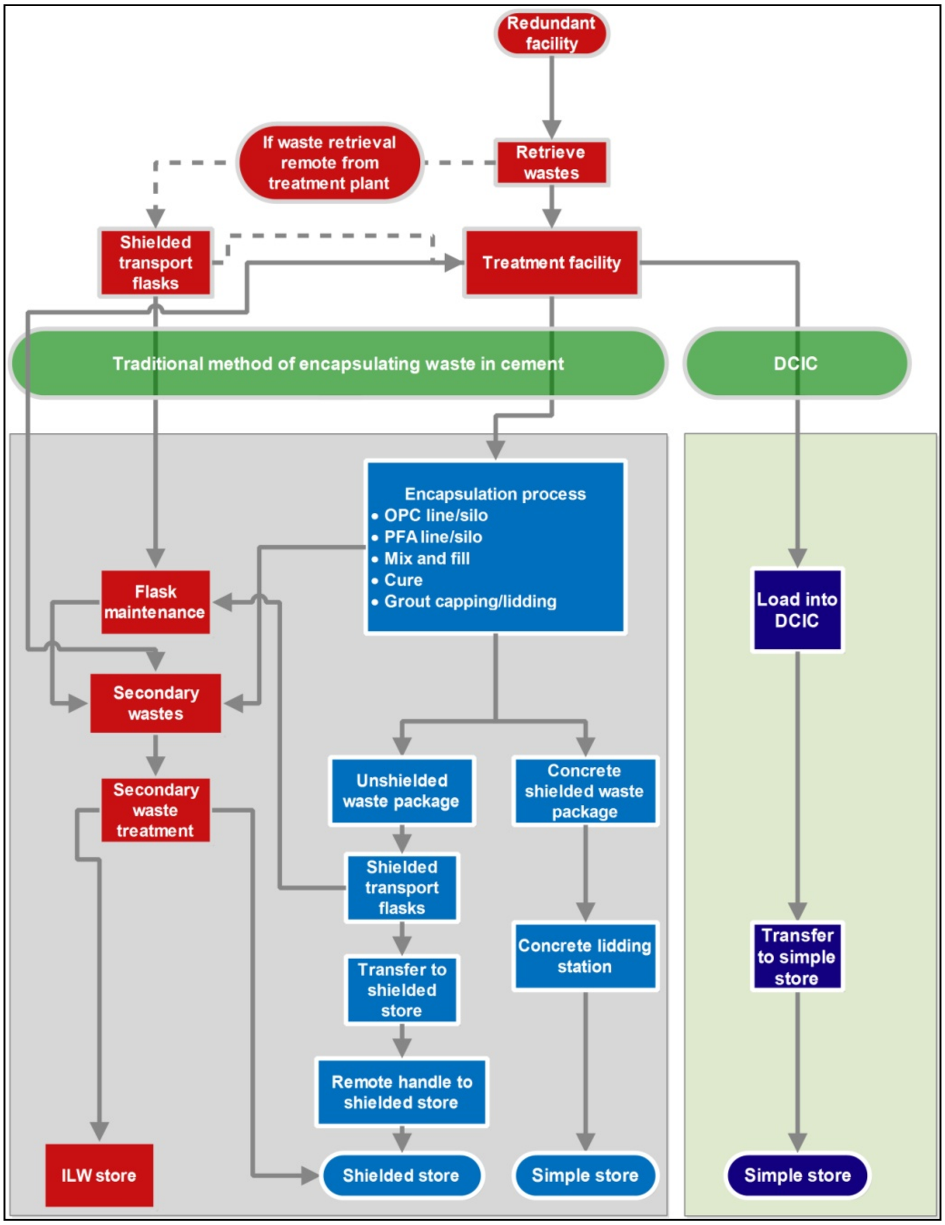

Figure 4. Illustration of different process steps for traditional encapsulation and use of DCICs

Cost Considerations for Packaging Strategies

As well as considering costs within a waste management strategy, other attributes have to be considered such as safety, technical performance (with practicability and feasibility), social and ethical, security [5] and affordability. These other factors may well influence a particular option or process but cost clearly plays an important part in deciding a strategy for packaging ILW [6].

The cost of using DCICs is regarded as higher than that of using unshielded containers and shielded waste containers manufactured from concrete. However, when other costs are factored into an LCC assessment a very different relationship can emerge, as the NDA illustration in Figure 5 shows. The higher cost of RSCs (i.e. DCICs) is offset by the higher capital cost of a shielded store for use of unshielded waste containers; just one element in an LCC assessment.

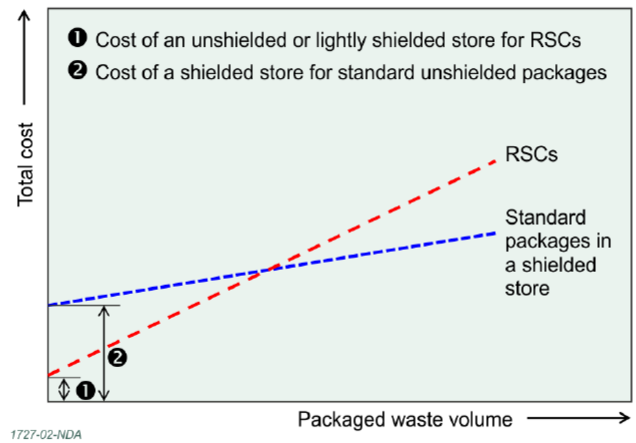

Figure 5. Indicative cost comparison of the cost of storage for RSCs (DCICs) and unshielded waste packages [4]

The economic viability of traditional methods of encapsulating as an integral part of a packaging process can be further challenged when the cost of other essential elements is factored into an LCC assessment:

- continued asset care and maintaining the safety of the hazardous waste materials until packaging plant and processes are available;
- programme extension for the design, construction, operation, maintenance and decommissioning of an encapsulation plant or engineered shielded store;
- packaging, transporting, storing and disposing of additional secondary wastes from operating and decommissioning plant and equipment; and
- procurement, maintenance and operation of remote handling plant and equipment and a fleet of shielded transport containers for unshielded waste packages.

To illustrate how considering LCC for various waste packaging options could influence a waste management strategy, several different scenarios are presented below. Comparisons are made between using DCICs for waste that was traditionally packaged into unshielded containers and for waste that would have traditionally been packaged in concrete shielded containers.

Case studies

Unshielded versus DCI (shielded) container options

The relative merits of packaging waste in an unshielded container are compared to a DCIC of equivalent displacement volume. The LCC assessments include UK estimated costs for operational plant, transport to a geological disposal site and disposal[1]. In the examples shown here the cost of the unshielded container is assumed to be around 20% of the cost of the equivalent DCIC; if container cost is the most important factor determining strategy then regardless of waste volume the unshielded container would be the preferred option. However when additional elements are considered within an LCC assessment (e.g. an encapsulation plant and heavily shielded store) the relationships illustrated in Figures 6 and 7 respectively emerge for a large and small waste processing facility (the step changes are due to the addition of additional storage capacity).

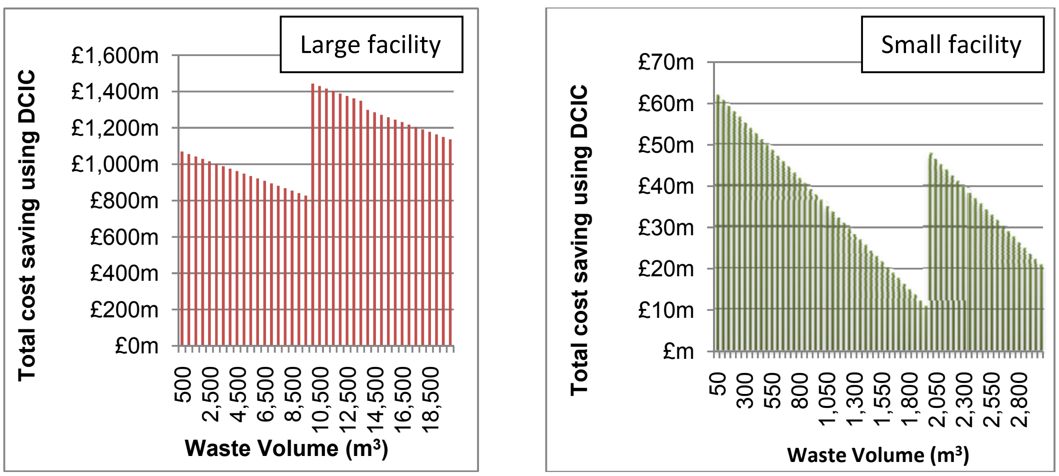

Figure 6 & 7. Indicative total cost saving using DCIC

In the smaller facility the capital costs are assume to be around 10% of those of the larger facility.

Regardless of facility size the LCC assessment shows that even when the additional cost of plant for unshielded containers is amortised over an increasing volume of processed waste the DCIC option still represents a considerable cost saving.

[1] Cost assumptions for both case studies can be found on the Croft Associates Ltd web site: (http://www.croftltd.com/about-us/published-papers/) under Life Cycle Costing in Radioactive Waste Packaging: Reducing Costs Whilst Accelerating Clean-Up

Shielded container options - concrete compared to DCI

What is also important in any assessment is the amount of waste that can be packaged into the container; the higher the packaging efficiency of a container, the lower the overall cost per m^3 of contained waste.

Within the UK nuclear industry there is a resurgent interest in using concrete boxes as shielded waste packages due to their potential low manufacturing costs. Comparing the capacities of shielded containers that use concrete for shielding with a DCIC container of the same external volume, the DCIC offers an increase in waste capacity for comparable shielding efficiencies, which means:

- fewer containers required;
- fewer packaging and handling operations;
- smaller store;
- reduction in transport movements (based on package volume);
- reduction in disposal costs (based on packaged volume); and
- reduced operational activities due to fewer containers, lower resource usage and reduced transport operations.

The reason for this is that iron is a much more efficient shield material than concrete because of its higher density and atomic number. In using fewer containers this may also reduce overall radiation exposures to operators and members of the public due to fewer operations and movements.

It has been assumed that the cost of a concrete container is about 25% of the cost of the equivalent displacement volume DCIC; if container cost is the most important factor determining strategy then regardless of waste volume the concrete container would be the preferred option. However, for the same shielding efficiency the DCIC offers a much larger waste capacity and hence reduces the number of DCIC boxes required compared to concrete. Also when the cost of the encapsulation plant is factored into an LCC assessment for the concrete box option, the relationship presented in Figure 8 emerges. Two LCC assessments are presented; both include waste processing but in one case transport and disposal costs to the GDF are included and in the other case they are excluded. In both cases the LCC assessment favours the use of DCIC as the more cost effective option. Other technical and maturity factors may also favour a DCIC option [7] such as:

- compatibility of the waste material with box internal storage environment;
- design features within DCICs can ensure more certainty of compliance with transport requirements in the future following long term storage as thes e waste packages are also transport packages;
- timescales for designing and building and gaining approval for an encapsulation plant might favour a quicker solution, e.g. for ageing legacy plant; and
- the requirements to carry out research and development on encapsulation processes might favour a quicker timescale and greater certainty.

A lower risk strategy such as that offered by the use of DCICs might also mean more certainty regarding timescales and implementation costs.

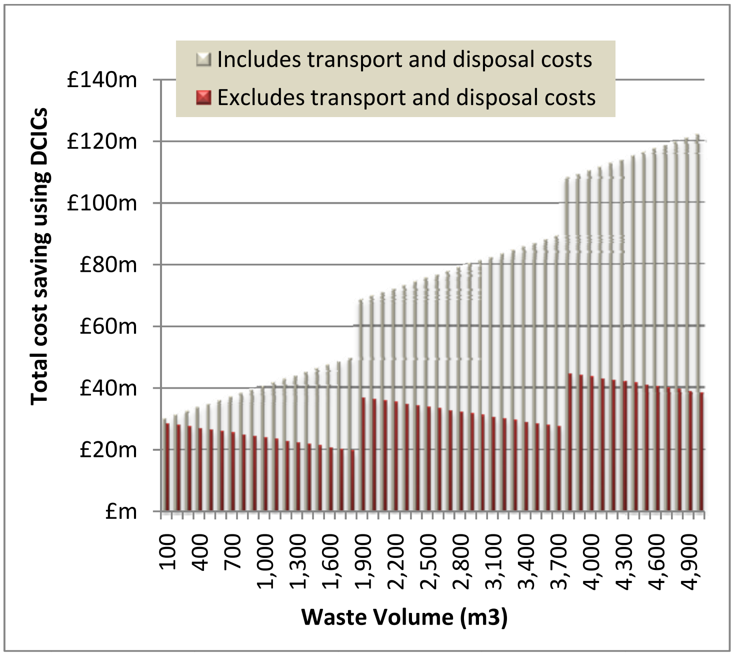

Figure 7. Indicative total cost saving using DCIC (iron) compared to concrete for shielding

Conclusions

An individual project element within an overall waste management programme may appear to present a cost saving and represent the most cost effective optimum waste package option; but in the context of an LCC assessment, this saving may prove to be illusory. The examples given comparing DCICs (RSCs) with more traditional methods illustrate this point, although there is more than one waste packaging solution and cost is only one issue. Any net savings and the point at which an option represents the most economic solution will depend on site specific requirements and waste volumes; the examples are intended to show how other factors in an LCC assessment can support a different solution than just container costs alone.

Removing the need for capital plant for waste packaging can accelerate clean-up and hazard reduction. DCICs also offer technical advantages for wastes not compatible with the traditional approach of encapsulation. Design features within DCICs can also ensure more certainty of compliance with transport requirements in the future following long term storage. DCICs are also more efficient at shielding and hence offer larger capacities for comparable box sizes with consequent savings on storage, transport, disposal and potentially lower environmental impact.

Balancing cost and risk reduction are important regulatory drivers, particularly for dealing with legacy issues. Many factors may need to be considered in deciding the right balance for a particular waste strategy but a thorough LCC assessment will assist in determining the most economic option, taking consideration of:

- the estimated full life cycle costs of each alternative, including capital costs, operational costs, costs arising from increased programme length; decommissioning costs and transport, storage and disposal costs;
- the uncertainty associated with those estimates. Programme and project risk is increased by lower levels of product maturity, technical uncertainties requiring R&D (and therefore with no certainty of a solution) and the need for large scale projects and ongoing operations, which by their nature may give rise to cost and schedule overruns;
- issues such as safety, technical performance (with practicability and feasibility), social, ethical and security; and
- solutions that offer a greater certainty and future demonstrability of technical and regulatory compliance.

This paper shows that whilst an individual element within a waste management strategy might be higher than alternative options (in the examples given container costs for DCICs) nonetheless they can offer a more economic solution when looking at an LCC assessment. However, where substantial costs for plant and equipment have already been incurred and facilities already exist and costs discounted, and no technical challenges are faced, then it may be, as in the examples explored here, that RSCs (DCICs) may not present the best option in terms of lowest future costs.

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