Radioactive Waste Management

NDA Report no. DSSC/441/01

Geological Disposal

Waste packages and the assessment of their disposability

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Preface

Radioactive Waste Management Limited (RWM) has been established as the delivery organisation responsible for the implementation of a safe, sustainable and publicly acceptable programme for the geological disposal of the higher activity radioactive wastes in the UK. As a pioneer of nuclear technology, the UK has accumulated a legacy of higher activity wastes and material from electricity generation, defence activities and other industrial, medical and research activities. Most of this radioactive waste has already arisen and is being stored on an interim basis at nuclear sites across the UK. More will arise in the future from the continued operation and decommissioning of existing facilities and the operation and subsequent decommissioning of future nuclear power stations.

Geological disposal is the UK Government's policy for higher activity radioactive wastes. The principle of geological disposal is to isolate these wastes deep underground inside a suitable rock formation, to ensure that no harmful quantities of radioactivity will reach the surface environment. To achieve this, the wastes will be placed in an engineered underground facility – a geological disposal facility (GDF). The facility design will be based on a multi-barrier concept where natural and man-made barriers work together to isolate and contain the radioactive wastes.

To identify potentially suitable sites where a GDF could be located, the Government has developed a consent-based approach based on working with interested communities that are willing to participate in the siting process. The siting process is on-going and no site has yet been identified for a GDF.

Prior to site identification, RWM is undertaking preparatory studies which consider a number of generic geological host environments and a range of illustrative disposal concepts. As part of this work, RWM maintains a generic Disposal System Safety Case (DSSC). The generic DSSC is an integrated suite of documents which together give confidence that geological disposal can be implemented safely in the UK.

Executive Summary

The UK has accumulated a legacy of higher activity waste from electricity generation, defence activities and other industrial, medical, agricultural and research activities. The Nuclear Decommissioning Authority (NDA) has established Radioactive Waste Management Ltd (RWM) as the body responsible for implementing UK Government policy for the management of those wastes, as set out in the 2014 *Implementing Geological Disposal* White Paper. The White Paper envisages the development of a geological disposal facility (GDF) in the UK alongside the ongoing interim storage of waste packages and supporting research. Under such plans RWM would be responsible for planning, building and operating a GDF.

A GDF is an engineered facility for the disposal of radioactive waste. It is likely to be located at a depth of between 200 m and 1,000 m below ground, in a stable geological environment that provides long-term isolation of the wastes from the human environment.

The wastes for disposal in a GDF include High Level Waste, Intermediate Level Waste, and Low Level Waste unsuitable for near-surface disposal. There are also other nuclear materials that have not been declared as wastes by the Government (because they are still considered to be of potential use), but which might be the subject of geological disposal in the future, namely spent fuel, separated plutonium and uranium.

By drawing on UK and overseas experience RWM is developing illustrative geological disposal concept examples that are relevant to the UK context, inventory and available geological environments. These illustrative examples are all based on the principle of passive safety provided by a combination of engineered barriers designed to complement the natural barrier provided by the geological environment. The system of multiple barriers will ensure that the radioactivity in the wastes is sufficiently contained so that regulatory requirements are met and that exposures resulting from any releases to the surface to be as low as reasonably achievable and, in any event, less than a small fraction of the exposures everyone receives each year from naturally occurring sources of radioactivity in the environment.

The implementation of a GDF for higher activity wastes requires RWM to demonstrate confidence that such a facility would be safe, during both the operational period and after it has been sealed and closed. As part of that process RWM has developed the Disposal System Safety Case (DSSC) the prime purpose of which is to demonstrate that a GDF can be implemented in a safe manner and in such a way that would meet all regulatory requirements.

This report has been produced as part of the suite of documents that make up the generic DSSC its purpose being to provide a description of the methods by which RWM ensure that packaged radioactive waste has the characteristics necessary for safe transport to, and disposal in, a GDF, and that is compliant with the assumptions made in the generic DSSC.

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1 Introduction

1.1 The generic Disposal System Safety Case

RWM has been established as the delivery organisation responsible for the implementation of a safe, sustainable and publicly acceptable programme for geological disposal of the UK's higher activity radioactive waste. Information on the approach of the UK Government and devolved administrations of Wales and Northern Ireland[1] to implementing geological disposal, and RWM's role in the process, is included in an overview of the generic Disposal System Safety Case (the Overview) [1].

A geological disposal facility (GDF) will be a highly-engineered facility, located deep underground, where the waste will be isolated within a multi-barrier system of engineered and natural barriers designed to prevent the release of harmful quantities of radioactivity and non-radioactive contaminants to the surface environment. To identify potentially suitable sites where a GDF could be located, the Government is developing a consent-based approach based on working with interested communities that are willing to participate in the siting process [2]. Development of the siting process is ongoing and no site has yet been identified for a GDF.

In order to progress the programme for geological disposal while potential disposal sites are being sought, RWM has developed illustrative disposal concepts for three types of host rock. These host rocks are typical of those being considered in other countries, and have been chosen because they represent the range that may need to be addressed when developing a GDF in the UK. The host rocks considered are:

- higher strength rock, for example, granite
- lower strength sedimentary rock, for example, clay
- evaporite rock, for example, halite

The inventory for disposal in the GDF is defined in the Government White Paper on implementing geological disposal [2]. The inventory includes the higher activity radioactive wastes and nuclear materials that could, potentially, be declared as wastes in the future. For the purposes of developing disposal concepts, these wastes have been grouped as follows:

- High heat generating wastes (HHGW): that is, spent fuel from existing and future power stations and High Level Waste (HLW) from spent fuel reprocessing. High fissile activity wastes, that is, plutonium (Pu) and highly enriched uranium (HEU), are also included in this group. These have similar disposal requirements, even though they don't generate significant amounts of heat.
- Low heat generating wastes (LHGW): that is, Intermediate Level Waste (ILW) arising from the operation and decommissioning of reactors and other nuclear facilities, together with a small amount of Low Level Waste (LLW) unsuitable for near surface disposal, and stocks of depleted, natural and low-enriched uranium (DNLEU).

RWM has developed six illustrative disposal concepts, comprising separate concepts for HHGW and LHGW for each of the three host rock types. Designs and safety assessments for the GDF are based on these illustrative disposal concepts.

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[1] Hereafter, references to Government mean the UK Government including the devolved administrations of Wales and Northern Ireland. Scottish Government policy is that the long term management of higher activity radioactive waste should be in near-surface facilities and that these should be located as near as possible to the site where the waste is produced.

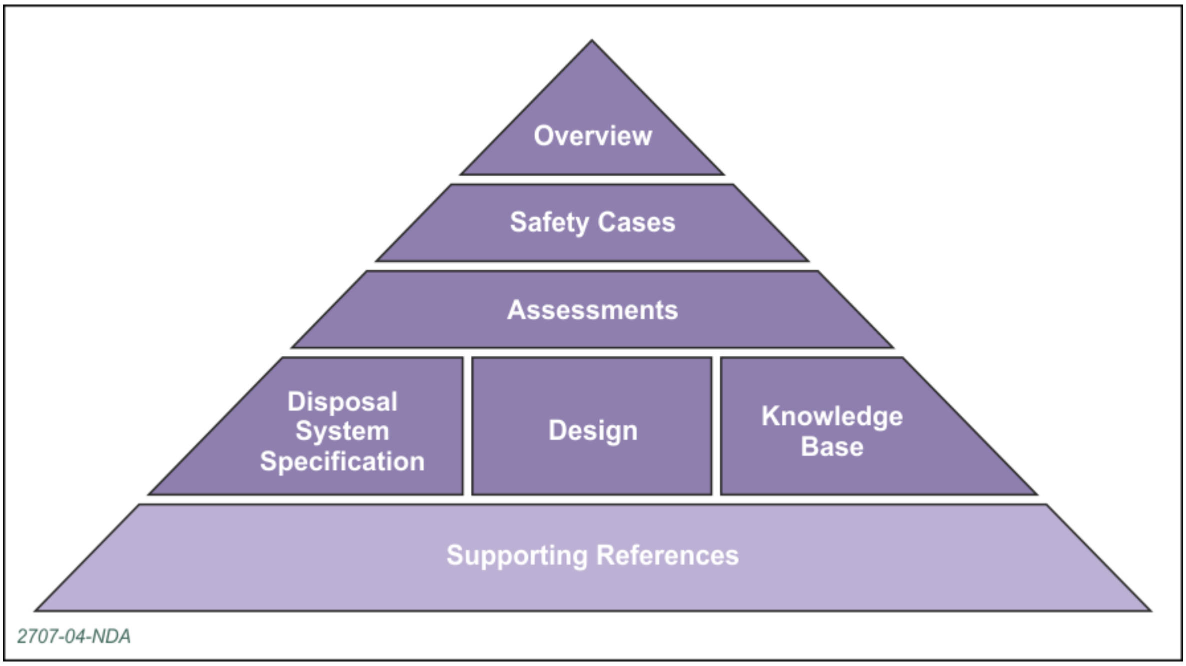
High level information on the inventory for disposal, the illustrative disposal concepts and other aspects of the disposal system is collated in a technical background document (the Technical Background) [3] that supports this generic Disposal System Safety Case.

The generic Disposal System Safety Case (DSSC) plays a key role in the iterative development of a geological disposal system. This iterative development process starts with the identification of the requirements for the disposal system, from which a disposal system specification is developed. Designs, based on the illustrative disposal concepts, are developed to meet these requirements, which are then assessed for safety and environmental impacts. An ongoing programme of research and development informs these activities. Conclusions from the safety and environmental assessments identify where further research is needed, and these advances in understanding feed back into the disposal system specification and facility designs.

The generic DSSC provides a demonstration that geological disposal can be implemented safely. The generic DSSC also forms a benchmark against which RWM provides advice to waste producers on the packaging of wastes for disposal.

Document types that make up the generic DSSC are shown in Figure 1. The Overview provides a point of entry to the suite of DSSC documents and presents an overview of the safety arguments that support geological disposal. The safety cases present the safety arguments for the transportation of radioactive wastes to the GDF, for the operation of the facility, and for long-term safety following facility closure. The assessments support the safety cases and also address non-radiological, health and socio-economic considerations. The disposal system specification, design and knowledge base provide the basis for these assessments. Underpinning these documents is an extensive set of supporting references. A full list of the documents that make up the generic DSSC, together with details of the flow of information between them, is given in the Overview.

Figure 1 Structure of the generic DSSC



1.2 Introduction to the Waste Packages and the Assessment of their Disposability report

This document describes the role that the Disposability Assessment process plays in the safety cases for the transport and geological disposal of higher activity waste. It does so by discussing how ‘raw’ waste is conditioned to form disposable waste packages, and the management processes RWM has in place to ensure that wastes are appropriately packaged by waste packagers. By describing these processes at this stage in the programme, RWM is providing a mechanism for early regulator engagement and oversight.

The generic DSSC was previously published in 2010. There are now a number of drivers for updating the safety case as an entire suite of documents, most notably the availability of an updated inventory for disposal [4]. This document updates and replaces *Radioactive Wastes and Assessment of the Disposability of Waste Packages* [5] published as part of the 2010 generic DSSC suite.

This update has been issued in particular to record the significant changes that have been made to the Disposability Assessment process, and to the form of the packaging specifications, since 2010.

1.3 Document structure

Section 2 discusses the role played by the waste package in a geological disposal system.

Section 3 describes RWM's approach to the definition of specifications for packaged waste.

Section 4 describes the standardised designs of waste container that can be used for the packaging of the different categories of higher activity waste.

Section 5 describes the Disposability Assessment process by which RWM assesses the suitability of proposed waste packages for geological disposal.

Section 6 outlines the possible outcomes of a disposability assessment.

Section 7 summarises the requirements on the manufacture of disposable waste packages, the production of package records and the interim storage of waste packages.

Section 8 describes the requirements on a waste acceptance process.

Appendix A lists the RWM Disposability Assessment Aim and Principles.

A glossary of terms specific to the generic DSSC can be found in the Technical Background [3].

2 The Role of the Waste Package in a Geological Disposal System

Much of the waste destined for geological disposal is generated in a form that is not immediately suitable for such disposal, and it must be treated or 'conditioned', and packaged in such a way as to render it:

- passively safe, such that it can be stored safely with the minimum need for actively managed safety systems, monitoring or prompt human intervention
- capable of safe handling during interim storage[2]
- 'disposable', in that it can be shown to be capable of safe transport to, and disposal in, a GDF, and compliant with the relevant regulations and safety cases for a GDF

In most cases this will require the use of a waste container and for many wastes, especially those in which the radionuclides are 'mobile' (eg liquids, slurries and particulates), a requirement for the waste to be 'conditioned' to form a solid product or 'wasteform'.

The waste package thus formed provides a physical containment barrier against the release of radionuclides during transport and their early release into the GDF engineered barrier system, thereby constituting the initial barriers that make up the multi-barrier containment system that is a key characteristic of any concept for the geological disposal of radioactive waste. Depending on the physical and chemical nature of the waste, this barrier may comprise that provided by the conditioned wasteform, or the waste container, or a combination of both of these two components of the waste package.

It should be noted that the term 'conditioned wasteform' can be used to describe a number of distinctly different types of waste package contents. Depending on the nature of the waste, the wasteform can be:

- waste which may have received only limited treatment (ie size reduction and/or drying). This is notably the case for materials such as spent fuel, irradiated metals and graphite, in which the radionuclides form part of the atomic structure of the material itself, or those for which encapsulation would not provide any advantage with regard to safety, but may add cost or significantly increase the volume of the waste for disposal.
- waste which, together with its associated radionuclides, has been physically 'encapsulated' by mixing the waste with a suitable material (eg a cementitious or polymeric material) to produce a 'monolithic' wasteform
- waste that has been subjected to a high temperature process to convert it to a very durable 'vitrified' or ceramic wasteform, into which the radionuclides are bound by the structure of the wasteform

The waste package will be required to provide a number of safety functions which contribute to safety during transport and following disposal. In the earlier stages of the long-term management of the waste package (ie during transport and the GDF operational period) some of the safety functions will be provided primarily by the waste container, whilst others will be provided by the wasteform. In the latter stages (ie in the GDF post-closure period) the wasteform may play a greater role.

As well as providing some fundamental waste package properties (eg shape and size, lifting feature and identification) during transport and the GDF operational period, the waste

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[2] After packaging it is expected that many waste packages will need to be stored for up to several decades pending the availability of a GDF.

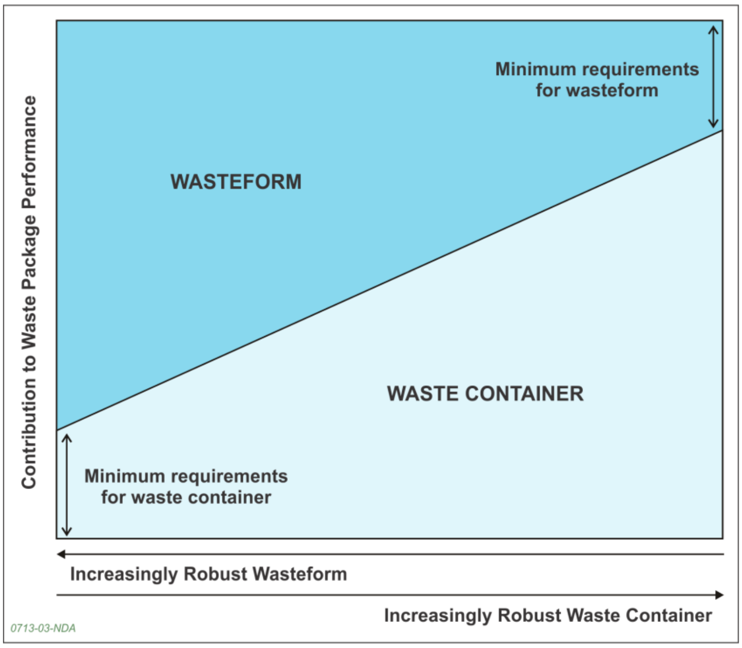
container will also provide a number of other safety functions during the post-closure period including:

- protecting the wasteform from physical disruption (eg by movement in the bedrock)
- restricting the access of groundwater to the wasteform
- controlling the groundwater conditions in the vicinity of the wasteform, specifically ensuring a reducing environment due to corrosion reactions, thus controlling the solubility of some radionuclides
- allowing the passage of gas from the wasteform into the surrounding engineered barrier system, thereby avoiding pressurisation of the waste package and the potential for damage to the waste container and/or wasteform

The waste container will be designed such as to maintain its integrity (ie its containment function and ability to provide a means of safe handling for the waste package) during transport and the GDF operational period. Depending on the nature of the disposal concept for a particular waste category[3] the containment function provided by the waste container may also be required to be maintained into the post closure period. Following loss of this containment function at some point during the post-closure period, the wasteform is assumed to provide a stable, low-solubility matrix that limits the rate of release of the majority of radionuclides by dissolution in groundwater that comes into contact with it.

The relative importance of the wasteform and waste container to waste package performance for a particular type of waste is illustrated in simple terms in Figure 2.

Figure 2 Relative contribution of the waste container and wasteform to waste package performance



This shows how the use of a more robust waste container can reduce the required contribution of the wasteform to overall waste package performance. The reverse also tends to be the case in that the production of a robust wasteform (eg one comprising vitrified waste) can lead to a reduced contribution to waste package performance by the

3 RWM uses the term 'waste category' to divide the range of radioactive materials that may be the subject of geological disposal into groups, characterised by their radiological characteristics (see Section 3.2).

waste container. In all cases the overall performance of the waste package, and its compliance with the requirements on transport and disposal, are the governing criteria.

The relative importance of these two barriers, and that which may be provided by the waste itself, for the waste package will also depend on the waste category, particularly the long-term durability that will be required of the waste package for that waste.

For the purposes of GDF design the Generic Disposal Facility Designs (GDFD) report splits the full range of higher activity wastes[4] into two broad groups; LHGW and HHGW, and further sub-divides these groups as shown in Table 1 [6], which also summaries the relative contributions of the waste, wasteform and waste container to the performance of waste packages containing these types of waste.

The required timescale for the containment provided by a waste container will depend to a large extent on the safety case and the disposal concept that will be adopted for a particular waste category. Containment will be provided for the period required by the use of container material with the necessary combination of adequate thickness and corrosion characteristics. For example, the current target durability timescale for ILW containers [7] of 500 years could equally be achieved by the use of relatively thin layer (ie a few mm) of a material with a high corrosion resistance in oxidising conditions (eg austenitic stainless steel) or by a greater thickness (ie a few 10's of mm) of a less corrosion-resistant material (eg cast iron). The means for achieving the necessary durability requirements on waste packages containing all categories of material that could be destined for geological disposal is discussed in [8].

4 The 2014 White Paper defines these as ILW, HLW and LLW that is not suitable for near surface disposal, together with any other radioactive materials which may be declared as waste in the future (e.g. spent fuel, plutonium, and uranium).

Table 1 Summary of relative role of waste package components for different waste categories

Waste category	Waste group	Relative roles played by the components of the waste package in the containment of radionuclides		
		Waste	Wasteform	Waste container
LLW		Generally low, but can be significant for neutron-activated metals and graphite	Relative importance depends on nature of waste container. For thin-walled containers, wasteform will play significant role which will reduce with increasing waste container robustness	
ILW	Shielded ILW[5]			
	Unshielded ILW[5]			
DNLEU		Low: Wasteform is expected to be uranium oxide in powder or granular form		Low: Waste container will play no role beyond containment during transport and GDF operational period
Vitrified HLW		High - Wasteform comprises vitrified waste within stainless steel canister		Extent of role will depend on the long-term durability of the vitrified waste and/or the canister
Spent fuel (SF)	Legacy SF	High - Intact fuel assemblies will provide significant containment of radionuclides, particularly in the short-term		High - Waste container will play important long-term role
	Mixed oxide SF			
HEU		Low, unless the waste already exists in, or is to be conditioned into, a ceramic form	High - Waste will be incorporated into high durability wasteform	Extent of role will depend on the long-term durability of the wasteform
Plutonium				

5 These different types of ILW are differentiated by the manner in which they are expected to be packaged.

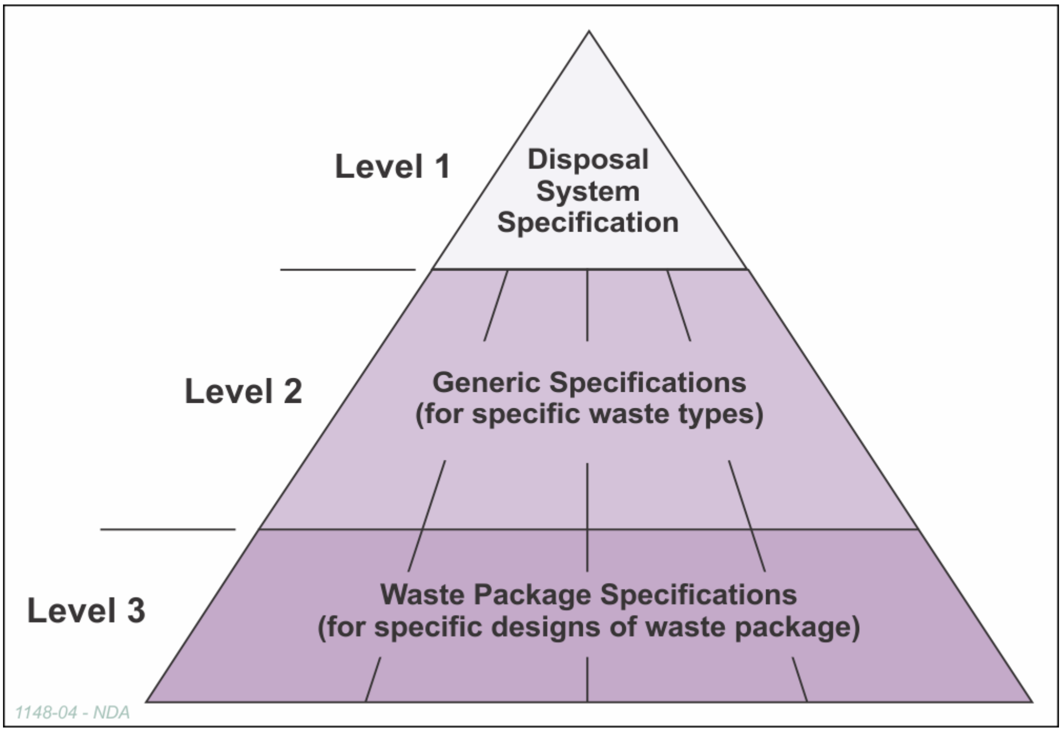
3 Packaging Specifications

RWM defines the requirements on packaged waste in the form of generic packaging specifications, which are derived from the gDSSC. These are designed to ensure the compatibility of waste packages with the safety cases for a GDF.

The packaging specifications play an important role in ensuring the safe and efficient packaging of waste for geological disposal by providing a baseline against which the suitability of waste packagers[6] plans to package waste for geological disposal can be judged. As such, the packaging specifications are an integral part of the Disposability Assessment process (Section 5) and act as the preliminary waste acceptance criteria (WAC) for a GDF (Section 8).

The packaging specifications form a hierarchy. Within each ‘level’ of the hierarchy the specifications are defined in such a manner to ensure that the needs of a particular group of users are satisfied. In this manner the needs of all users are addressed. The hierarchy, which is illustrated in Figure 3, comprises three ‘levels’ of packaging specifications in which each successive level represents an increasing degree of specificity, both to the nature of the waste and the expected designs of the waste package.

Figure 3 Hierarchy of the RWM packaging specifications



Each of the levels in the hierarchy satisfies a specific function and is produced for a particular audience, as explained below.

6 The distinction between the terms ‘waste producer’ and ‘waste packager’ is relevant to this report. A waste producer is an organisation responsible for the creation and/or storage of radioactive waste in an unconditioned form, whereas a waste packager is an organisation responsible for the packaging of radioactive waste in a form suitable for transport and disposal. The terms are not interchangeable, as the functions they cover are not the same, although in many cases a waste producer may also be a waste packager. In general the term ‘waste packager’ is used in this document, it being primarily concerned with the packaging of waste for disposal.

3.1 The Disposal System Specification

As part of RWM's programme for the implementation of geological disposal in the UK, and to set out a clear definition of the requirements on the disposal system, the generic *Disposal System Specification* (DSS) has been developed.

The DSS comprises two documents:

- Part A: High Level Requirements [9]; the purpose of which is to identify and document the overall objectives of, and constraints on, the geological disposal system. It describes the high-level requirements on the disposal system which are presented in a form suitable for a wide range of stakeholders.
- Part B: Technical Requirements [10]; which underpins and develops the high-level requirements in Part A by describing the disposal system in more detail, justifying the requirements that it defines. It defines the scope and bounds of the engineering design work and provides the designers of the disposal system with the requirements that must be satisfied.

In the context of waste packaging, the purpose of the DSS[7] is to define requirements on all waste packages, containing any waste category, and which could be subject to geological disposal. This is achieved by defining the role that the waste package is expected to play within a geological disposal system and identifying the specific safety functions that waste packages will have to provide during transport and the GDF operational and post-closure periods. The DSS also identifies a series of *packaging criteria*, these being measurable or calculable properties of a waste package that indicates the extent to which a safety function is fulfilled. These packaging criteria, which are used as the basis for defining generic high-level packaging requirements on all waste packages destined for geological disposal, comprise:

- for the waste container: External dimensions, handling feature, stackability, identification and durability of integrity
- for the wasteform: General requirements (eg for physico-chemical properties)
- for the waste package as a whole: Activity content, gross mass, external dose rate, heat output, surface contamination, gas generation, criticality safety and accident performance

3.2 Generic Specifications

The *Generic Specifications* define the requirements on all waste packages that will be disposed of in accordance with a specified concept or range of concepts, and which will, in general, encompass waste packages containing wastes with similar radiological characteristics, which may comprise one or more waste categories. They are produced for industry regulators and for use by waste packagers involved in the development of innovative approaches to packaging. This would include the proposed use of a new design of waste container or waste conditioning process.

It is anticipated that Generic Specifications will be produced, as needed, to ensure that packaging specifications will be available for all categories of higher activity waste and other radioactive materials which may be the subject of geological disposal. Figure 4 is a schematic illustration of the wastes for which it is currently anticipated that Generic Specifications will be produced, defined on the basis of their radiogenic heat output and fissile material content.

[7] This role was previously played by the *Generic Waste Package Specification.*

Figure 4 Wastes for which Generic Specifications may be produced

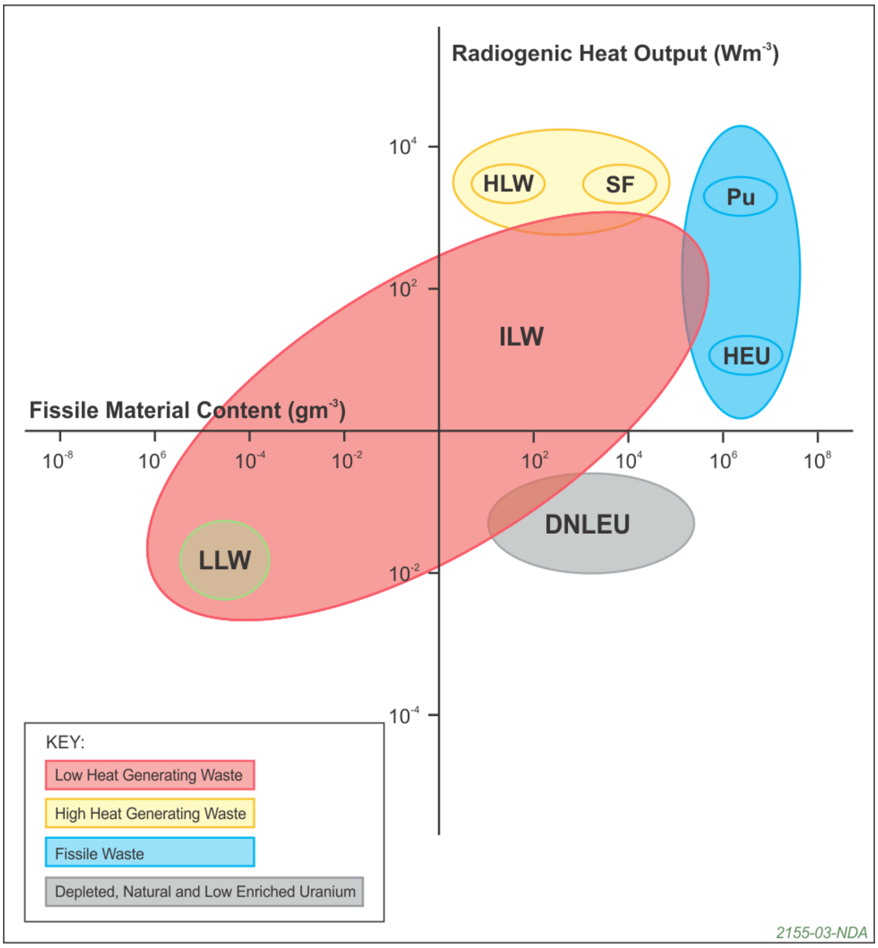


Figure 4 identifies four types of waste for which distinct disposal concepts could be identified, and for which Generic Specifications have been, or are expected to be, produced:

- LHGW; Wastes typically with a radiogenic heat output of up to ~100 Wm^{-3} and fissile material contents of up to ~10^3 gm^{-3}. This is intended to encompass all ILW in the UK RWI, together with LLW not suitable for near surface disposal, and DNLEU with uranium-235 enrichments of greater than 1%.
- HHGW; Wastes typically with radiogenic heat outputs of >100 Wm^{-3} and/or fissile material contents of up to ~10^5 gm^{-3}. This is intended to encompass vitrified HLW and SF
- Materials with high concentrations of uranium[8] (ie DNLEU), with uranium-235 enrichments of up to ~1%
- Wastes typically with fissile material contents of up to 10^5 gm^{-3} and radiogenic heat output of up to ~100 Wm^{-3}. This would be expected to encompass HEU and separated plutonium

It should be noted that the range of wastes encompassed by the anticipated Generic Specifications illustrated in Figure 4 overlap, indicating that the disposal of some types of waste could take place in accordance with more than one group of disposal concepts.

8 These would typically be relatively pure uranic compounds such as U_3O_8.

RWM has established a methodology for the production of Generic Specifications (Figure 4) which ensures that such a specification is founded on:

- the geological disposal concept(s) identified as being suitable for the waste category
- the designs of the systems for transport and disposal developed to meet the requirements of the DSS
- the safety cases for transport and the operational and post-closure periods of the GDF

all relevant regulations for the transport and geological disposal of radioactive waste

To date, Generic Specifications for waste packages containing LHGW [7], HHGW [11] and DNLEU [12] have been produced, these being the types of waste for which sufficient information is available regarding the inputs shown in Figure 5. It is anticipated that further Generic Specifications will be produced for the other types of waste and other radioactive materials identified above, as the necessary information identified in Figure 5 becomes available.

3.3 Waste Package Specifications

The *Waste Package Specifications* (WPS) define the requirements on waste packages containing a specific type of waste and which are to be manufactured using a standardised design of waste container. These designs of waste container are those which have been shown to be suitable for the manufacture of waste packages containing a specific type of waste, and which are compatible with the anticipated needs for the transport and disposal of that waste. Such containers are identified in the DSS and are described in Section 4 [10]. The WPS are produced for use by waste packagers intending to use such a design of waste container for the packaging of waste.

Each WPS (eg [13]) is derived from the Generic Specification which applies to the type of waste that the waste package will contain (eg LHGW) and defines a series of requirements on the waste packages that would be compliant with the requirements on their transport and geological disposal.

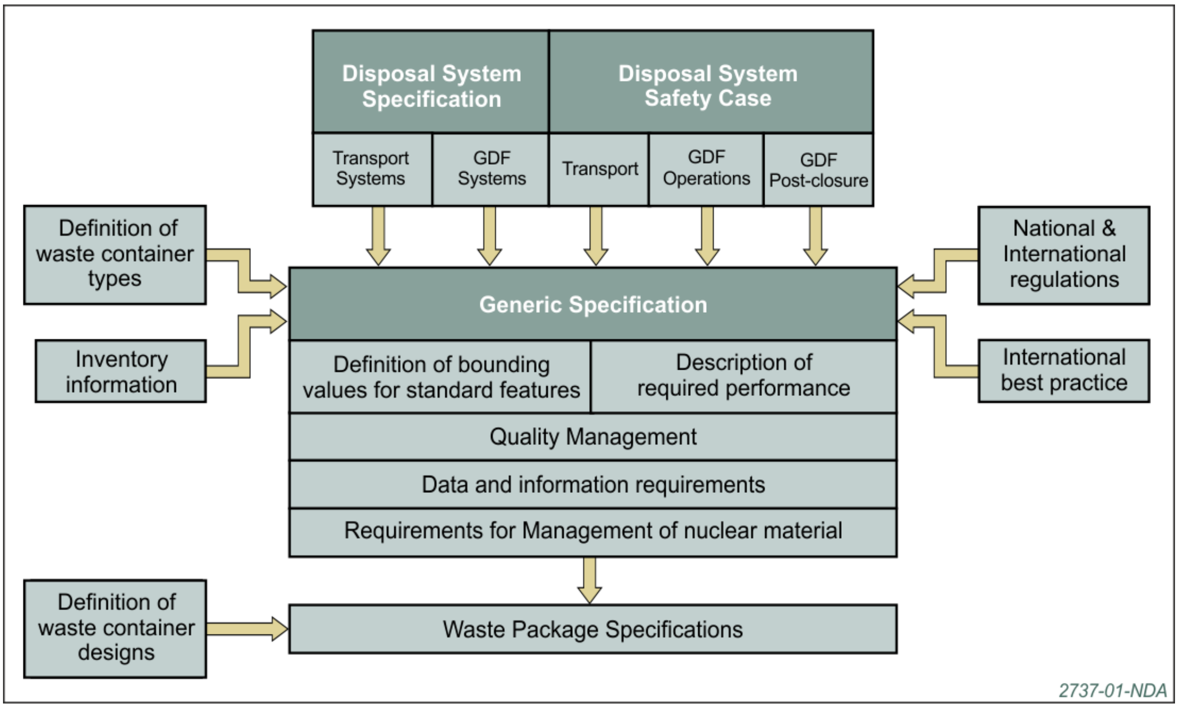
Currently WPS are only available for waste packages containing LHGW, at the time of publication of this report, a suite of 12 such WPS have been produced. Additional WPS will be added to the suite as and when further standardised designs of waste container are added to those identified by the DSS.

3.4 Basis for the definition of the packaging requirements

The methodology employed for the production of the packaging specifications is illustrated in Figure 5. The objective of this methodology is to define qualitative and/or quantitative requirements on each of the packaging criteria identified by the DSS. Table 2 lists the basis for the definition of the packaging requirements for each of the packaging criteria in a Generic Specification, and the additional basis, where relevant, for a WPS.

As discussed above, the successive levels in the hierarchy of the packaging specifications (ie DSS to Generic Specification to WPS) represent increasing degree of specificity to waste category and waste package design, with the Generic Specifications being the first level at which the disposal concepts, the systems designs and the safety cases for transport and disposal, are considered. The manner in which these influence the definition of the requirements that make up the Generic Specifications and the WPS is summarised in Table 2.

Figure 5 Inputs to a Generic Specification



An example of how the packaging requirements become more specific at each level in the hierarchy of packaging specifications can be illustrated in the case of the requirements for the identification of waste packages:

- DSS: *"The waste package shall enable unique identification until the end of the GDF operational period."*
- Generic Specification[9]: *"The waste package shall be marked at multiple defined locations with a unique alpha-numeric identifier. The waste package shall remain identifiable by automated systems for a period of 150 years following manufacture."*
- WPS[10]: *"The waste container shall be marked with a unique alpha-numeric identifier, located at four positions, on the vertical surface of the waste container lifting feature spaced at 90º around the circumference of the waste container. The identifier shall comprise ten OCR-A characters between 6mm and 10mm high. The waste package shall remain identifiable by automated systems for a minimum period of 150 years following manufacture."*

9 From the Generic Specification for waste packages containing LHGW [7].

10 From the WPS for 500 litre drum waste packages [**Error! Bookmark not defined.**13].

Table 2 Basis for the definition of the packaging requirements in Generic Specifications and WPS

Packaging criterion	Basis for the definition of requirements in a Generic Specification	Additional basis for the definition of requirements in a WPS
General requirements on waste container	Generic requirement to make adequate contribution to waste package performance	No additional requirements
External dimensions	Bounding values derived from transport infrastructure, transport systems (ie transport container) and GDF systems,	External dimensions of specified waste container
Handling feature	Generic requirements on lifting and tie down	Design of handling feature for specified waste container
Stackability	Bounding maximum stack height for illustrative disposal concepts identified for the waste category (where relevant[11])	Quantified load for waste package at bottom of maximum height stack of waste packages with maximum specified gross mass
Identification	Generic requirement for form of identifier	Identifier positions for specified waste container
Durability of integrity	Generic requirement based on duration of GDF operational period and post-closure containment requirement defined by concept	No additional requirements
General requirements on wasteform	Generic requirement to make adequate contribution to waste package performance Requirements on wasteform evolution to ensure continued compatibility with requirements of transport, GDF operational and post-closure safety cases	No additional requirements
Activity content	Radiological constraints (dose rate, heat output etc.) set by transport and GDF operational safety cases. Regulatory limits on contents of transport packages.	Transport Regulations requirements for waste packages transported as Industrial Packages
Gross mass	Bounding values derived from transport infrastructure, transport systems (ie	Value for waste packages manufactured using

[11] For some disposal concepts waste packages are not stacked. Also for some designs of waste package (eg the 500 litre drum, see Section 4.1.2), stacking devices, such as stillages, are used such that no stacking loads are borne by the waste package itself.

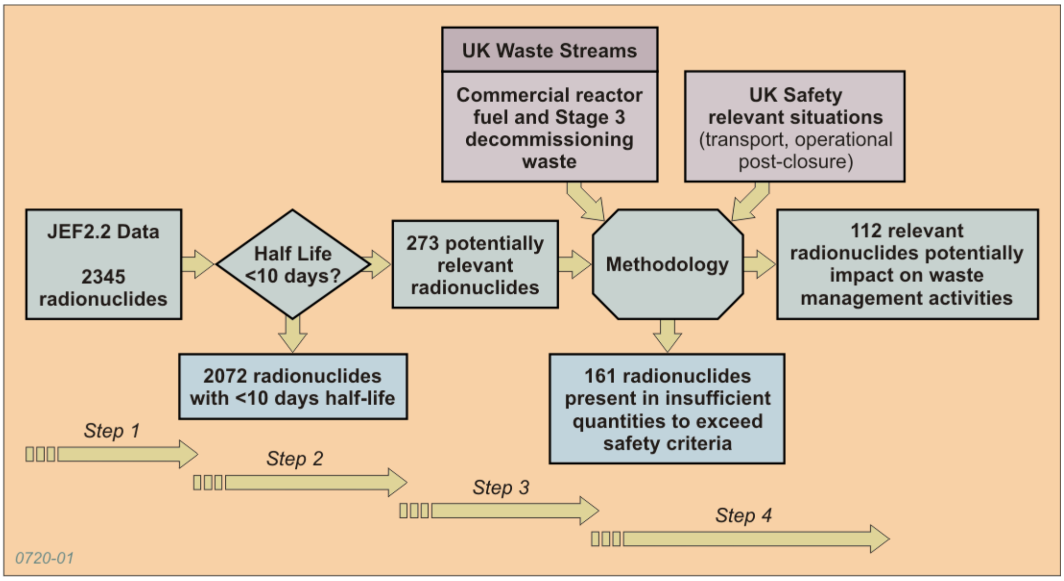
Packaging criterion	Basis for the definition of requirements in a Generic Specification	Additional basis for the definition of requirements in a WPS
	transport container) and GDF systems	specified waste container
External dose rate	Requirement to be ALARP Regulatory limit for transport packages defined by Transport Regulations	Transport Regulations requirement for transport packages, applied with or without shielding provided by transport container
Heat output	Maximum heat output during transport defined by Transport Regulations. Screening level and upper limit (in Wm^{-3}) set by post-backfilling temperature limits	Quantified heat outputs for waste packages manufactured using specified waste container
Surface contamination	Requirement to be ALARP Regulatory limit for waste packages which are transport packages defined by Transport Regulations	No additional requirements
Gas generation	Regulatory limit for transport packages defined by Transport Regulations Need to limit internal pressurisation of waste packages. Screening levels for release of gaseous activity (in Bqm^{-3}) during GDF operational period	Quantified gas generation and activity release limits for waste packages manufactured using specified waste container
Criticality safety	Regulatory requirement for transport defined by Transport Regulations Requirement to be ALARP during GDF operational period, defined by SAPs Low likelihood/low consequences during GDF post-closure period	No additional requirements
Accident performance	Activity release low and predictable, dose consequences to be ALARP Regulatory limits on activity release and/or dose consequences during transport, defined by Transport Regulations, and GDF operational period, defined by SAPs	No additional requirements

3.5 The identification of radionuclides of relevance to the geological disposal of higher activity waste

It has long been acknowledged, by the UK nuclear industry and the industry regulators, that not all of the radionuclides known to exist will be present in significant quantities in radioactive waste and, of those that are present, only a limited number will have relevance to the long-term safe management of the waste. It has accordingly been recognised that it is neither necessary nor practical for the radionuclide content of waste to be recorded in terms of all known radionuclides and that this should be limited to a smaller number of radionuclides the presence of which does have relevance for safety.

A methodology has been developed for the identification of radionuclides which have relevance to the safety of the transport and geological disposal of ILW and LLW. The methodology, which is illustrated in Figure 6, has been used to screen the 2,345 then known radionuclides (as identified in the JEF2.2 nuclear data library [14]), to identify a smaller sub-set that can be considered significant for geological disposal of waste.

Figure 6 Method for the identification of 'relevant radionuclides'



Of the 2,345 radionuclides known to exist, almost 90% can be screened out on the basis that their short half-lives means that they will have decayed to insignificant quantities before the wastes are packaged. The methodology assumes a 10 day half-life for this screening step and this leads to 273 radionuclides being carried forward to the next stage of screening. Of the remaining radionuclides, some are parents of short-lived daughters. If such a daughter is capable of making a significant contribution to, for example, radiation dose or heat generation, this contribution is added to that made by the parent.

Consideration of the remaining 273 radionuclides revealed that 161 either existed in such small quantities in the inventory for disposal and/or would have no significant impact on the safety of any of the three main stages of geological disposal (ie transport, GDF operations and the post-closure period) such that they could also be ignored. The remaining 112 'relevant radionuclides' provide the basis for the radionuclide information requirements on all waste packages containing ILW and for the safety assessments reported in the generic DSSC [15].

It is noted that the original definition of the list of 112 radionuclides was carried out on the basis of the geological disposal of ILW and LLW only[12]. However, RWM believes that, since the process described above considered all known natural and man-made radionuclides, and made pessimistic assumptions regarding the quantities of the radionuclides present in ILW, the outcomes are broadly valid for other categories of higher activity waste. It is also recognised that the list must be maintained and periodically reviewed and updated, and that the next such updating will take account of the full range of wastes that may be subject to geological disposal.

During a disposability assessment the list of 112 relevant radionuclides provides the initial basis for reporting and analysing radionuclide inventories. In practice, for many waste streams, only a subset of these 112 relevant radionuclides are likely to be present in significant quantities and for which waste package inventory information is required. In order to provide a proportionate focus in assessing the suitability of a proposed approach to the packaging of a specific waste, two methodologies have been developed in order to determine which of the relevant radionuclides are present in the waste in significant quantities. In this context 'significant' refers to the relative significance of the reported quantities of radionuclides to transport, operational and post-closure safety:

- the Guidance Quantities methodology, a conservative methodology which allows a waste packager to identify the radionuclides that are of significance to the packaging of a particular waste stream, and those for which information will be required when proposals to package that waste stream are assessed by RWM (see Section 5)
- Significant Radionuclide Analysis, which is applied by RWM as part of a disposability assessment to reduce the conservatism introduced by the Guidance Quantities methodology, by taking credit for wasteform and waste package specific factors, and the number of waste packages concerned

3.6 The transport of waste packages

The transport of waste packages through the public domain is subject to the *Regulations for the Safe Transport of Radioactive Material*[13] [16] produced by the International Atomic Energy Agency (IAEA) and implemented in the UK through the *Carriage of Dangerous Goods Act* [17]. The regulations are aimed at minimising the radiation exposure of workers and members of the public under both normal and accident conditions of transport. Specifically the regulations place controls on the properties and performance of transport packages in respect of activity content and its release under normal and accident conditions of transport, dose rate, heat output and criticality safety. In this way the IAEA Transport Regulations define general requirements and, in some cases, quantified limits for a range of properties of radioactive materials which apply to their transport and these are, where relevant, incorporated into the packaging specifications.

The distinction between a 'waste package' and a 'transport package' is important here as it influences the manner by which the requirements of the IAEA Transport Regulations are applied to waste packages:

- a waste package will, in general, comprise a container in which conditioned waste is placed and which is suitable for disposal without further treatment

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[12] The definition of the list was also based on the radionuclides that would be expected to be present in wastes arising from the reprocessing of uranium fuel irradiated in thermal reactors only.

[13] Known colloquially as the 'IAEA Transport Regulations'.

- a transport package is an item suitable for transport, which may comprise a waste package or one or more waste packages contained within a protective transport container.

This distinction lead to two basic types of waste package; those which can be transported without additional protection, and are ‘transport packages in their own right’, and those that require such protection, usually in the form of an overpacking transport container, or other device to provide protection against mechanical and/or thermal shocks.

The IAEA Transport Regulations define two categories of transport package which are suitable for the transport of higher activity waste:

- Industrial Packages (Type IP transport packages); for the transport of materials with limited specific activity and for which protection is vested in controls placed on the form and specific activity of the contents of the transport package
- Type B transport packages; for the transport of much larger quantities of activity, and for which protection of transport workers and members of the public relies on the structure of the transport package itself

4 Standardised Designs of Waste Container

Standardisation of waste container designs is internationally recognised as good practice [18]. It promotes the safe and efficient operation of storage, transport and disposal systems, notably by simplifying the design of transport and disposal facilities, notably the handling of waste packages, and thereby reducing opportunities for faults such as those that could result in impact accidents.

For each standardised design of waste container that is identified by the DSS a WPS is produced (see Section 3.3). This will comprise a definition of the standard features of the container design (eg dimensions, shape and lifting feature) as well as the requirements on the performance of the waste packages that the container could be used to produce.

4.1 Waste containers for ILW and LLW

The DSS identifies twelve standardised designs of waste container that have been shown to be suitable for the packaging of ILW and LLW[14] for geological disposal. The waste packages that these containers can be used to produce fall into three basic types, the properties of which reflect the nature of the waste they are used to package, and the role that the container will play in the delivery of the required waste package performance.

4.1.1 Shielded waste packages

For use with wastes with low radionuclide content[15], such as would not generally require the extensive use of remote handling techniques, waste containers incorporating integral concrete radiation shielding can be used to create *shielded waste packages*. Shielded waste packages would generally be expected to be capable of being transported through the public domain as Type IP transport packages without additional protection, as transport packages in their own right.

The DSS identifies five standardised designs of waste container that can be used to produce shielded waste packages, the key properties of which are listed in Table 3.

Table 3 Key properties of standardised designs of shielded waste container

Waste container	External dimensions (m)		Payload volume (m^3)	Maximum gross mass of waste package (t)
	Plan	Height		
2 metre box	2.0 x 2.4	2.2	5.0 - 9.5[16]	40
4 metre box	4.0 x 2.4	2.2	8.1 - 18.9[16]	65
6 cubic metre concrete box	2.2 x 2.4	2.2	5.8	50
500 litre drum	1.1 diameter	1.3	0.5	6
1 cubic metre drum	1.4 diameter	1.3	0.9	8

14 Such containers would be suitable for the packaging of other categories of LHGW

15 Such as would satisfy the IAEA Transport Regulations definition of ‘low specific activity material’ [16]

16 The actual payload volume depends on thickness of the shielding using.

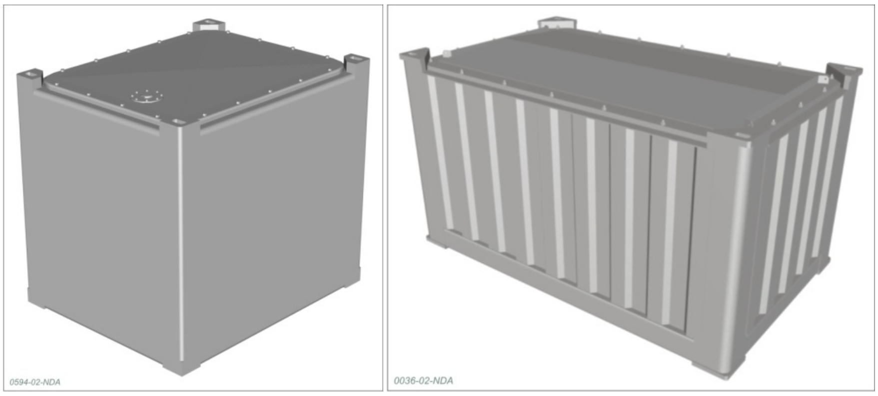
2 metre and 4 metre boxes

The 2 metre box [19] and 4 metre box [20] have been developed for use in the packaging of large waste items typically arising from the decommissioning of nuclear facilities. Depending on their physical and/or chemical properties, and the nature and quantities of the radionuclides associated with them, such wastes may be encapsulated, for example using a cementitious grout, or left unencapsulated.

The designs of these two waste containers (Figure 7), notably their external dimensions (Table 3) are based on the principles established for Series 1 International Organisation for Standardisation (ISO) freight containers [21]. The width dimensions[17] of the two boxes correspond to the ISO standard and the lengths correspond to one-third and two-thirds of the standard 6 metre ISO container.

The outer containment of the 2 and 4 metre boxes will generally be manufactured using stainless steel, and the containers can be used with or without integral shielding depending on the external radiation emitted by its contents. The DSS assumes that shielding thicknesses of 100 mm or 200 mm could be used with the 2 metre box, and 100 mm, 200 mm or 300 mm used with the 4 metre box.

Figure 7 2 metre and 4 metre boxes



6 cubic metre concrete box

The 6 cubic metre concrete box [22] (Figure 8) was originally developed for the packaging of LLW and ILW arising from the decommissioning of the Windscale Advanced Gas-cooled Reactor[18]. For this role the container was manufactured from reinforced concrete[19], with walls 240 mm thick and it was mainly used for the packaging of large items of steel and graphite encapsulated using a cementitious grout. The 6 cubic metre concrete box can be used for the packaging of a range of solid heterogeneous wastes which are placed into the container and backfilled with cementitious grout. After conditioning of the waste in this way the waste package is completed by the *in situ* casting of a 'lid'.

The external dimensions of the 6 cubic metre concrete box were originally defined to suit the needs of the original use of the container. The height of the container (ie 2.200 m) and one of its plan dimensions (ie 2.438 m) are the same as those of the 2 and 4 metre boxes

Corrosion-protected carbon steel collars can be incorporated around the top and base of the box to minimise damage and spalling of the external concrete surfaces during normal

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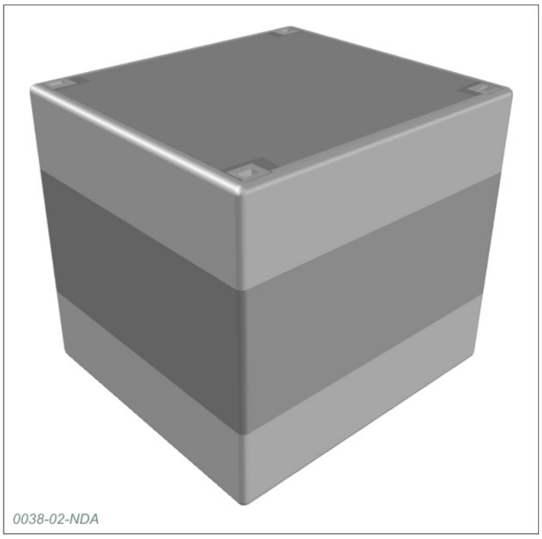
17 This actually being the 'length' of the 6 cubic metre box due to the orientation of the twistlock apertures.

18 This led to the waste container being known colloquially as the "WAGR Box".

19 The concrete used can incorporate high-density materials (eg haematite) to maximise its radiation shielding properties.

handling operations and in case of impact accidents. The walls of the container, being gas permeable, allow for the release of internally generated gases and therefore the waste container does not require an engineered vent.

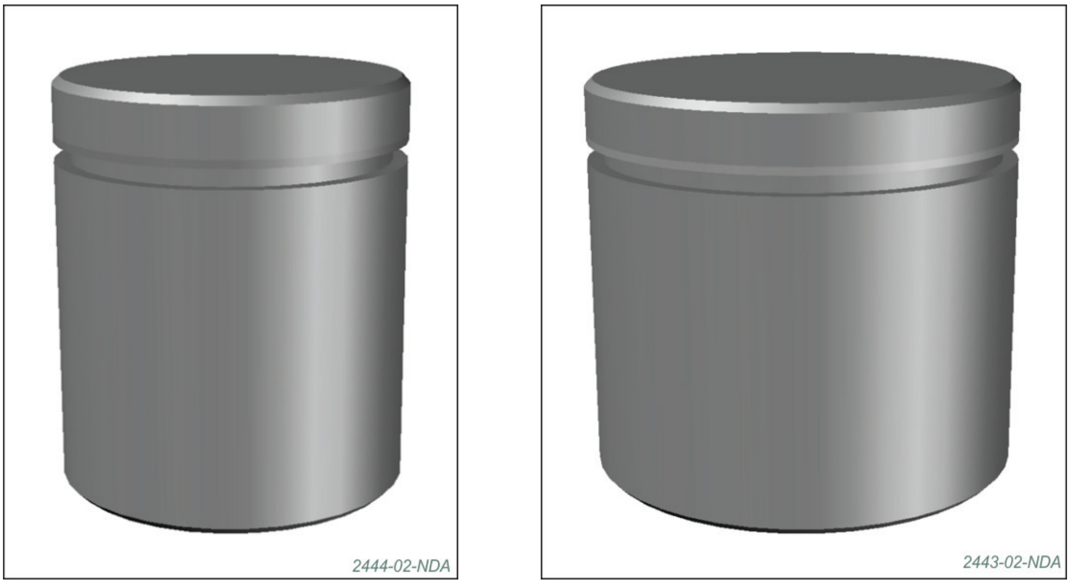
Figure 8 6 cubic metre concrete box



500 litre and 1 cubic metre concrete drums

The 500 litre and 1 cubic metre concrete drums [23, 24] (Figure 9) are cylindrical waste containers made from reinforced concrete with walls typically 160 mm thick. They have been proposed for use in the packaging of a wide range of power station operational wastes, including dewatered sludges, ion exchange resins, filters and other heterogeneous solid wastes. In general, such wastes would be encapsulated using cementitious grout and the waste package completed by the *in situ* casting of a lid.

Figure 9 500 litre and 1 cubic metre concrete drums



4.1.2 Unshielded waste packages

For wastes with higher specific activities, such as would generally require the use of remote handling techniques, relatively thin-walled (ie a few mm) metal containers can be used to create *unshielded waste packages*. Because of their external radiation dose rate, or requirements on the containment of their contents, such waste packages would be expected to be transported through the public domain in reusable shielded transport containers.

The DSS identifies five[20] standardised designs of waste container that can be used to produce unshielded waste packages, the key properties of which are listed in Table 4.

Table 4 Key properties of standardised designs of unshielded waste container

Waste container	External dimensions (m)		Payload volume (m^3)	Maximum gross mass of waste package (t)
	Plan	Height		
500 litre drum	0.80 diameter	1.2	0.5	2.0
3 cubic metre box20	1.7 x 1.7	1.2	2.6	12
3 cubic metre drum	1.7 diameter	1.2	2.2	8
MBGWS Box	1.9 x 1.9	1.47	3.6	12

The transport of unshielded waste packages will take place using one of three variants of the standard waste transport container (SWTC - Figure 10) specifically designed for use with the range of unshielded waste containers listed in Table 4. The three variants of the SWTC provide different thicknesses of radiation shielding of the waste package contents (ie 70mm, 150mm and 285mm) and permit such waste packages to be transported as part of a Type B transport package (see Section 3.6 and [3]).

500 litre drum

The 500 litre drum (Figure 11, [13]) was originally developed for the packaging of ILW arising from the de-canning of Magnox fuel at Sellafield. It has since been used for the packaging of a much wider range of wastes at a number of sites across the UK including:

- heterogeneous solid wastes which are placed in the drum and backfilled with, eg, a cementitious grout or polymeric material
- homogeneous wastes (eg sludges and slurries) which are mixed with an encapsulating medium inside the drum. by means of an integral mixer [21]
- mixed ‘soft’ wastes which are compacted within sacrificial mild steel drums prior to placement in a 500 litre drum and surrounded with grout to form a so-called ‘annular grouted’ wasteform

It is assumed that 500 litre drum waste packages will be handled, transported and emplaced in the GDF using stillages, each containing four waste packages (Figure 11).

[20] Two variants of the 3 cubic metre box exist, see below.

[21] This process is referred to as ‘in-drum mixing’.

Figure 10 Unshielded waste packages in a SWTC

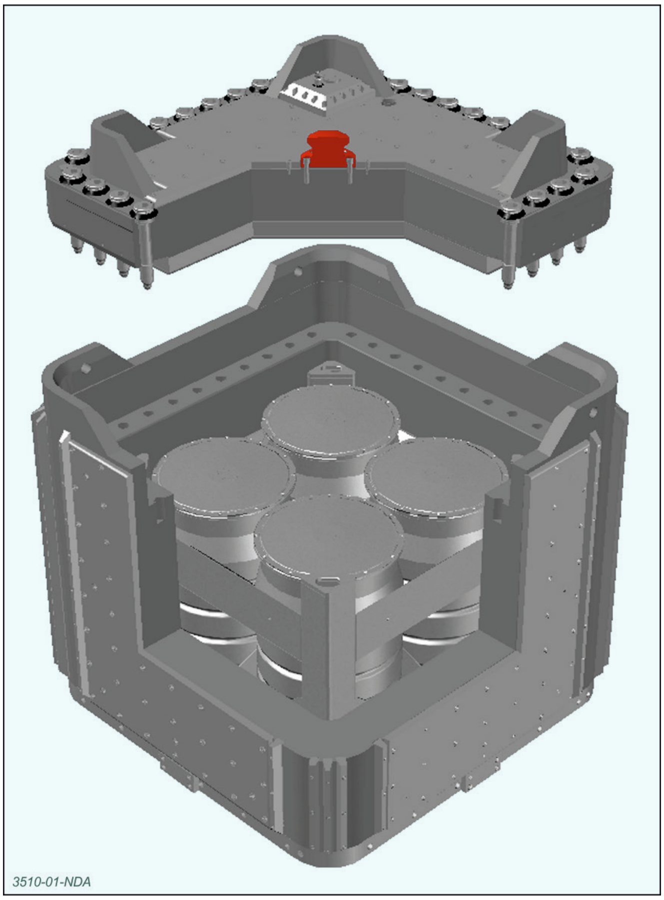
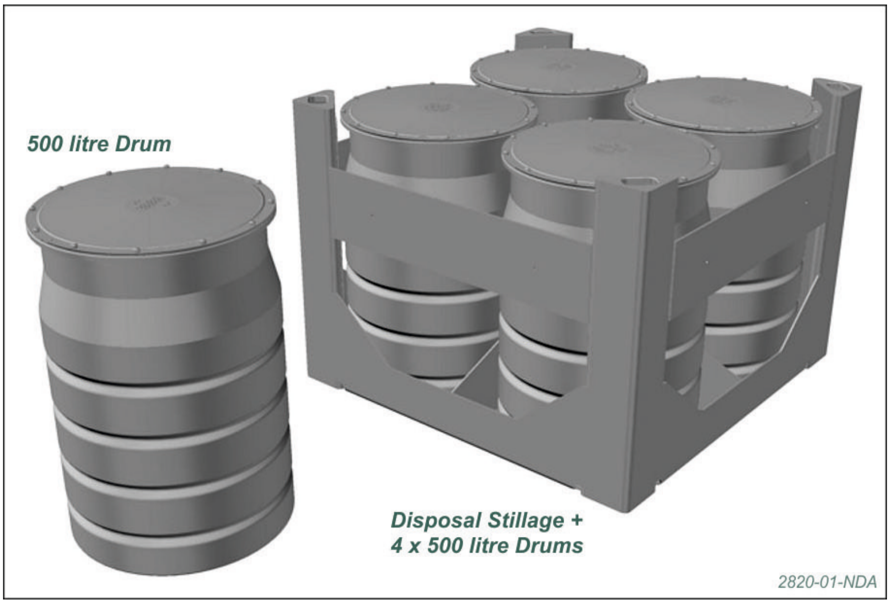


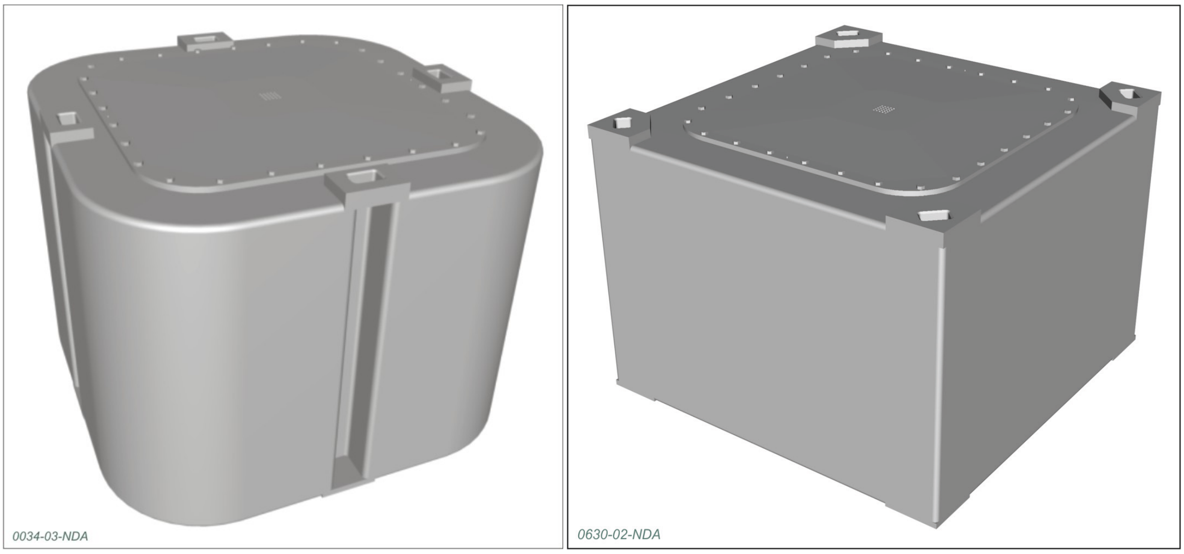
Figure 11 500 litre drum and stillage



3 cubic metre box

The 3 cubic metre box was originally developed as a larger alternative to the 500 litre drum, intended for use in the packaging of decommissioning wastes. Two variants of the 3 cubic metre box have been developed (Figure 12, [25, 26]) to align with the operational requirements of different waste packagers.

Figure 12 3 cubic metre boxes



3 cubic metre drum

The 3 cubic metre drum (Figure 13, [27]) is generally used for the packaging of liquid, sludge and slurry wastes which are typically conditioned of by a process of in-drum mixing of the waste with an immobilising material.

Figure 13 3 cubic metre drum

Miscellaneous Beta/Gamma Waste Store box

The Miscellaneous Beta/Gamma Waste Store (MBGWS) box (Figure 14, [28]) is currently used for the storage of a range of un-encapsulated solid ILW at Sellafield. MBGWS boxes were fabricated from either mild or stainless steel and the existing MBGWS box waste packages are not currently considered suitable for disposal. Therefore, it is anticipated that, prior to export to the GDF the waste currently held in MBGWS boxes, will have to be further conditioned to produce disposable waste packages.

Figure 14 MBGWS box

4.1.3 Robust shielded waste packages

For all types of ILW, thick-walled (ie many 10's of mm) waste containers, typically made of ductile cast iron, can be used to provide both radiation shielding and physical containment of their contents, and to create *robust shielded waste packages*, so-called owing to the robustness of the containers which, on their own, can provide the most or all of the necessary fire and impact protection for the waste during transport and GDF operations. Such waste packages may be capable of being stored, transported and disposed of without the need for remote handling techniques or for additional physical protection of radiation shielding during their transport, and may qualify as transport packages in their own right.

The DSS currently identifies two standardised designs of robust shielded waste container, the key properties of which are listed in Table 5.

Table 5 Key properties of standardised designs of robust shielded waste container

Waste container	External dimensions (m)		Payload volume (m^3)	Maximum gross mass of waste package (t)
	Plan	Height		
500 litre robust shielded drum	1.1 diameter	1.5	~0.5	10
3 cubic metre robust shielded box	2.0 x 1.6	1.7	~3.0	25

500 litre robust shielded drum

This is a cylindrical container, which can be fabricated with a range of wall thicknesses, and which can be used to manufacture robust shielded waste packages (Figure 15, [29]). It is currently assumed that 500 litre robust shielded waste packages which, it is currently assumed, will be transported within an SWTC-150 as part of a Type B transport package (Figure 16).

Figure 15 500 litre robust shielded drum

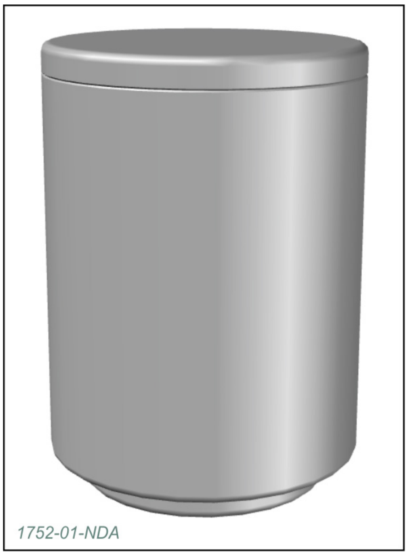
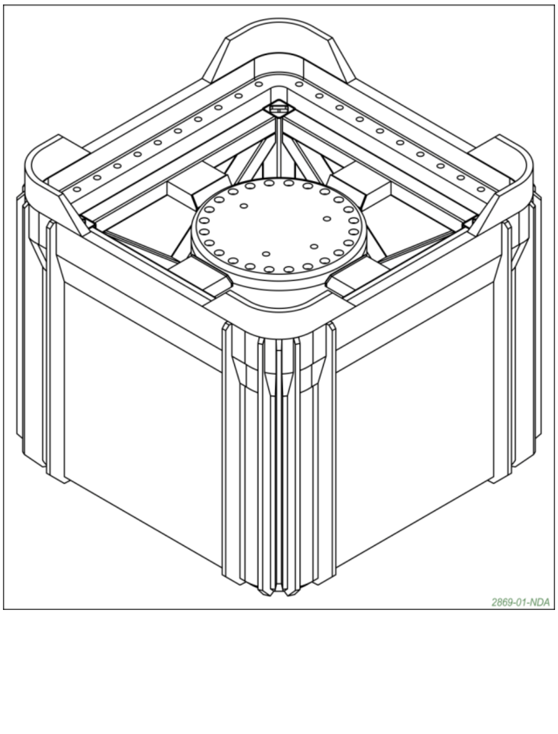


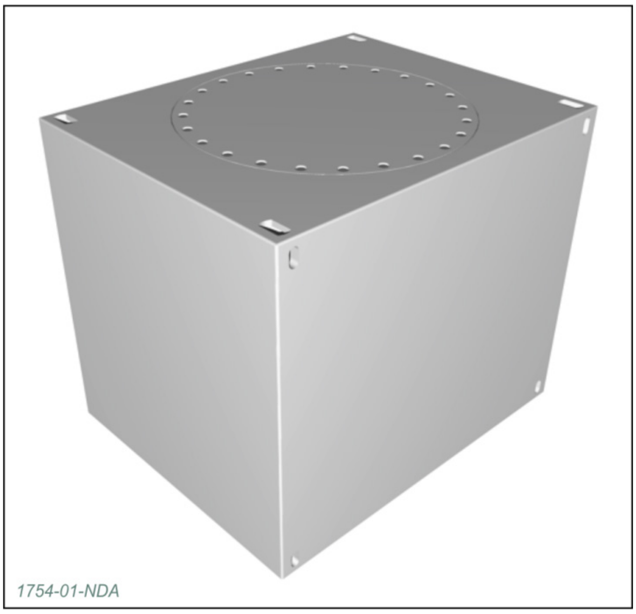
Figure 16 500 litre robust shielded drum in SWTC-150



3 cubic metre robust shielded box

This is a cuboidal container, which can be manufactured with a range of wall thicknesses, and which can be used to produce robust shielded waste packages (Figure 17, [30]). It is currently assumed that 3 cubic robust shielded box waste packages will be transported within a transport container, the design of which will be based on the relevant ISO standards, as part of a Type IP-2 transport package. Such a container is required to provide additional containment of radionuclides during transport and, whilst it is not assumed to provide any significant physical or thermal protection during accidents, or radiation shielding, it could be so designed to play such a role if necessary.

Figure 17 3 cubic metre robust shielded box



4.2 Waste containers for DNLEU

It is anticipated that all of the DNLEU that could be destined for geological disposal will exist in the form of uranium oxide produced as a product of the reprocessing of spent fuel or of the de-conversion[22] of uranium enrichment plant 'tails'. These materials will have been packaged in various ways for storage, none of which are currently deemed suitable by RWM for geological disposal. It is currently assumed that most of the current stocks and anticipated arisings of DNLEU will be overpacked, in their 'as-stored' packages, within stainless steel 'transport and disposal containers', the dimensions of which would be based on that of the Series 1 ISO freight container. The main exception to this assumption is DNLEU arising from the reprocessing of spent fuel from UK AGRs, some of which has a uranium-235 enrichment of greater than 1%. It is currently assumed that this material will be 'repackaged' by mixing it with cement within 500 litre drums (ie Figure 11) and managing the resulting waste packages in the same manner as those containing LHGW. In addition there may be other forms of DNLEU (such as that arising from other fuel cycle processes) for which this latter approach to packaging and disposal would be more suitable.

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[22] This material is currently held in the form of uranium hexafluoride.

4.3 Waste containers for HLW and spent fuel

RWM has undertaken development work to standardise waste container designs for HLW and spent fuel notably their external dimensions and lifting features, with the aim of [31]:

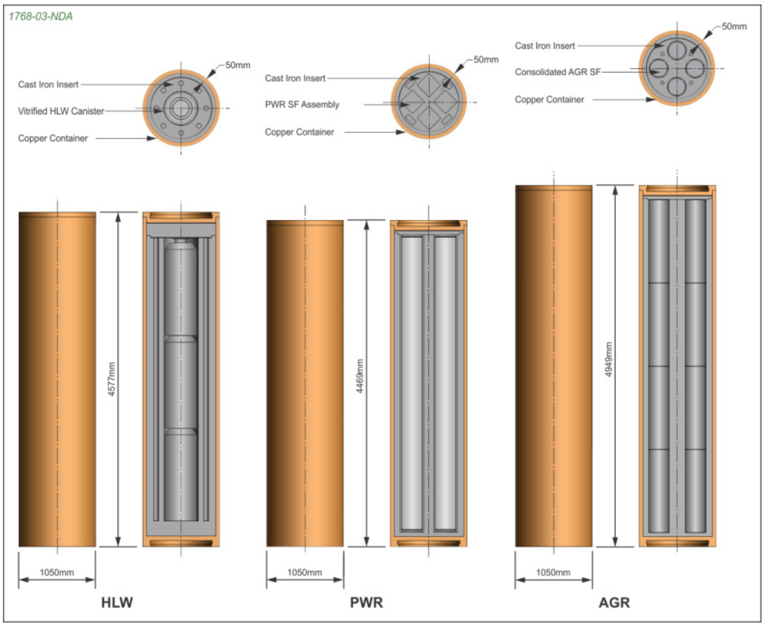
- reducing the number of waste packages to be disposed, and therefore the size of the GDF 'footprint'
- reducing the extent of underground excavation, spoil generated and materials used for construction of the GDF
- providing additional flexibility in emplacement (and retrieval) operations for waste packages in either a horizontal or vertical orientation

Two basic designs of standardised waste container have been developed, based on the assumed requirements on the disposal of HLW and spent fuel in accordance with the three illustrative disposal concepts identified for HHGW in the Technical Background:

- Variant 1: Fabricated from copper[23], with a cast iron insert (Figure 18), used in the illustrative disposal concept for HSR
- Variant 2: Fabricated from carbon steel[23] (Figure 19), used in the illustrative disposal concepts for LSSR or EVR

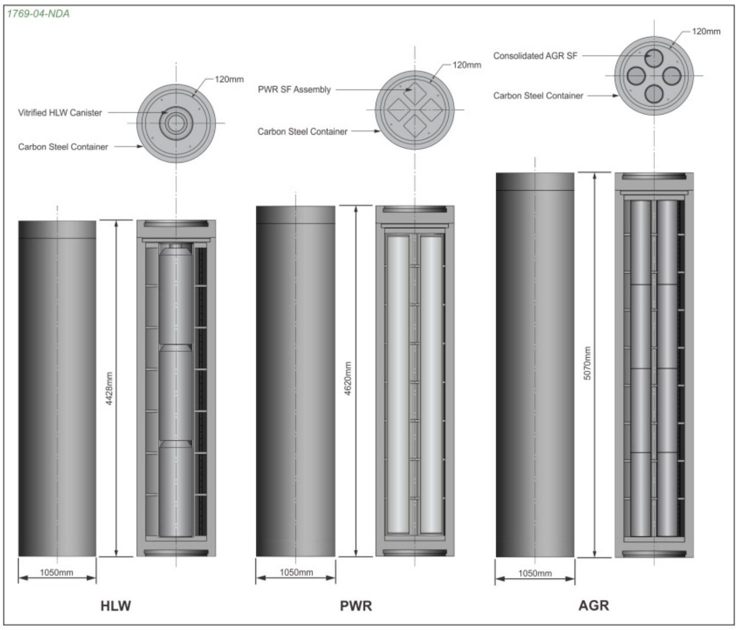
The standardised designs have a common external diameter (ie 1.05 m) and handling feature design, and with overall lengths and radiation shielding provision to suit the anticipated contents of the waste packages. Designs have been developed for the full range of HLW and spent fuel that currently exists, or that could arise in the future. This comprises the three types of 'legacy' wastes (ie vitrified HLW, and spent fuel from UK Advanced Gas-cooled and Pressurised Water Reactors), as well as other UK spent fuel (including that from Magnox reactors, from experimental and submarine reactors, and that arising from the operation of a new generation of UK power stations, including mixed oxide fuel).

Figure 18 Variant 1 waste container designs



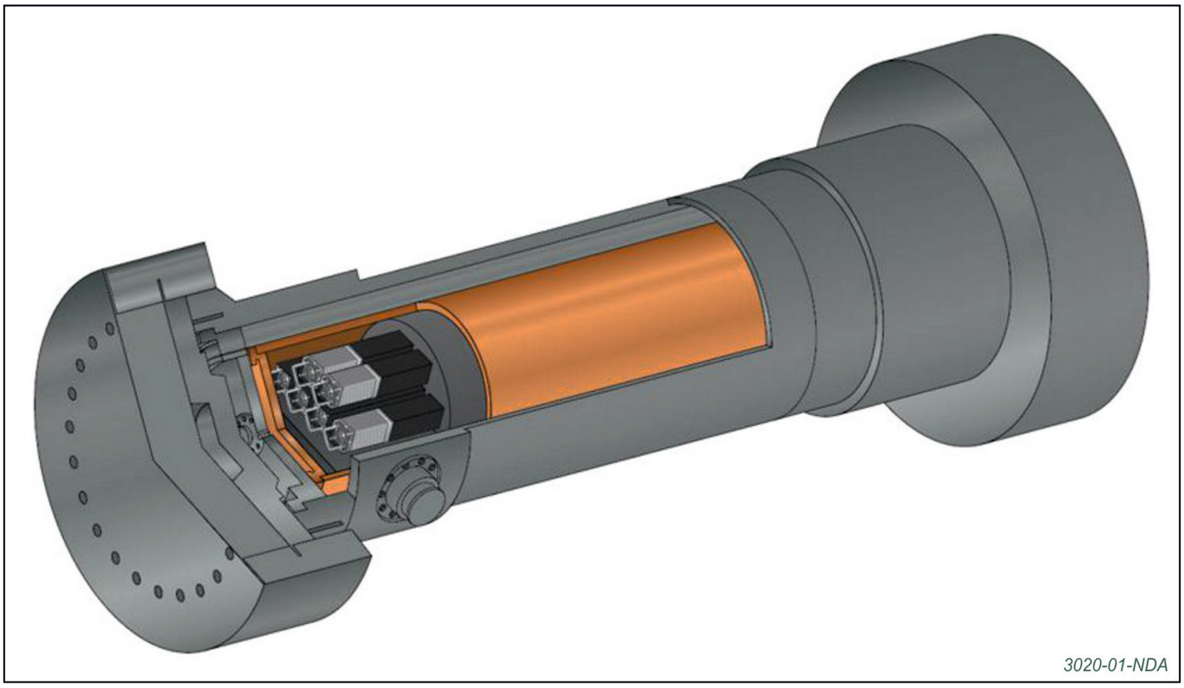
23 It should be noted that whereas copper and carbon steel have been identified as suitable for the fabrication of waste containers for HHGW, no decisions have been made to adopt them as such and that other materials may prove equally suitable for that purpose.

Figure 19 Variant 2 waste container designs



To facilitate the transport of waste packages manufactured using these standardised waste container designs, the *Disposal Container Transport Container* (DCTC - Figure 20) has been developed [32].

Figure 20 DCTC for HHGW waste packages



4.4 Waste containers for fissile waste

Specific disposal concepts for fissile waste (ie HEU and separated plutonium) have not yet been developed to the point at which waste container designs can be defined. The DSS categorises fissile wastes as HHGW and the types of waste container defined for other types of HHGW (ie HLW and spent fuel) above could be equally suitable for the geological disposal of fissile wastes. Depending on the disposal concepts that are chosen for fissile wastes, alternative designs of waste container could be developed, their principle aims being long-term containment and the maintenance of an adequate degree of criticality safety into the GDF post-closure period.

5 Assessing the Disposability of Waste Packages

5.1 Background

A waste package is deemed by RWM to be 'disposable' if it can be shown to be compliant with the packaging criteria specified by relevant WPS and with the assumptions made in the safety cases for a GDF. This should ensure that it can be safely transported to and disposed in a GDF. RWM uses the Disposability Assessment process [33] to judge whether the implementation of proposals to package a specific waste stream in a given manner would result in disposable waste packages.

The assessment of the potential disposability of waste packages has a long history, with the earliest formal advice and 'endorsement' of proposals to package waste being issued in 1986. The assessment process was originally developed to give confidence to waste packagers that their proposed approaches to the packaging of ILW would result in waste packages that were compatible with the developing plans for geological disposal. At that time, the endorsement of such plans was signified by the issue of a 'Letter of Comfort'.

During the early 1990s, the process matured to a point that assessments were carried out on a more formally structured basis with more detailed advice (designated *Advice Reports*) being issued to waste packagers. This allowed the identification of additional information needs and/or results from further development and research work, before endorsement could be made, by way of the issue of a *'Letter of Compliance'* (LoC). The process was also modified to align with the assumed implementation of a packaging plant project, with staged interactions occurring at key points during the development of the packaging proposal and the construction and commissioning of the packaging plant.

The role of the Disposability Assessment process in assessing the suitability of waste packages for geological disposal is explicitly recognised in the regulatory framework for the management of higher activity wastes in the UK [34]. Following publication of Scottish Government Policy regarding the management of higher activity wastes on Scottish sites [35] it was also considered that wastes packages assessed as being disposable in a GDF would also be suitable for long-term storage.

In summary, the main purposes of the Disposability Assessment process, as currently constituted, are to:

- give confidence to waste packagers that the implementation of their proposals for the packaging of waste will result in waste packages that would be compliant with the eventual needs for transport to, and disposal in, a GDF
- ensure that packaging strategies, and ultimately investment decisions by waste packagers, are soundly based and will result in waste package designs that best meet the needs for processing and storage as well as disposal
- provide RWM with assurance that the geological disposal concepts considered within the DSSC will be appropriate for the wastes they will be expected to cover
- permit the identification of wastes that could challenge current disposal concepts and allow early consideration of the changes that may be required to those concepts to permit the wastes to be accommodated

It should be noted that, although the Disposability Assessment process primarily considers the performance and safety of waste packages, it also considers the effects that the interim storage of waste packages prior to transport to a GDF may have on waste package performance and safety (ie as a result of changes caused by the evolution of the waste package). The term 'disposal' is used hereafter to denote all three of these periods of management as they are considered in a disposability assessment.

5.2 The Disposability Assessment Aim and Principles

RWM has produced a statement of the aim of the Disposability Assessment process and a list of principles that define the philosophy which underpins the approach to assessment of the disposability of waste packages. The *Disposability Assessment Aim and Principles* (DAAPs) [36], which are listed in Appendix A, have been produced with the objectives of:

- providing a succinct statement to encapsulate the purpose of RWM's work in support of waste packaging and disposability assessment
- setting down the underlying principles governing the conduct of disposability assessments and the issue of LoCs
- setting down the conditions under which an LoC can be issued, and the status of that LoC, at each stage of the assessment process

The DAAPs are defined in such a manner as to be applicable to all higher activity wastes and other radioactive materials which may be the subject of geological disposal, to align with UK [2] and Scottish Government policy [35] and with regulatory guidance [34]. They also reflect the NDA mission statement: *'…to adopt a safe and cost effective approach to the management of waste and the reduction of the hazard posed by such wastes and materials.'* and support the RWM vision of *'A safer future by managing radioactive waste effectively, to protect people and the environment.'*

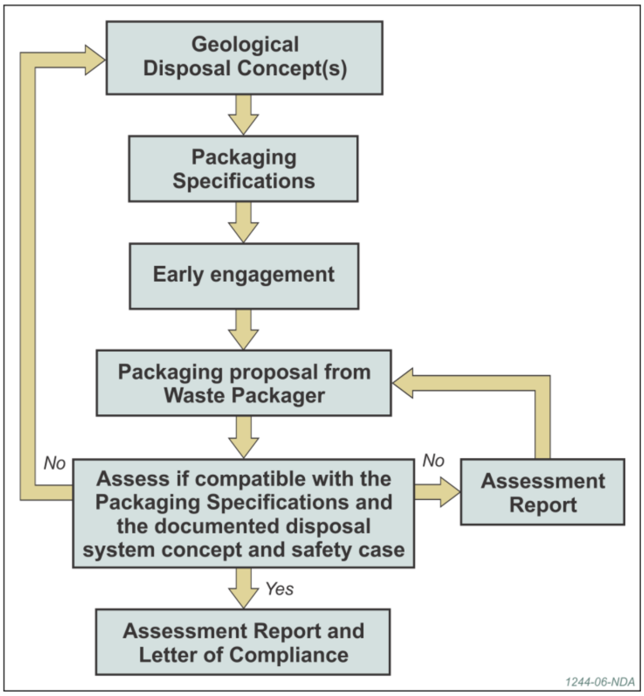
5.3 Application of the Disposability Assessment process

The manner in which RWM applies the Disposability Assessment process and, in particular, the role played by the packaging specifications is summarised in Figure 21. This shows that disposability assessments are carried out against the packaging specifications, which are based on the illustrative designs and safety cases which apply to the type of waste to be packaged, and in response to a proposal submitted by the waste packager (see Section 5.7). The main output of any assessment is an *Assessment Report*, a full description of which is given in Section 6.1.

If a disposability assessment concludes that the implementation of the packaging proposal would result in disposable waste packages which *'are assessed to be compliant with published RWM packaging specifications'* [36], the Assessment Report can be accompanied by an LoC endorsing the packaging proposal.

The development work involved in the packaging of a waste stream, from the initial consideration of packaging options to the manufacture of waste packages, generally takes place over several years, especially if it involves the design and construction of a packaging plant. Because of this RWM, offers a flexible and 'staged' approach to the conduct of disposability assessments, the nature and extent of the optional individual stages being based on an idealised vision of a packaging development project. This approach has been shown to offer considerable benefits to both RWM and the waste packager by providing the opportunity to submit information proportionate to the state of development of the proposals and allowing the progressive accumulation of information and assessment of the same. This approach provides step-wise reduction in project risk for the waste packager, ideally aligned with their staged decision-making or sanctioning within the development of a packaging project.

Figure 21 Application of the Disposability Assessment process



The staged approach to disposability assessments, if adopted in full, would result in a sequence of interactions between RWM and the waste packager during the development and implementation of a packaging project, which broadly follows that illustrated in Figure 22. The actual sequence of interactions will be tailored to suit the demands of each particular packaging proposal and, whilst Figure 22 shows the various assessment activities in chronological order, the actual number of stages and the timescales for their performance can vary widely to suit the demands of the proposal. RWM's activities are also shown and these indicate the approximate points in the process when disposability assessment could be sought and the interactions that will continue up to the time of export of the waste packages to a GDF.

Figure 22 Indicative interactions between RWM and the waste packager on an idealised packaging project

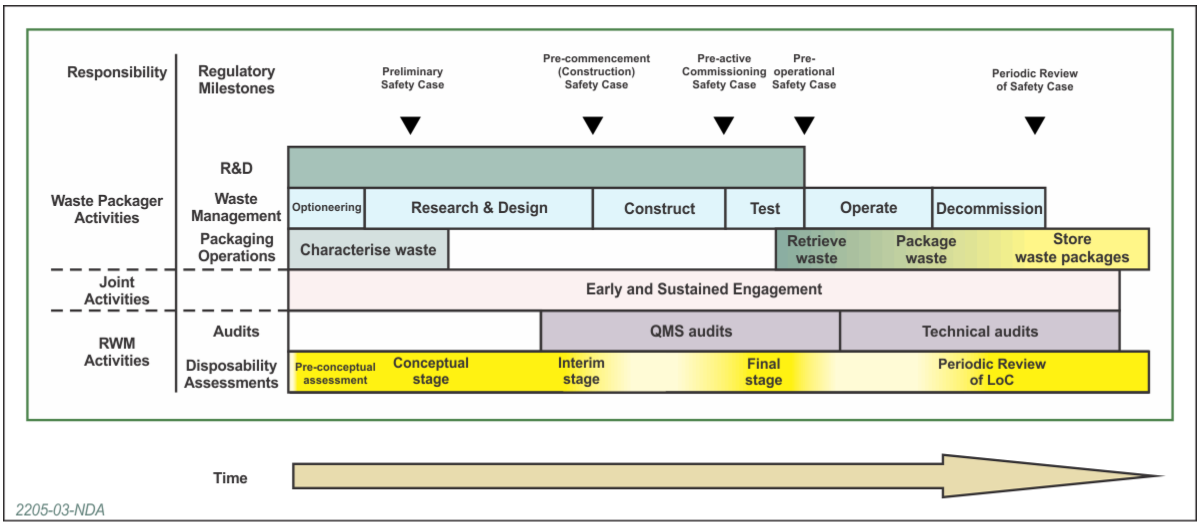


Figure 22 identifies the following stages, some or all of which may take place as part of the disposability assessment of proposals to package a particular waste stream:

- *Pre-conceptual assessment* (option development and review stage): Interaction and provision of advice (optionally as a formal Assessment Report) as packaging options, and other waste management approaches, for a particular waste stream are reviewed and eliminated by the waste packager before a packaging proposal is submitted
- *Conceptual stage* (focusing on analysis of feasibility): Establishing whether, in principle, and when suitably developed, the proposed waste packages are likely to be compliant with RWM requirements, as defined by the relevant Generic Specification. Assessment at this stage is based on information describing the expected waste inventory and volume, outline packaging proposals and development plans, and on existing knowledge and analogies with previous proposals and assessments
- *Interim stage* (seeking underpinning evidence): Determining whether the evidence allows demonstration that the as-designed waste packages are compliant with RWM requirements. At this stage detailed inventory data and final design specifications, including results from research and development are assessed in order to confirm that the intended waste packages would be compliant with the standards and specifications defined within the relevant WPS
- *Final stage* (confirming plant characteristics): Determining whether the evidence allows demonstration that the waste packages as they would be manufactured would be compliant with RWM requirements as defined by the relevant WPS. Confirmation that suitable controls are in place during waste package manufacture and that adequate would be created for each manufactured waste package

In practice, the route to a Final stage LoC is not the same for every packaging proposal and this will depend upon a number of factors, including the extent of the understanding of the properties of the waste to be packaged and the maturity of the proposed waste container and/or waste conditioning process(es).

In some cases it may be that some or all of the stages preceding the Final stage may be omitted, for example, where an existing packaging plant is to be used to condition a different waste stream with similar properties. In such cases it would be possible to commence the assessment process at the Interim or Final stage. Furthermore, for appropriate packaging proposals, a ‘fast track’ route to Final stage endorsement is possible using a *Standard Waste Package Description* (SWPD, see Section 5.10). RWM will engage with waste packagers to establish the most appropriate staging for a particular proposal, consistent with maintaining the integrity of the overall assessment process.

An important aspect in conduct of a disposability assessment is the development of an *Assessment of Disposability* (AoD) of the waste packages that would result from the implementation of a packaging proposal. The AoD is a formal statement of the reasoning that allows the disposability case for the proposed waste packages to be made. The AoD is progressively developed as the packaging process matures and the packaging plant is designed, built, commissioned and operated. At the Conceptual stage it is expected that the AoD would be in outline form only, but sufficiently developed to judge the overall feasibility of the packaging concept. It would be nearing completion at the Interim stage, with fewer gaps and information needs, and would be fully developed by the conclusion of the Final stage.

RWM uses *Action Points* as a formal means of identifying distinct issues which will require resolution before an LoC can be issued, or that will need to be resolved as part of the next stage of an assessment. Action Points are given a unique identifier for tracking purposes and will include the identification of which stage of the disposability assessment the issue should be closed out.

5.4 Management of the Disposability Assessment programme

RWM manages a schedule of Disposability Assessments in collaboration with the waste packagers. This programme facilitates resource planning within RWM and allows waste packagers to identify priorities. Conflicts in priorities are managed in consultation with the relevant parties, taking due account of the significance of the relevant process for hazard reduction and the potential influence on delivery of packaging. Prioritisation of disposability assessments is undertaken in discussions between the waste producer, RWM and NDA, as appropriate.

The programme is maintained through a change management process, formalised as quarterly updates that are shared with all parties.

5.5 Early and sustained engagement

A key aspect in ensuring the efficiency of the Disposability Assessment process is early and sustained engagement between RWM and the waste packagers. RWM encourages such engagement at the earliest stage in the development of a packaging proposal, before the preparation of any formal submission to help ensure that such submissions are concise and robust. Early engagement will also enable the identification of key issues to reduce the number of iterations required during the assessment process and thereby achieve prompt endorsement. The potential value of interactions prior to submission of a packaging proposal should not be under-estimated, particularly for ‘challenging’ wastes (eg, those with high heat output or fissile material content) or where some aspect of the packaging process has not previously been assessed (eg a novel conditioning process or waste container design).

Engagement also continues during each disposability assessment and after each step in the process is concluded. For example, RWM may perform early reviews of the submission documents received at the start of each disposability assessment to determine if sufficient information is available to sensibly undertake the assessment. As necessary, RWM will engage with the waste packager to seek further information or a revised submission, iterating as necessary to maximise the efficiency of the process. RWM can also comment on draft responses by the waste packager to issues raised during an assessment.

RWM encourages interaction following each assessment to ensure that the waste packager understands the findings of the assessment and the underlying reasoning. RWM may also be able to provide advice on the requirements on any future development work and how uncertainties and any identified issues in the packaging proposal could be addressed.

5.6 Expert view

RWM’s approach to early engagement may be formalised by way of the ‘Expert View’ process by which RWM can provide a rapid response to outline packaging proposals, in advance of a disposability assessment. The process provides waste packagers with advice on the risks and issues arising from a proposed waste packaging process.

This process does not provide an Assessment of Disposability based on the full Disposability Assessment process. Instead it provides an alternative means of gaining rapid and sufficient insight to support the preparation of a submission and subsequent disposability assessment.

Examples of where Expert View may be appropriate are:

- to obtain an initial opinion from RWM on the relative risks and issues for a suite of options for the packaging of a waste stream;
- to obtain an initial opinion from RWM on the relative risks and issues arising from a proposed course of action.

The conclusions of an Expert View are presented in the form of a letter which outlines the foreseen risks to disposability arising from any identified issues, and a judgement as to the impact of these risks on the potential risk they represent to the eventual endorsement of the proposed approach to packaging.

5.7 The submission of a packaging proposal for assessment

As discussed above, the disposability assessment of a proposal to package a waste is generally a staged process the entirety of which may take place over several years. Each stage of an assessment is normally instigated by the waste packager by the 'submission' of a document (or suite of documents) to RWM describing the packaging proposal. Detailed guidance of the information that should be included in a submission is available in [37]. Table 6, which is to be found in this guidance, summarises the type of information that is required to be contained in a submission, the extent of which will depend of the stage of the assessment that is to be undertaken. Submissions for the successive stages in a disposability assessment would build on each other and therefore waste packagers may consider supplying revised, typically more detailed, versions of the same submission at each stage. However, assuming the standard approach has been followed with submissions at the Conceptual and Interim stages, the assessment focus at the Final stage is on evidence supporting demonstration that the manufactured packages would meet RWM requirements, data recording and management system procedures. Therefore, a waste packager would normally supply a more tailored submission at this stage.

Table 6 Information needs for a submission for disposability assessment

Submission topic area	Coverage
Nature of the waste	The site, plant and processes which generated the waste The current and historical storage arrangements The history of the current project, including optioneering, IWS, BAT Project plans Physical characteristics of the waste Major chemical components of the waste Radionuclide inventory of the waste and radiation sources Relationship between the information provided in the submission and the information provided for the most recently published UK RWI Safeguards status of the waste and future plans Description of nuclear materials accountancy arrangements Description of physical security and safeguard obligations and how these will be fulfilled Close out of Action Points from previous assessments
Production of the waste package	Proposed waste retrieval process and waste treatment processes to be applied prior to waste packaging Waste packaging process including the waste container type and design features and any waste conditioning process and materials Details of the relationship between the submission information and the

Submission topic area	Coverage
	most recently published UK RWI concerning the waste packaging process Close out of Action Points from previous assessments
Waste package properties and expected performance	Package physical, chemical and radionuclide composition and inventories which will arise from the proposed waste and packaging process Compliance with packaging specification requirements (eg, activity and dose restrictions, heat output, pressurisation, free liquid content, hazardous materials, gas release, etc.) Immobilisation of radionuclides and particulates Radionuclide releases in impact and fire accidents Wasteform heterogeneity Close out of Action Points from previous assessments
Waste package evolution and maintenance of integrity	Estimates of the effect of package evolution on the package properties and characteristics Waste package long-term integrity and durability Interim storage facilities and environmental conditions Proposed waste package monitoring system Close out of Action Points from previous assessments
Criticality safety	Criticality safety and definition of safe fissile mass Criticality Compliance Assurance Documentation Close out of Action Points from previous assessments
Management system	The management system established, its implementation and maintenance, covering all safety, quality and data recording aspects for the entire lifetime of the package Compliance with RWM requirements on quality management When objective evidence has been, and will in future be, provided Overview of the plant management system Waste Product Specification Close out of Action Points from previous assessments
Package records	Compliance with RWM requirements on data recording Waste package data recording methodology Methods to be applied to derive a waste stream and waste package physical/chemical and radionuclide inventory for recording Close out of Action Points from previous assessments

5.8 Conduct of a disposability assessment

In general a disposability assessment comprises three distinct components:

- establishing an understanding of the properties of the proposed waste packages. This is achieved by a series of technical evaluations, which establish that the characteristics of the waste package are understood in sufficient detail

- comparing the performance of the packaged waste against the safety assessments. This is achieved by a series of assessments in which the numbers and expected properties of the proposed waste packages are substituted for the generic assumptions made in the safety cases for transport and disposal
- ensuring that suitable management arrangements will be in place during the packaging of the waste and that adequate records are produced on each waste package

In order to achieve these objectives effectively and efficiently, and to provide assurance as to the robustness and traceability of an assessment, RWM applies a methodology illustrated in Figure 23 and described below.

5.8.1 Establishing waste package properties

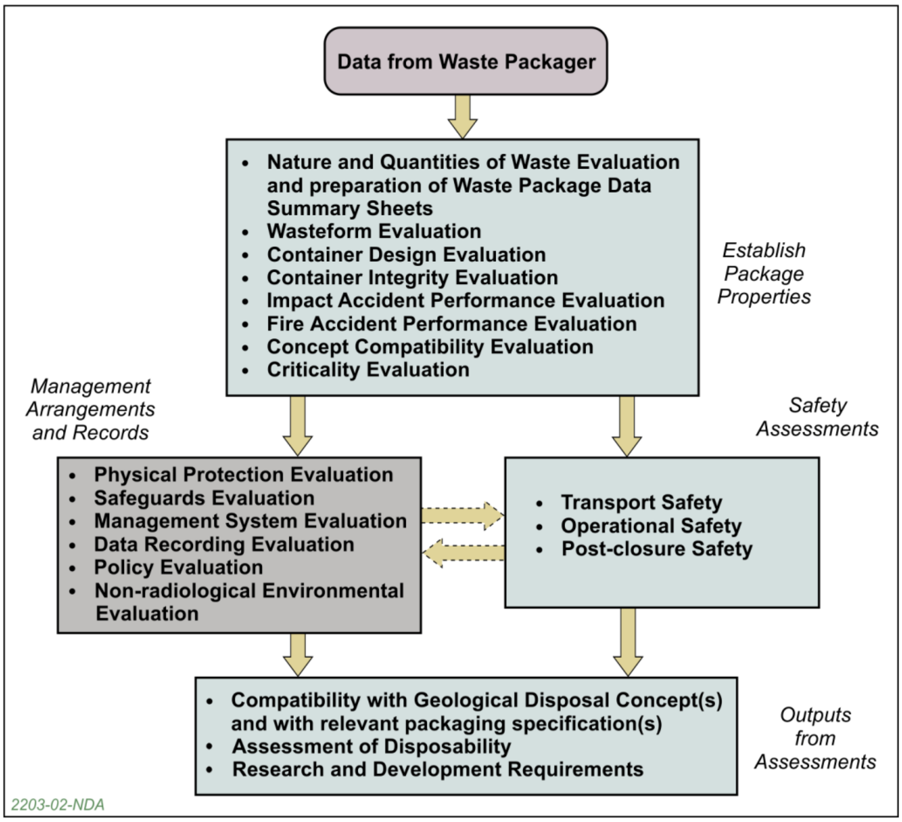
A series of technical evaluations is carried out to allow the development of an understanding of the properties and performance of the proposed waste package, to enable a comparison with the assumptions underpinning the safety assessments. This will require:

- an independent review of the radionuclide and physical/chemical inventory of the waste and, where necessary, augmentation to ensure that the assessment inventory is comprehensive and that any potential information 'gaps' have been addressed
- determination of the expected performance of the waste package under normal and potential impact and fire accident conditions, based on waste package specific modelling or analogue data
- evaluation of the expected behaviour (ie evolution) of the waste package under extended storage and disposal conditions

Table 7 summarises the main objectives of each of the technical evaluations carried out during a disposability assessment[24].

[24] It should be noted that not all of the technical evaluations are carried out at every stage of the assessment process and that the depth of the evaluations will vary depending on which stage is reached. For more information see [37].

Figure 23 Outline of a disposability assessment



5.8.2 Comparison with the safety assessments

The definition of the expected properties and performance of the proposed waste packages in the initial part of the assessment process is necessary to confirm the robustness of the packaging proposal. It provides vital inputs to the assessment of the safety of the transport and disposal of the waste packages. This latter requirement involves a comparison of performance of the proposed waste packages against the assumptions that underpin the safety assessments.

An output of the technical evaluations discussed above is an estimate of the number of waste packages that would result from the implementation of a proposal to package a particular waste stream. This information, together with the expected mean and maximum radionuclide inventories of the waste packages, and the range of performance characteristics (ie heat and gas generation rates, external dose rates and impact and fire accident performance) describes the notional waste packages that are 'tested' against the generic assumptions made for the waste stream in the safety assessments. In this way the proposals to package the waste stream are 'tested' against each of the assessments to determine whether the real package data would change the outcomes of any of them.

This second part of the assessment process also plays an important role in ensuring that the generic DSSC is robust and that the safety assessments remain up to date by reflecting actual waste package rather than the generic properties assumed by the 2013 Derived Inventory (see Glossary).

Table 7 Objectives of the technical evaluations

Evaluation	Evaluation objective[25]
Nature and quantities of waste[26]	Provide, or confirm, a description of the origins, composition and quantity of the waste proposed to be packaged, and a critical analysis of the quality of the information available.
Wasteform properties	Provide, or confirm, a description of the range of composition and anticipated properties of the proposed wasteforms, including the potential effects of wasteform evolution and behaviour under storage and disposal conditions.
Container design	Provide, or confirm, a description of the proposed waste container design and material specifications.
Waste package integrity	Provide, or confirm, a description of the proposed waste container and the environment to which its internal surfaces will be expected to be exposed, together with its anticipated corrosion-related properties. Consider the potential effects of wasteform evolution on waste package integrity during interim storage.
Impact accident performance	Provide, or confirm, a description of the proposed waste package design and properties together with anticipated impact accident performance, including the potential effects of waste package evolution and ageing.
Fire accident performance	Provide, or confirm, a description of the proposed waste package design and properties together with anticipated fire accident performance, including the potential effects of waste package evolution and ageing.
Concept compatibility	Confirm that the proposed waste packages (and any proposed transport system) are consistent with the relevant packaging specifications, or otherwise highlight potential inconsistencies.
Criticality safety	Assess whether deployment of the proposed waste packaging process is likely to result in production of waste packages that are compliant with a justified safe fissile mass, where the method of control of package fissile content is defined and justified.

Transport safety

The transport of waste packages between nuclear licensed sites (ie from the site of manufacture and/or interim storage to a GDF) presents a number of particular circumstances by which transport workers and/or members of the public could be exposed to the hazards associated with them. The risks associated with the transport of waste, and their consequences for both of these groups of people are addressed in the generic *Transport Safety Case* (TSC) [38].

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25 This includes conducting a critical analysis of the quality of the information available and assessing whether the expected waste package properties and performance are consistent with the requirements defined by the relevant packaging specification.

26 Including preparation of the waste package data summary sheets

The distinction between a ‘waste package’ and a ‘transport package’ is important to the TSC. A waste package will, in general, comprise a container in which waste is placed and which is suitable for disposal without further treatment whereas a transport package may comprise such a waste package, with or without protective devices (to provide additional thermal and/or impact protection and/or additional radiation shielding), which is capable of satisfying the specific requirements on transport.

Waste packages could be transported by road, rail, inland waterway or sea, or by a combination of two or more of these methods of transport. Whichever mode is used the possibility exists for external and internal exposure to radiation to transport workers or members of the public during normal operations by:

- the routine release of very small quantities of radioactive gases or particles from the transport package, through the transport container and/or waste package seals;
- non-fixed surface contamination of the transport package; or
- radiation emitted from the transport package.

Exposure can also result from transport accidents which may involve more extreme mechanical (ie impacts) and thermal (ie fires) challenges to transport packages, and the possibility of greater release of activity and potential exposure to radiation.

As discussed in Section 3.6, the IAEA Transport Regulations place controls on the properties and performance of transport packages in respect of:

- external radiation dose rate
- releases of radioactive material in gaseous and particulate form
- the presence of non-fixed contamination of external surfaces
- the elimination of the possibility of an accidental criticality

The TSC [38] demonstrates why RWM believes that transport of higher activity wastes and materials will be accomplished safely. The TSC addresses the specific contribution of the form of packaging in the *Transport Package Safety Report* [39], describing in detail the controls applied to packaging and the means by which these are defined and recorded within a *Package Design Safety Report* (PDSR). A PDSR defines the permitted radionuclide and physical/chemical inventory of a specific design of transport package such that it can be transported in accordance with the deterministic criteria specified by, or derived from, the IAEA Transport Regulations.

All of the requirements imposed on waste packages by the transport operation, and the associated regulatory controls, are reflected in the packaging specifications, as described in Section 3. Many quantified requirements of the IAEA Transport Regulations are directly incorporated into those specifications. In addition, the overarching health and safety regulatory requirement that risks will be as low as reasonably practicable (ALARP) also applies. In transport, demonstration that risks (generally risks due to routine dose uptake) are ALARP is made in a Radiological Protection Programme supported by application of measures such as segregation, limitation of exposure times, use of external shielding or other operational controls, where necessary. The ALARP principle should also be applied during design, manufacture and the preparation of waste packages for transport.

The assessment of the transport safety of the proposed waste packages comprises two parts:

- a deterministic assessment of the compliance of the anticipated transport packages against quantitative criteria specified in or derived from the IAEA Transport Regulations

- a probabilistic assessment of the effect of the proposed waste package on the total doses predicted from the 2013 Derived Inventory in the TSC

The first stage of assessment will require the type of transport package to be used (ie either Type IP or Type B, see Section 3.6) to be identified and confirmation that the relevant limits for external radiation dose rate, heat output, gas generation and the release of activity under normal and accident conditions specified for that transport package will not be exceeded by the proposed waste packages. It will also be necessary to show that the inventory of fissile materials within the expected waste packages will be such that:

- for waste packages transported as Type IP transport packages, the contents can be excepted from the requirements on fissile packages
- for waste packages transported as, or as part of, Type B transport packages, the required level of criticality safety will be maintained under both normal and accident conditions of transport

The second stage of assessment predicts the average annual dose received by workers on the transport system[27] from the proposed waste packages. It then compares these doses to the average annual dose received by workers from all waste streams in the Derived Inventory, based on estimated exposure and proximity information. The assessment checks whether the average annual dose from all waste packages, including the proposal, is below the relevant criteria in the RWM *Radiological Protection Manual* [40].

GDF operational safety

Following their receipt at a GDF, waste packages will be subject to a range of handling and stacking operations, some of which have the potential to result in accidents that could result in waste packages being exposed to impacts and/or fires. Radioactive material released as a result of such accidents has the potential to cause radiation dose to GDF workers and, were it to be occur in such a manner as to cause an off-site release, members of the public. In addition, the routine release of radioactive material from waste packages, in the form of radioactive gases such as tritium, isotopes of radon and other gases containing radionuclides such as tritium and carbon-14, may also result in on- and off-site exposure.

Waste packages containing fissile material may be more susceptible to accidental criticality when stacked in arrays and this could result in the exposure of workers and, in principle, members of the public.

The risks associated with operations at a GDF, and their consequences for both of these groups of people are addressed by the Operational Safety Case (OSC) [41] and in the ESC through the Operational Environmental Safety Assessment [42].

The OSC considers four distinct aspects of the operational safety of a GDF:

- non-radiological safety during construction of the facility [43]
- radiological safety during routine operations at the facility (ie receipt, emplacement and storage of waste packages) [44]
- the radiological consequences of accidents during the operational period [45]
- criticality safety during the operational period [46]

The radiological consequences of releases of activity as a result of both normal operations and potential accidents at all nuclear licensed sites are subject to targets set down in the Office for Nuclear Regulations (ONR) Safety Assessment Principles [47]. These set down

[27] Doses are calculated for a train driver, a HGV driver; a member of a ship's crew and a GDF crane operator.

Basic Safety Objectives (BSOs) and Basic Safety Levels (BSLs) for on- and off-site exposure to radiation where radioactive material is released from its ‘normal’ containment which, in the case of a GDF, would be the waste packages. These requirements are captured in the RWM Radiological Protection Manual [40].

An analysis of the potential for accidents capable of resulting in the release of waste package contents during the operational period of the GDF has been undertaken on the basis of existing generic designs for a GDF, and this forms part of the OSC. This analysis will be refined in an iterative manner as the GDF development programme progresses. As the site selection process progresses, this will permit RWM to move from generic GDF designs and safety cases to those tailored for specific sites. This will allow the nature, severity and frequency of potential accidents, and the determination of their radiological consequences, to be better defined.

As in the case of transport, the assessment of safety during the GDF operational period, as considered in the OSC [41], includes both deterministic and probabilistic elements.

In addition to the specific criteria indicated above, the following general criteria are also considered in the assessment:

- limits on dose to workers under normal operational conditions
- limits on toxic chemical release
- limits on radioactive gas release (dose to public under normal operating conditions)
- impact on probabilistic risk for a GDF as a whole
- compliance with requirements on criticality safety

GDF post-closure safety

Following the emplacement of waste packages in a GDF, the risk of exposure of persons to radiation is significantly reduced by the combination of the multiple barriers provided by the whole disposal system. When the facility is finally closed and sealed it is said to have entered the ‘post-closure’ period and the risk of exposure to radiation in the short term is reduced further still. However the timescale over which exposure must be considered is more extended, as the risk associated with the post-closure period are those resulting from the return of radionuclides to the geosphere. Exposure to radiation would therefore be to future generations living on the surface in the vicinity of a GDF.

The *Post-closure Safety Assessment* (PCSA) [48] supports the *Environmental Safety Case* (ESC) [42] in addressing the environmental requirements associated with the authorisation of the disposal of radioactive waste in the GDF. These include the ‘principles and requirements’ contained in the *Guidance on Requirements on Authorisation* (GRA) [49], which encompass management, radiological and technical aspects of the safety case for a GDF.

The GRA requires the assessment of radiological and non-radiological hazards associated with a GDF, including:

- radiological risk to the public after the period of authorisation, including risks from possible gas releases, releases to groundwater and potentially disruptive natural events (such as erosion resulting from glacial action and climate change) including human intrusion
- consequences of inadvertent human intrusion of a GDF in terms of radiation doses to individuals undertaking the intrusion and individuals and other organisms who might occupy the area affected by releases from the intrusion event
- a demonstration that the possibility of a local accumulation of fissile material such as to produce a neutron chain reaction is not a significant concern, and investigate, as

a variant scenario, the impact of a postulated criticality event on the performance of the disposal system

- radiological hazards to the accessible environment from possible releases, eg, through damaging habitat quality, and to non-human species
- a consideration on the non-radiological risks to the public and the environment

The PCSA explains RWM's approach to assessing these risks, in particular how the treatment of the uncertainties which inevitably arise because of the requirement to demonstrate safety over very long timescales. A quantitative analysis is presented for the groundwater pathway, the pathway by which radionuclides could give rise to a radiological risk to future populations by their dissolution and transport in groundwater. Current knowledge of the potential consequences of gas generated in a GDF is summarised. Two variant scenarios are considered in this assessment; inadvertent human intrusion into a GDF and the likelihood of an accumulation of fissile material leading to a criticality.

A staged process is adopted to consider the impact of each waste packaging proposal with respect to the ESC and hence long-term safety and environmental protection issues. The extent of the post-closure performance assessment at each assessment stage will depend on the potential significance of the waste to the overall long-term safety of a GDF.

During a disposability assessment an initial screening assessment is undertaken to determine whether or not a more detailed post-closure assessment is necessary, and to define the nature and extent of any such assessment.

The initial screening assessment is based on the comparison of the packaging proposal with the post-closure safety case:

- the general nature of the proposed waste packages
- whether or not the waste stream is included within the inventory assessed in the safety case
- the waste composition, including the inventory of non-radiological hazards and chemotoxic species
- the radionuclide inventory of the waste
- the influence of any complexing agents present in or produced by the waste
- the spatial distribution of radionuclides arising from the proposed waste packages and whether this distribution could undermine the assumption of homogeneous radionuclide chemistry made in the safety case

In each case, the initial screening may identify issues that require further, more detailed assessment. In this manner, the nature and extent of any detailed assessment is defined.

Such a detailed evaluation would require the examination of the consequences of the proposed waste packages for overall GDF performance in a number of key areas and would be required to show that the assessed radiological risks would remain consistent with the annual risk of 10^{-6}, which is defined as the regulatory guidance level.

In addition to these quantitative criteria, a number of other general issues are considered, and their potential impact on post-closure performance scoped. These include a consideration of the influence of a number of materials that could be present in waste including:

- halogenated polymers
- other organic materials, including non-aqueous phase liquids
- reactive metals

- chemical species that have the potential to affect the chemical conditioning within a GDF

There is also a consideration of the significance of any toxic materials in the waste and of heat generated by the proposed waste packages.

5.8.3 Management arrangements during waste package manufacture and the production of package records

As part of each disposability assessment, usually at the Conceptual stage, a non-radiological environmental assessment of the packaging proposal is carried out to check that there are no aspects of the proposal that are inconsistent with wider environmental protection considerations. This includes an assessment of the impact of the implementation of the proposal with regard to protection of human health and the natural environment.

There is also a review of the packaging proposal from the perspective of various specialist functions which could influence the design or operations of the transport and/or disposal system and/or which might have consequences for waste package design. This includes:

- reviewing the status of the waste packages from the perspective of physical security of any NM they will contain to ensure that that they will be compliant with the security plan developed for transport to and operations at the GDF. Advice from ONR Civil Nuclear Security may be sought in this area
- reviewing the status of the nuclear material[28] (NM) content of the packaged waste stream from the perspective of international safeguards. This is to ensure that the status of the NM in the proposed waste packages will be consistent with the safeguards arrangements currently envisaged for the GDF. Advice from ONR Safeguards may be sought in this area
- providing confirmation that the waste packager will meet the requirements for quality management during the retrieval and packaging of wastes, and during the interim storage of waste packages [50]
- ensuring that sufficient information of adequate quality pertaining to the waste packages is recorded during manufacture and storage, and that this information is suitably preserved [51]. RWM will approve the waste package records to confirm that adequate records have been produced and that those records are being maintained (see Sections 7.3 and 7.4)
- reviewing the packaging proposal from the perspective of the RWM DAAPs (Section 5.2, [36]) and RWM Health, Safety, Security and Environmental Policy [52]
- confirming that the waste packager has considered the expectations for sustainability in developing the packaging proposals and that they are generally consistent with the generic Environmental [53], Socio-economic [54] and Health Impact Assessments [55].

5.9 Consideration of the consequences of different geological environments

The implications for safety of the implementation and long-term performance of the GDF in a range of different geological environments have been considered in the generic DSSC, leading RWM to conclude that a GDF can be constructed and operated in a safe, secure and environmentally acceptable manner in a wide variety of geological environments. The

[28] This generally includes isotopes of uranium, plutonium, thorium and certain other actinides.

Disposability Assessment process uses this consideration of different geological environments during the comparison of proposed waste packages with the generic operational and post-closure safety case assessments[29].

The generic DSSC considers three host rocks in which a GDF could be constructed in the UK, higher strength rock, lower strength sedimentary rock and evaporite rock, and identifies illustrative geological disposal concepts that could be implemented in each for LHGW and HHGW.

The different geological environments and their respective concepts will place different demands on waste packages during the GDF operational and post-closure periods. The packaging specifications, and thereby disposability assessment are aimed at ensuring that the design of wastes packages would not preclude their disposal in accordance with any of the relevant illustrative concept. As a result the requirements defined by the packaging specifications are intended to be bounding of those arising from all of the relevant disposal concepts. For example, of the concepts identified for LHGW that for higher strength rock is assumed to result in the largest disposal vaults. As a result, waste packages would be stacked higher than with the other two concepts and the stacking load that waste packages would have to be able to resist would be the highest of the three concepts. Similarly, higher stack heights would result in potentially greater ‘drop heights’ for impact accidents [41]. In the case of disposal vault thermal behaviour, the total heart output of the waste packages in a larger vault will be greater and this would lead to higher temperatures, particularly at the centre of the vault. Conversely, the frequency of dropped loads and impact events could conceivably be argued to be greater for those concepts employing stacker trucks rather than cranes for emplacement, but this cannot be established definitively at this generic stage.

The differences between the three host rocks are less obvious in the case of post-closure safety, the most notable being the characteristics of the groundwater (ie flow rate and chemistry) as it interacts with waste packages. For the purposes of the Disposability Assessment process RWM assumes the characteristics of a GDF constructed in higher strength rock on the basis that this is likely to be conservatively bounding of all three host rocks when considering the post-closure performance of waste packages [56].

A qualitative consideration of any differences that arise due to disposal in other geological environments is undertaken for each packaging proposal. RWM’s understanding of the performance of the GDF constructed in a higher strength rock is more developed than that for other geological environments. However, it is believed that the understanding of the consequences of these other geological environments is sufficiently developed for qualitative assessments to be carried out. As examples, such a qualitative consideration might encompass some of the following matters:

- the compatibility of the proposed packages with differing handling and emplacement arrangements required for a GDF in the various geological environments, including any constraints on the geometry or dimensions of packages
- the potential for interactions between the waste or wasteform and any backfill specific to the geological environment, or with the surrounding rock
- the significance of the expected heat loading
- the significance of the expected gas generation rate

The consideration would also include any observations regarding the possible relaxation of packaging constraints for some geological environments.

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29 The transport safety case considers the implications for transport safety of locating a GDF in any geographical location in England and Wales. The impact of different geological environments for the transport safety case is reflected through any differences in waste packages.

5.10 Use of precedents to endorse subsequent packaging proposals

As discussed in Section 5.3, RWM applies the Disposability Assessment process in a flexible manner and will engage with waste packagers to establish the most appropriate approach for each packaging proposal. If appropriate, a route to Final stage endorsement may be based on the precedent of a previously endorsed packaging concept. Two such precedent approaches have been established to achieve this:

- A 'second of a kind' approach; where significant aspects of a packaging proposal are the same as those previously endorsed (e.g. the use of an identical waste container design for the packaging of a similar type of wastes). In such cases the information produced during the original assessment would be 'copied across' to the new assessment, with an accompanying reduction in the time taken, and the cost of the assessment.
- In cases where a packaging proposal is fully meets the parameter envelope that defines one previously endorsed, the use of a *Standard Waste Package Description* (SWPD) may be appropriate. An SWPD is a complete description of a disposable waste package defined using information produced during a disposability assessment that resulted in the issue of an unqualified Final stage LoC. The Final stage endorsement of a subsequent packaging proposal against a SWPD relies on the waste packager providing sufficient information to RWM to permit a judgement to be made that the proposed waste packages would be bounded by those previously endorsed.

5.11 The treatment of innovation in approaches to packaging

RWM works with waste packagers to facilitate innovation in waste packaging where this can lead to optimum packaging solutions and deliver value for money. An innovative packaging proposal may be defined by one or more of the following criteria:

- the proposed packages are not designed to, or are not expected to, comply with an existing WPS
- the proposed packages are not designed to, or are not expected to, comply with a Generic Specification for a defined waste category
- the proposed packages are expected to require the use of safety functions or arguments that are not adequately encompassed by existing safety case arguments in the generic DSSC

A GDF represents a valuable resource with finite capacity. Furthermore, the introduction of a new packaging approach potentially represents increased complexity in the disposal system concept and the operability of a GDF, and changes to the safety cases, such that both the cost and safety of a GDF may be affected. Where safety is not compromised, and provided that any increased use of resources and capacity, compared to existing alternative packaging approaches, is suitably balanced by benefits earlier in the waste management cycle (ie a 'net benefit' is achieved), RWM will modify the disposal concept following due process (see Section 6.3). Conversely, in the absence of a net benefit, RWM may not progress the necessary change to the disposal concept, preventing endorsement.

When a packaging proposal is identified as 'innovative', the relevant RWM procedure for the preliminary assessment of innovative packaging proposals is invoked. The objective of the assessment will be to establish the basis for pursuing an innovative packaging proposal through the Conceptual stage assessment and to define a work programme that will deliver the necessary additional or expanded contributions to the Conceptual stage assessment. Satisfactory completion of the preliminary assessment, confirming any necessary changes to the disposal system concept and safety case are feasible and appropriate, is required before endorsement of the innovative proposal may be offered at the Conceptual stage.

The preliminary assessment also establishes the basis for an evaluation involving the RWM change management procedure. Subsequent assessment and endorsement at stages subsequent to the Conceptual stage must follow the approval of the changes to the disposal system concept. For example, where an innovative proposal does not comply with an existing detailed WPS, the submission would be assessed against the Generic Specification for the relevant waste category at the Conceptual stage. The change management evaluation would identify that an appropriate WPS requires development and this must be produced before the proposal could be endorsed at the Interim stage. The proposal will no longer be regarded as innovative once the identified necessary changes to the disposal system have been implemented via the change management procedure, prior to an Interim stage assessment.

6 Outcomes of the Disposability Assessment Process

6.1 The Assessment Report

The main output of any disposability assessment is an Assessment Report (see Figure 21). This is typically an extensive document that details the outcomes of the work that has been undertaken in support of the assessment, by drawing together the results of the technical evaluations and comparisons with the safety assessments that have been carried out. The overall aim of the Assessment Report is to show, in a transparent manner, whether or not the waste packages that would result from the implementation of the proposed approach to the packaging of specific wastes would be disposable.

To this end it will include an Assessment of Disposability (AoD) outlining the reasoning that allows the disposability case for the proposed waste packages to be made. An Assessment Report will also include any Action Points identified by the assessment, together with the stage in the Disposability Assessment process by which they will needed closing out. Action Points will have particular significance in cases where the disposability of the proposed waste packages has not been demonstrated, where they will identify the areas of non-compliance and the work and/or information that will be necessary to address them.

Depending on the extent of an assessment, a full Assessment Report (including a fully developed AoD) may be issued. Alternatively, the output of an assessment might take the form of a more limited technical report or a letter containing advice on a specific aspect addressed by a packaging proposal.

6.2 The Letter of Compliance

In the event that the AoD identifies no significant uncertainties[30] relating to the disposability of the waste packages that would result from the implementation of the packaging proposal, an LoC will be issued to accompany the Assessment Report, as a means of formally endorsing the packaging proposal. Depending on the stage of the assessment[31], the issue of an LoC indicates:

- Conceptual stage: that the proposed waste package would in principle be compliant with the generic geological disposal concept(s)
- Interim stage: that evidence has shown that the as-designed waste package would be compliant with the generic geological disposal concept(s)
- Final stage: that evidence has shown that the as-manufactured waste package would be compliant with the generic geological disposal concept(s)

Where significant uncertainties remain at the end of an assessment, such as to prevent the issue of an LoC, this will result in the identification of one or more Action Points, requesting close-out of the uncertainty. In some cases of limited uncertainty a 'qualified' LoC may be issued. Such qualification may comprise:

- a *caveated* LoC; where there is uncertainty as to whether an issue may arise during packaging, which may result in a need for additional assessment and/or remedial action during or after the manufacture of waste packages

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30 These are referred to as 'compliance gaps' in Assessment Reports.

31 As stated earlier, a pre-Conceptual stage assessment will not result in the issue of a LoC.

- a *conditional* LoC; where further evidence is required regarding the proposed packaging process, that may have to be obtained during active commissioning of the packaging plant
- an LoC with *exclusions*; where specified components of the waste stream are excluded from the endorsement

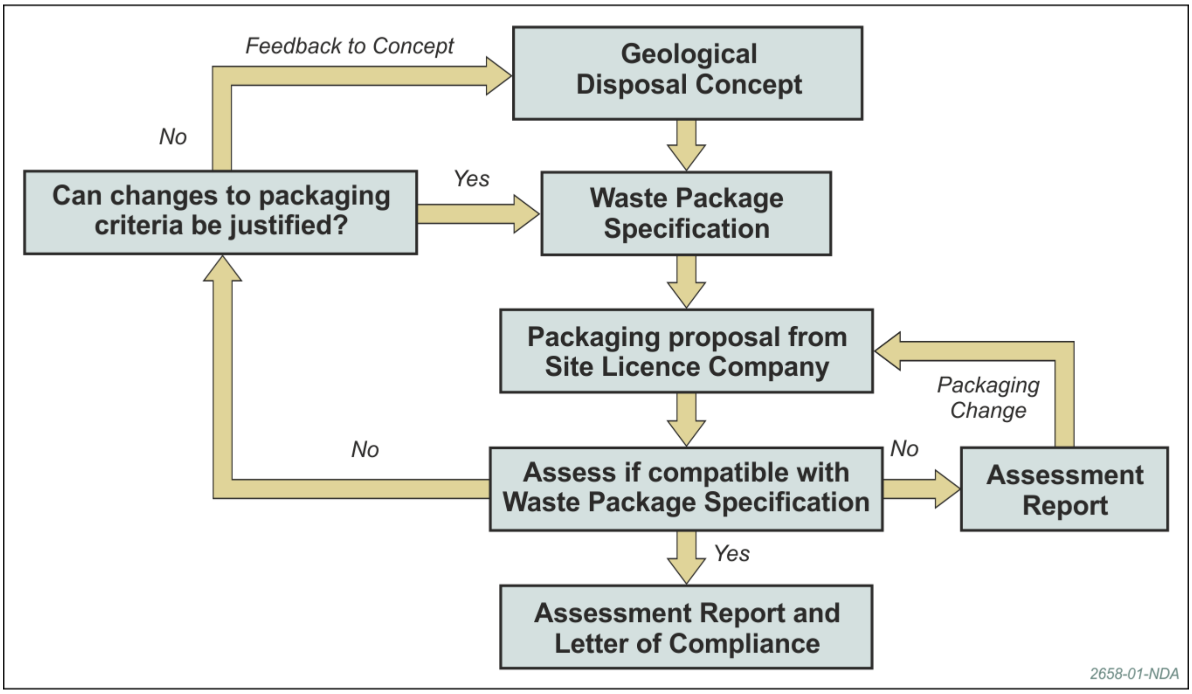
6.3 Dealing with compliance gaps identified by the Disposability Assessment process

As noted above, a disposability assessment may or may not result in the issue of an LoC. The failure to gain such endorsement may mean that the anticipated waste packages cannot be shown to comply with the relevant packaging specification or that the packaging proposal as a whole cannot be shown to comply with one or more of the safety assessments. Such compliance gaps may be the consequences of a lack of sufficient evidence in the original submission such that one or more aspects of compliance cannot be adequately demonstrated. In such cases RWM will raise an Action Point detailing the information required to close out the compliance gap.

In other cases, the reason for the compliance gap may be that some property of the as-designed waste package would not comply with the limits defined by the relevant WPS. For example, the proposed radionuclide inventory of the waste packages may be such that their external dose rate would exceed that permitted for transport, or the fissile material content could exceed that for which adequate criticality safety could be demonstrated. Alternatively there may be conflict between the waste package design and an aspect of the geological disposal concept, as currently defined, which precludes endorsement. For example, this could result from the proposed use of a waste container which is not identified by the DSS.

Figure 24 illustrates the possible outcomes of a disposability assessment and shows the possible approaches that can be adopted in the event that an assessment cannot justify the endorsement of the packaging proposal.

Figure 24 Possible outcomes of a disposability assessment



This shows that there are three possible approaches which could lead to the endorsement of such a packaging proposal:

- the waste packager could change an aspect of the packaging proposal (eg by reducing the proposed radionuclide inventory or by adopting alternative conditioning processes) such that previous areas of non-compliance are removed
- RWM could consider revising the basis for the definition of the packaging requirement with which compliance could not be shown. The aim would be to investigate whether the relevant requirement could be 'relaxed' without any risk to the overall safety of the disposal concept.
- RWM could change an aspect of the disposal concept to accommodate the proposed waste packages

For changes involving either of the latter two approaches RWM has established a procedure for disposal concept change control [57]. The purpose of this procedure is to ensure that proposed changes to the geological disposal concept are recorded, assessed and, if justified, implemented at an appropriate time and in a consistent way. This would include assessing the effects of any change on each of the disposal safety cases and ensuring that changes are recorded in the relevant documentation; such as the DSS, the transport and disposal systems designs, and/or the packaging specifications.

6.4 Periodic Review of LoC endorsement

It is important for the validity of Final stage LoCs, and their supporting AoDs, that they remain current with respect to RWM's developing plans for geological disposal and the associated safety cases for transport, operations and disposal. As a means of ensuring this, RWM has developed a process of Periodic Review, whereby LoCs and their underpinning AoDs are revisited and updated on a notional ten-yearly cycle [58]. In this way the LoC and its associated records are kept 'live' and the disposability case would never be more than 10 years old. This is achieved by reviewing the existing AoD against the current geological disposal concept and updating it as necessary. A further benefit of Periodic Review is that it supports waste packagers in ensuring that the required waste package records are generated and maintained, and that the manufactured packages are maintained under suitable conditions to support their export and disposal in the GDF.

Although generally taking place approximately every 10 years, a Periodic Review could be performed more frequently, for example by an extension of the terms of an existing LoC endorsement (eg in response to a proposal to package new wastes using a previously endorsed process), and/or by a review of any safety case relevant to the manufacture and/or storage of the waste packages. In this context, Periodic Reviews will be aligned with continuous operational safety reviews undertaken by ONR.

The scope and focus of each Periodic Review will be tailored to the specific needs of the waste, waste package type and/or packaging plant. This scope is particularly influenced by whether the packaging plant is still operating, or if all of the waste packages relevant to a specific LoC have been manufactured and are now in long-term storage. For example:

- where waste packages are being produced from plants still operating at the time of the Periodic Review, the emphasis of the review will be on the status of the conditions, restrictions and caveats, a review of actual plant performance, assessment of the status of the management system and relevant audits, and any proposals for processing new wastes
- where waste packages are in interim store at the time of the Periodic Review, the review will concentrate on the condition of packaged wastes, closure of plants and preservation of manufacturing records, and on the significance of any new issues or audit actions

For waste packages which are more than 10 years old, it is anticipated that the process for Periodic Review would include a review of the waste package monitoring arrangements, and the information this has yielded, and a consideration of the consequences of any package evolution that this monitoring has identified.

7 The Manufacture of Waste Packages

The issue of a Final stage LoC is not a singular, definitive event but is part of the wider process of the long-term management of the waste. Following such endorsement, it will be important to ensure that waste packages are manufactured and stored in accordance with the processes endorsed by the Final stage LoC, in accordance with an approved quality management system, and that independent checks have been made to confirm that this is the case. It is also important that sufficient data of an adequate quality is generated during the manufacture of each waste package, and its storage, and that such data is recorded in a manner that ensures its long-term availability.

7.1 The Waste Product Specification

A key document in controlling waste package manufacture is the Waste Product Specification (WPrS), a document that effectively describes the waste package that is to be produced by the proposed processes. The WPrS defines the key limits and controls that will apply during waste package manufacture [59] such that the composition, and thereby the properties and performance characteristics, of the actual waste packages conform with the assumptions made during the disposability assessment. In this manner the WPrS also plays a role in defining the information that needs to be recorded during waste package production, thereby helping to ensure that adequate records are obtained at that key stage in the long-term management of the waste.

Production of a WPrS is the responsibility of the waste packager and a draft version forms part of a submission for the Interim stage disposability assessment of a packaging proposal. RWM will review the draft WPrS at that stage with a view to a final version being produced as part of a submission for the Final stage disposability assessment.

7.2 Criticality Compliance Assurance Documentation.

As part of each disposability assessment, the criticality safety of the proposed waste packages is demonstrated. During the retrieval of waste and the manufacture of waste packages it is important that the assumptions that underpinned that demonstration are achieved in practice. This is achieved by way of the *Criticality Compliance Assurance Documentation* (CCAD) which describes the procedures that will be followed to control the quantities of fissile material that are included in waste packages during manufacture [60]. Specifically the CCAD will define and justify an appropriate safe fissile mass for the proposed waste packages, and show how adequate controls will be in place during waste package manufacture to ensure that this mass cannot be exceeded under any credible circumstance.

Production of CCAD is the responsibility of the waste packager and it should form part of a submission for the Final stage disposability assessment of a packaging proposal.

7.3 The Package Record

An essential aspect of waste package manufacture is the creation of a Package Record. This will follow a waste package through the subsequent stages of its onward long-term management and will form the basis for the ‘handshakes’ that take place between each of those stages.

The key roles of the Package Record are to:

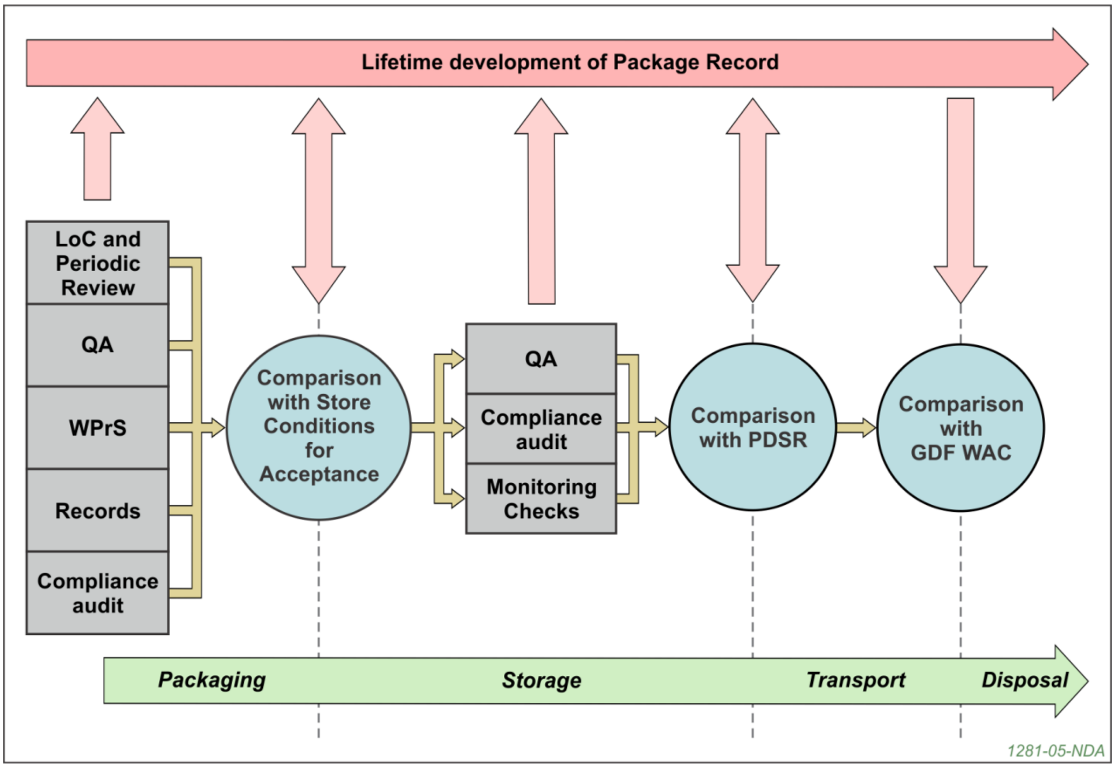
- demonstrate that the waste package has been manufactured and stored in accordance with the terms of the LoC endorsement

- ensure the maintenance of adequate records of the contents and treatment of each waste package during and subsequent to manufacture
- permit the prediction of waste package properties and performance under all relevant circumstances
- facilitate acceptance of the waste package for subsequent stages of management, notably for transport to, and disposal in, a GDF

These will be achieved by recording information obtained during the entire cycle from the development of the waste package design up until the time of receipt of the waste package at a GDF.

The development of the Package Record (summarised in Figure 25), commences prior to waste retrieval with information produced as part of the different stages of the disposability assessment, including the outcomes of any Periodic Reviews of the Final stage LoC. The information contained in the Package Record will have been specified during the development of the packaging proposal, and endorsed as part of the Final stage disposability assessment.

Figure 25 Development of the Package Record



In order that all of these requirements on Package Records are satisfied RWM requires that waste packagers establish a data recording system for acquiring, recording and subsequently managing information for each waste package. The waste packager is responsible for the development of a data recording system that establishes an information capture strategy to create the data record for each package. However, the range of information that would need to be recorded for each distinct waste package will be unique and the development of a tailored system may be required for each waste stream and packaging campaign.

RWM has produced a *Waste Package Data and Information Recording Specification* [51] and supporting guidance [61] and will advise on and, where appropriate formally endorse, the adequacy of the proposed data recording system during a disposability assessment.

Subsequent to the manufacture of waste packages and the production of the associated waste package records, RWM will provide approval of the records. This approval would be based on demonstrated consistency with the RWM specification (i.e. [51]) and the endorsed system for producing the records for the particular waste stream.

7.4 Auditing activities

As the ultimate receiver of waste packages for disposal, RWM undertakes audits of waste producer quality arrangements. The main purpose of such audits is to verify that waste packagers have established, and are implementing, appropriate systems to control activities that could impact directly or indirectly on the quality of the packaged waste, and to establish that waste packages have been manufactured within the requirements endorsed by the LoC.

The audits are designed to confirm that the waste is being packaged in a controlled manner by appropriately qualified/trained operators, to obtain evidence that appropriate records are generated, to demonstrate that packaged waste is consistent with the envelope defined in the WPrS, and that procedures exist for management of non-conforming product, in the event that deviations occur. The type of evidence that is sought in an audit includes:

- Control of container manufacture and storage prior to use
- Appropriate procedures and operating instructions for the plant and store
- Evidence of a procedure for management of non-conforming products
- Demonstration of data acquisition on plant and how these data are captured, retained and maintained within the waste package records, supporting the records approval activity noted above
- Confirmation that finished waste package storage environmental conditions are consistent with the endorsed WPrS
- Demonstration of appropriate controls on container/package numbering, taking account of the requirements of the relevant RWM specification.

7.5 Post-manufacture treatment of waste packages

Following their manufacture waste packages may spend an extended period (ie up to several decades) in interim surface storage prior to their transport to a GDF during which time they would be expected to ‘evolve’. The effects of the evolution of waste packages during storage is evaluated as part of a disposability assessment, the aim being to ensure that waste packages satisfy the requirements of the packaging specifications, ie:

> *“Evolution of the wasteform shall ensure maintenance of the waste package properties that are necessary for safe transport and operations at the GDF.*
>
> *Evolution of the wasteform shall ensure maintenance of the required safety functions for post-closure performance as set out in the ESC.”*

Two of the technical evaluations, of wasteform properties and waste package integrity (see Table 7), carried out as part of each disposability assessment specifically identify the evolution mechanisms which could occur for a proposed waste package design, and consider the consequences of each for waste package performance on the long-term, particularly during transport and the GDF operational period.

In order to minimise such evolution it is important that:

- the storage environment for waste packages is maintained in such a manner to minimise the deleterious effects of evolution

- the condition of waste packages is monitored to identify those which may be evolving in such a way that they:
  - are no longer compliant with the needs for their ongoing management
  - are showing signs of deterioration that may lead to them being non-compliant with the needs of transport or disposal

RWM has produced guidance on the requirements and means of achieving suitable storage environments for waste packages [62] and monitoring regimes for waste packages during interim storage [63]. The NDA also produced guidance on an integrated approach to the long-term storage of waste packages in interim storage facilities [64].

8 The Acceptance of Waste Packages for Disposal

When a GDF has been constructed and licensed to receive waste, a programme for the emptying of interim stores will commence and waste package can be transported to the GDF for disposal. Prior to this, the compliance of waste packages with the needs of a GDF will have been addressed by the Disposability Assessment process, against criteria defined by the relevant packaging specification. However, once the design, location and mode of operation of a GDF have been agreed and licensed, the acceptance of waste packages for disposal will be against facility-specific waste acceptance criteria (WAC).

The purpose of the WAC is to ensure that waste disposed of to a GDF is consistent with the assumptions made as part of the facility safety case. RWM's environmental permit and nuclear site licence will require RWM to establish WAC and to have arrangements in place to make sure that the WAC are met before consignments of waste, in the form of waste packages, are brought onto the site and emplaced in the facility.

8.1 Waste package compliance with the requirements on transport

The requirements on the transport of such materials are based on the IAEA Transport Regulations, as implemented into UK law, the responsibility for ensuring that these requirements are satisfied being that of the waste consigner, regulated by ONR. Demonstrating compliance with the IAEA Transport Regulations will generally be by way of a formal check that a transport package is compliant with the relevant approval issued by ONR, the process for which is explained in full in the Transport Package Safety Report [39].

As discussed above, some designs of waste package are expected to be transported without additional protection and are therefore also transport packages (ie 'in their own right'). Others will be transported inside protective transport containers and in such cases it is the combination of the transport container and the waste package(s) that constitute the transport package. The manner in which the requirements of the IAEA Transport Regulations are applied to waste packages will be different for these two types of transport package.

For waste packages transported as, or as part of, Type B transport packages, and for all packages containing significant quantities of fissile material[32], approval is by way of a two stage process which comprises:

- approval by a Competent Authority[33] of the PDSR for the specific design of transport package and the granting of a Certificate of Approval
- a demonstration that the proposed payload inventory of a particular transport package is compliant with the terms of the Certificate of Approval

For Type IP transport packages (such as carry limited quantities of radioactive material and such as can be excepted from the requirements on packages containing fissile material), a process of 'self-approval' can be used [65].

Compliance with the regulations for transport is the responsibility of the waste package consignor. Typically, for packages that that are designed to carry a range of different radionuclides (such as would be present in waste) a Contents Specification is used to define what can be transported. A Contents Specification uses the various transport

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32 Such as cannot be 'excepted' from the requirements defined by the IAEA Transport Regulations for packages containing fissile material.

33 The competent authority for the transport of radioactive material in the UK is the Secretary of State for Energy and Climate Change.

package limits defined by the IAEA Transport Regulations to derive numerical limits on the waste package radionuclide inventory for the full range of radionuclides that could be present. These limits are set on the basis of:

- total activity
- radiogenic heat generation
- external radiation dose rate
- radioactive gas generation and release
- activity release under normal and accident conditions of transport
- criticality safety

For Type IP transport packages it would also be necessary to show that the radionuclide inventory and physical properties of the waste package contents are such that they can be classed as low specific activity material or surface contaminated objects and which are capable of being excepted from the requirements on packages containing fissile material.

Demonstration of waste package compliance with the relevant Contents Specification, and therefore with the PDSR, will be mainly by way of information contained in the Package Record. This should provide the actual values for quantities such as the radionuclide inventory of waste packages containing material from a particular waste stream.

In the case of all waste packages which are transport packages in their own right, physical measurements (eg of external dose rate and surface contamination) and visual examination to confirm the lack of visible signs of any deterioration of the waste container that could have occurred since manufacture (eg corrosion and loss of lid sealing function).

8.2 Waste packages compliance with GDF WAC

The frameworks for controlling the accumulation and disposal of radioactive waste in the UK, and which would be expected to apply to a GDF, are set out in:

- the Environmental Permitting (England and Wales) Regulations 2010 (EPR10) [66] in England and Wales
- the Radioactive Substances Act 1993 (RSA93) [67] in Scotland and Northern Ireland
- the Safety Assessment Principles for Nuclear Facilities [47]

Responsibility for regulation and control under the first two of these sets of regulations is exercised by the relevant environment agency[34], and for the third by the ONR.

Added to these general requirements will be those specific to a GDF which will comprise:

- limits on the nature and quantity of the contents of waste packages, in particular their radionuclide inventory, to ensure compliance with a GDF safety case
- waste package properties and performance requirements derived from the physical and other constraints imposed by the design of a GDF, including external dimensions, handling features, stacking performance and impact and fire accident performance

The WAC will need to capture all of these requirements in a form that will ensure the effective, efficient and transparent acceptance of waste packages.

[34] This being the Environment Agency in England, Natural Resources Wales, the Scottish Environment Protection Agency or the Northern Ireland Environment Agency.

As in the case of transport, the process of demonstrating compliance of each waste package with the WAC (ie the 'acceptance process') will primarily be by means of the information in the Package Record, backed up by measurements and/or visual inspections.

RWM has carried out work to investigate the form of the WAC at other radioactive waste disposal facilities, both in the UK and abroad, notably:

- the Waste Isolation Pilot Plant, the GDF for trans-uranic wastes[35] constructed in an evaporite rock in the USA
- the Konrad GDF for low heat generating wastes[35], constructed in a higher strength rock geology in Germany
- the Low Level Waste Repository, a surface disposal facility for LLW located in Cumbria

The WAC for these three facilities are similar in form in that they each define:

- basic features (eg dimensions and shape) of a limited number of standardised waste containers
- general requirements on all waste packages that are to be disposed of at the facility
- specific requirements on the physical and chemical properties of the waste and the wasteforms produced by its conditioning
- prohibited materials and those for which limits are placed on their quantities
- the radionuclides that have significance to the safe operation of the facility, or which have been identified by regulatory authorities as part of the disposal authorisation
- limits on the inventories of those radionuclides, together with specific controls on the quantities of fissile material

The form of the WAC for a UK GDF has not yet been defined but it is reasonable to assume that it will be similar to that outlines above, and that it will be influenced by the fact that, at the time when a GDF is available to accept waste, much of the waste in the UK RWI will have been packaged.

35 Both these types of waste have similar radiological characteristics to UK ILW.

9 Summary

In order that geological disposal can be implemented for the long-term management of the UK's higher activity waste in a safe, secure and environmentally acceptable manner, it is important that the wastes are packaged in a manner compliant with the safety cases for a GDF.

Waste packages form the initial barrier of the multi-barrier concept, and therefore play an important role in ensuring the safety of a geological disposal system. Requirements on waste package properties and performance are defined in the form of packaging specifications, which are in turn derived from the gDSSC. The packaging specification are used by RWM as a basis for assessing the disposability of the waste packages proposed by waste packagers which, when combined with suitable controls on the manufacture of those waste packages, ensures that they can be accepted for transport to, and disposal in, a GDF.

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Glossary

A glossary of terms specific to the generic DSSC can be found in the Technical Background document.

Appendix A – RWM's Disposability Assessment Aim and Principles

Disposability Assessment Aim	
The principal aim of the Disposability Assessment process is to minimise the risk that the conditioning and packaging of radioactive wastes results in packages incompatible with geological disposal, as far as this is possible in advance of the availability of Waste Acceptance Criteria for a geological disposal facility. As such, it is an enabler for early hazard reduction on UK nuclear sites.	
Disposability Assessment Principles	
1	Independent disposability assessments are undertaken against published RWM packaging specifications and the documented disposal system concept and safety case.
2	A Letter of Compliance can be issued when proposed waste packages are assessed to be compliant with published RWM packaging specifications.
3	Proposed waste packages should not unnecessarily or disproportionately consume the resources for geological disposal or disposal system capacity.
4	A staged approach to the submission of information and, hence, the assessment and endorsement of proposed waste packages is encouraged, supported by active engagement with waste owners.
5	Resolution of outstanding issues arising from the assessment of proposed waste packages will be managed in a systematic manner to facilitate timely resolution.
6	The adoption of common waste packaging approaches and sharing of substantiated good practice in waste packaging is encouraged, subject to consistency with other principles.
7	Innovative approaches to the packaging of wastes that reflect the hazard presented will be facilitated, subject to consistency with other principles and an appropriate justification.
8	Where there are proposed to be multiple waste management steps prior to the production of a disposable package, these should not jeopardise, and ideally should facilitate, production of a disposable package.
9	The continued validity of Letters of Compliance will be ensured by a process of periodic review of the supporting disposability assessments and related information.
10	The principles of openness and transparency will be applied to the Disposability Assessment process and RWM will engage with interested stakeholders in the process, subject to the constraints of security and commercial considerations.
Principles applying to Higher Activity Wastes arising in Scotland	
11	RWM recognises Scottish Government Policy and provides advice and endorsement of proposed packages for Scottish wastes based on Principles 1-10, based on the requirements of the geological disposal system.

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