The management of higher activity radioactive waste on nuclear licensed sites

Waste minimisation, characterisation and segregation

Joint guidance from the Health and Safety Executive, the Environment Agency and the Scottish Environment Protection Agency to nuclear licensees

November 2008

We are issuing this version of the guidance for comment and trial use. We would welcome comments by 30 January 2009.

Contents

Explanatory note

This explanatory note will not form part of the guidance

Trial use and comment

We are issuing this version of the guidance for comment and trial use. We would welcome comment on any other aspects of this document.

Please provide any comments by 30 January 2009. We will issue a revised version that takes account of all comments received, and after a further year we will review whether there should be further revision. We will also publish a summary of the responses received during the consultation period.

Responses are invited on the understanding that they may be made public by the regulators. Comments will be attributed, unless a respondent makes a specific request to the regulators for their comments to remain anonymous.

During this period there will be trial use of this document. Regulators will use it in discussions with licensees to test the practical implications of its use. Observations from such trial use will be fed back to inform the production of a final version.

Comments should be directed to: NDenquiries@hse.gsi.gov.uk referencing 'Joint Guidance' in the title of the message.

Health and Safety Executive
Environment Agency
Scottish Environment Protection Agency
November 2008

Foreword

The Health and Safety Executive (HSE), the Environment Agency and the Scottish Environment Protection Agency (SEPA) (together referred to as 'the regulators') have issued this guidance jointly.

You are not required to follow this guidance, and you are free to take other action. However, if you do follow this guidance, you will normally be doing enough to comply with the law as interpreted by the regulators at the time of writing, and the regulators may refer to this guidance as illustrating good practice. However, compliance with this guidance does not automatically mean that we will approve an application for a nuclear site licence, a consent or agreement under the licence or an authorisation.

Given the long timescales involved in radioactive waste management, you should be aware that standards, legislation and national policy might change. While this guidance forms the best advice that the regulators can give at present, nothing in this guidance overrides, or is intended to pre-empt, the ability of the regulators to discharge their statutory powers and duties in accordance with legislation, standards and policy applicable at any time.

Policies for the disposal of higher activity waste differ in Scotland and in England/ Wales. We consider that packages conditioned in anticipation of deep geological disposal are also suitable for long-term storage, as required by Government policy

in Scotland. On this basis the following guidance can be used equally in England, Scotland and Wales, but any references to geological disposal will mean long-term storage when applied to Scotland. We will keep the packaging advice being developed by the Nuclear Decommissioning Authority's (NDA's) Radioactive Waste Management Division (RWMD) under review and if any developments mean that this assertion is no longer valid, we will provide further guidance.

We will review this guidance periodically to ensure that it continues to provide sound advice.

Freedom of information – disclosure of information

The regulators are public authorities for the purposes of the Freedom of Information Act 2000 (FOIA00) and the Environmental Information Regulations 2004 (EIR04) in England and Wales, and the Freedom of Information (Scotland) Act 2002 (FOISA02) and the Environmental Information (Scotland) Regulations 2004 (EISR04) in Scotland. If we receive a request for information that we hold, we will have to consider the request in accordance with this legislation.

This document is available on our websites, in accordance with our respective policies of openness and transparency.

Executive summary

Waste minimisation, characterisation and segregation are central to both establishing and updating a radioactive waste inventory and optimising waste management in line with the waste management hierarchy. Opportunities for waste minimisation, characterisation and segregation should be considered in all stages of waste management, including design, construction, operation, decommissioning, storage and disposal.

This document provides an overview of the relevant policy drivers, regulatory requirements and expectations relating to waste minimisation, characterisation and segregation during the management of higher activity radioactive wastes on licensed nuclear sites. It identifies the relevant technical considerations that need to be addressed in the requisite radioactive waste management cases.

Scope

1 This document is part of a suite of guidance documents covering the management of higher activity radioactive wastes on licensed nuclear sites. It deals specifically with waste minimisation, characterisation and segregation. Further detailed considerations for higher activity radioactive wastes are covered by companion guidance modules in the 'Joint Guidance' series,[1–5] produced by HSE, the Environment Agency and SEPA.

2 In the context of this guidance:

- **management of radioactive waste** means the whole process of managing waste from its generation to (but not including) its disposal;
- **higher activity radioactive waste** means all radioactive waste other than:
  - low-level radioactive waste (LLW) which will be disposed of promptly at the Low Level Waste Repository near Drigg or to similar future facilities; and
  - very low-level radioactive waste which will be disposed of promptly at suitably authorised disposal facilities; and
  - radioactive wastes exempted under the provisions of any relevant exemption order;
- **promptly** means as soon as is reasonably practicable after waste generation without the need for any treatment other than basic segregation, sorting and compaction to make it suitable for its intended disposal route. Advice about the disposal of those categories of radioactive waste that are not covered in this guidance can be obtained from the Environment Agency or SEPA.

3 Licensees are reminded that the same general safety and environmental standards apply to all activities involving radioactive materials whether or not the material involved is declared as radioactive waste.

Objective

4 The objective of this document is to provide guidance on complying with the legislation below in accordance with current policy by:

- describing regulatory expectations in relation to waste minimisation, characterisation and segregation; and
- providing links to other guidance on how these components of the radioactive waste management case (RWMC)[2] may be produced.

Applicable legislation and Government policy

5 Applicable legislation with respect to radioactive waste is as follows:

- Nuclear Installations Act 1965 (as amended);[6]
- standard conditions applied to nuclear site licences;[7]
- Health and Safety at Work etc Act 1974;[8]
- Radioactive Substances Act 1993 (RSA93);[9] and
- conditions attached to authorisations under RSA93.

Details of how each of the above apply are given in *Radioactive waste management cases*.[2]

6 Government maintains and continues to develop a policy[10] and regulatory framework which ensures that:

- radioactive wastes are not unnecessarily created;
- such wastes as are created are safely and appropriately managed and treated;
- they are then safely disposed of at appropriate times and in appropriate ways.

7 Fundamental to this is the aim of safeguarding the interests of existing and future generations and the wider environment in a manner that commands public confidence and takes due account of issues.

8 With respect to waste minimisation, a 2004 Government policy statement on the decommissioning of the UK nuclear industry's facilities[11] states that 'By the use of Best Practical Means (BPM) strategies should minimise the volumes of radioactive wastes which are created, particularly the volume of ILW.'

9 The Government requires that the regulators ensure that the policy and regulatory framework is properly implemented in accordance with their statutory powers. Within the framework, the producers and owners of radioactive waste are responsible for developing their own waste management strategies, consulting the Government, regulatory bodies and disposal organisations as appropriate.

Other relevant guidance

10 Throughout the UK HSE's Safety Assessment Principles (SAPs)[12] apply:

- SAP RW.2 states: 'The generation of radioactive waste should be prevented or, where this is not reasonably practicable, minimised in terms of quantity and activity.'
- SAP RW.4 states: 'Radioactive waste should be characterised and segregated to facilitate subsequent safe and effective management.'

11 For England and Wales, the Environment Agency's draft* *Radioactive Substances Regulation: Environmental Principles*[13] apply (these do not apply in Scotland, for additional guidance in this area, licensees should contact SEPA):

- Principle RSMDP3: Use of best available techniques (BAT) to minimise waste, states, 'The best available techniques should be used to ensure that production of radioactive waste is prevented and where that is not practicable minimised with regard to activity and quantity'. (In draft statutory guidance[14] for England and Wales, the Environment Agency is required to ensure that BATs are applied in place of the current techniques of best practicable means (BPM) and best practicable environmental option (BPEO). It also states that operators who currently meet the requirements of BPM and BPEO will satisfy the current requirements of BAT.) BPM and BPEO continue to apply in Scotland.
- Principle RSMDP8: Segregation of wastes, states 'The best available techniques should be used to prevent the mixing of radioactive substances with other materials, including other radioactive substances, where such mixing might compromise subsequent effective management or increase environmental impacts or risks.'
- Principle RSMDP9: Characterisation, states 'Radioactive substances should be characterised using the best available techniques so as to facilitate their subsequent management, including waste disposal.'

* The Environment Agency's Radioactive Substances Regulation: Environmental Principles are currently out for consultation and the principles quoted are therefore not yet finalised. The final version of this document will use the finalised version of the principles.

Guidance on waste minimisation, segregation and characterisation

Overview

12 The successful implementation of a radioactive waste management strategy requires that several activities are planned, undertaken and reviewed. Among these activities waste minimisation, segregation and characterisation are key to both establishing and updating a radioactive waste inventory, and optimising waste management in line with the waste management hierarchy.

13 Opportunities for waste minimisation, segregation and characterisation should be considered in all stages (basic steps) of waste management, including design, construction, operation, decommissioning, storage and disposal (Figure 1).

Minimisation

14 Minimisation of waste is fundamental good practice in radioactive waste management. It should be considered during the design of facilities and applied during all of the basic steps. Effective methods of minimising the accumulation of radioactive waste include the clearance of waste that is exempt from regulatory control and the reuse or recycling of radioactive material.

15 Minimisation is an important initial step in waste management and therefore operators procedures should seek to design, construct, operate and decommission plant in such a manner that both the waste volume and radioactivity are minimised.

Characterisation

16 Characterisation of radioactive waste involves determining its physical, chemical, biological and radiological properties. It may be carried out in association with several of the other basic steps. It may be required for record keeping, moving waste between steps and also to determine the best method of managing waste.

17 Waste characterisation should also form an integrated part of an overall waste management strategy in support of the management of waste throughout its lifecycle. The drivers for the characterisation may differ throughout the lifecycle; while the initial focus may be on optimising plant or process design parameters, the ultimate focus should be to support the long-term management option (eg disposal). However, at each stage characterisation activities should be undertaken for a defined purpose with cognisance of the next stage in the lifecycle.

Segregation

18 An activity where types of waste or material (radioactive or exempt) are separated or are kept separate on the basis of radiological, chemical and/or physical properties, to facilitate waste handling and/or processing.

19 Segregation of waste materials at source provides an efficient means of managing wastes in relation to their hazard. A mixed waste stream may prove more challenging to manage and may have options foreclosed when compared to segregated waste materials.

20 With regards to planning an overall waste characterisation strategy, the International Atomic Energy Agency's (IAEA's) *Strategy and methodology for radioactive waste characterization*[15] notes that activities in the various stages of the lifecycle may have significant effects on the cost and efficiency of the overall characterisation programme, in that:

- characterisation is generally much easier and cheaper in the earlier stages of the lifecycle. For example, waste properties that could easily be measured in the raw waste state may be difficult or impossible to measure after some treatment stages, certainly after conditioning has been undertaken;
- if wastes streams are appropriately segregated and controlled early in the lifecycle, then a greater proportion of the wastes may fall into the simple and stable waste type; and
- alternatively, if raw waste streams are mixed and if valuable history is lost, more of the waste will fall into the complex and variable type, requiring a characterisation programme that is more intensive and costly.

21 For the purposes of this guidance, waste characterisation, segregation and minimisation are discussed as separate activities but, in reality, these are all part of an integrated process for management of a particular waste stream.

Integrated waste strategy

22 An integrated waste strategy (IWS) is a strategy which describes:

- how a site optimises its approach to waste management in an integrated way;
- the waste streams and discharges expected from current and future operations; and
- actions required to improve the site's approach to waste management.

23 Waste minimisation, characterisation and segregation should be carried out within the context of an integrated waste strategy.

Waste minimisation, characterisation and segregation should be part of an integrated waste strategy

24 From a regulatory point of view, an IWS provides a key approach for the safe, environmentally sound and timely management of radioactive waste on a site. Licensees should produce and maintain a strategy which gives an overview of their approach to the current and future management of all wastes generated on or received by sites. It should integrate and optimise all waste-related activities on a site ranging from operational activities through to decommissioning activities and wastes arising from contaminated land management.

An IWS should be transparent, systematic, complete, integrated and optimised

25 An IWS should demonstrate that the waste can be appropriately managed at the time and rate at which it will arise. It should be developed in a manner which involves regulators and other stakeholders and using appropriate and consistent quality assurance arrangements that include criteria and specifications for data and information, taking account of health, safety, environmental and security management systems as appropriate. The strategy should not be restricted to the consideration of material that the licensee currently regards as waste: it should also cover all material that may, in the future, become waste.

An IWS should deliver best practice in waste avoidance, minimisation, management and disposal

26 An IWS should define a structured approach which is optimised and co-ordinated for individual facilities on the same or different sites. It should clearly demonstrate:

- the existence of an optimised strategy in line with best practice for the management of all the wastes over the whole lifecycle of the site;

- compliance with relevant legal obligations (eg licence conditions and instruments, authorisations, permits, consents);
- consistency with Government policy and regulatory expectations, including the Government's overall policy aims on sustainable development;
- the application of the waste management hierarchy;
- that the hazards posed by historic wastes are adequately controlled and progressively reduced; and
- that all radioactive wastes on site have been covered and that no 'orphan streams' remain.

27 The strategies should be adequate to allow licensees to cost their radioactive waste management and disposal liabilities and make appropriate financial provision for meeting them. From a safety and environmental regulatory point of view it is not necessary to actually set out the costs in the IWS.

28 If a licensee is responsible for a number of sites, then it may be appropriate to produce a corporate strategy supported by a series of site-specific strategies. Consideration should also be given as to how the strategy links to those of other licensees where there may be shared resources or where waste is transferred to or from another licensee.

29 The IWS should be written as far as practicable to avoid the need for protective or commercial marking – if information requiring such markings is necessary as part of the IWS, then the protectively-marked information should be clearly identified (for example in a separate appendix) so that the rest of the document can be published in an unrestricted form.

30 The IWS should contain sufficient information to be self-standing and should wherever relevant provide links to other documents (either in the IWS document or a separate route map document) where the site's strategy is described and substantiated in detail.

31 NDA has produced specifications[16,17] for integrated waste strategies for application on its sites. The regulators view these as examples of good practice.

Strategic options study

32 It is anticipated that a strategic options study would be conducted to identify an optimised strategy, which ensures that opportunities for waste minimisation are maximised as far as is practicable throughout the lifecycle from operations to decommissioning. Where appropriate, waste reuse and recycling should be given precedence over options for waste disposal. This is considered particularly important when a site enters its decommissioning phase because of the increased potential for solid waste volumes to be generated when materials from contaminated facilities, plant and land need to be managed. An operator's strategic options study should consider a range of options consistent with the concept of waste hierarchy, including means for recycling and reuse of the materials, and decontamination and segregation, rather than simply means for bulk waste disposal.

33 An example of how such a strategic options study may be carried out is given in *Guidance for the Environment Agencies' Assessment of Best Practicable Environmental Option Studies at Nuclear Sites.*[18]

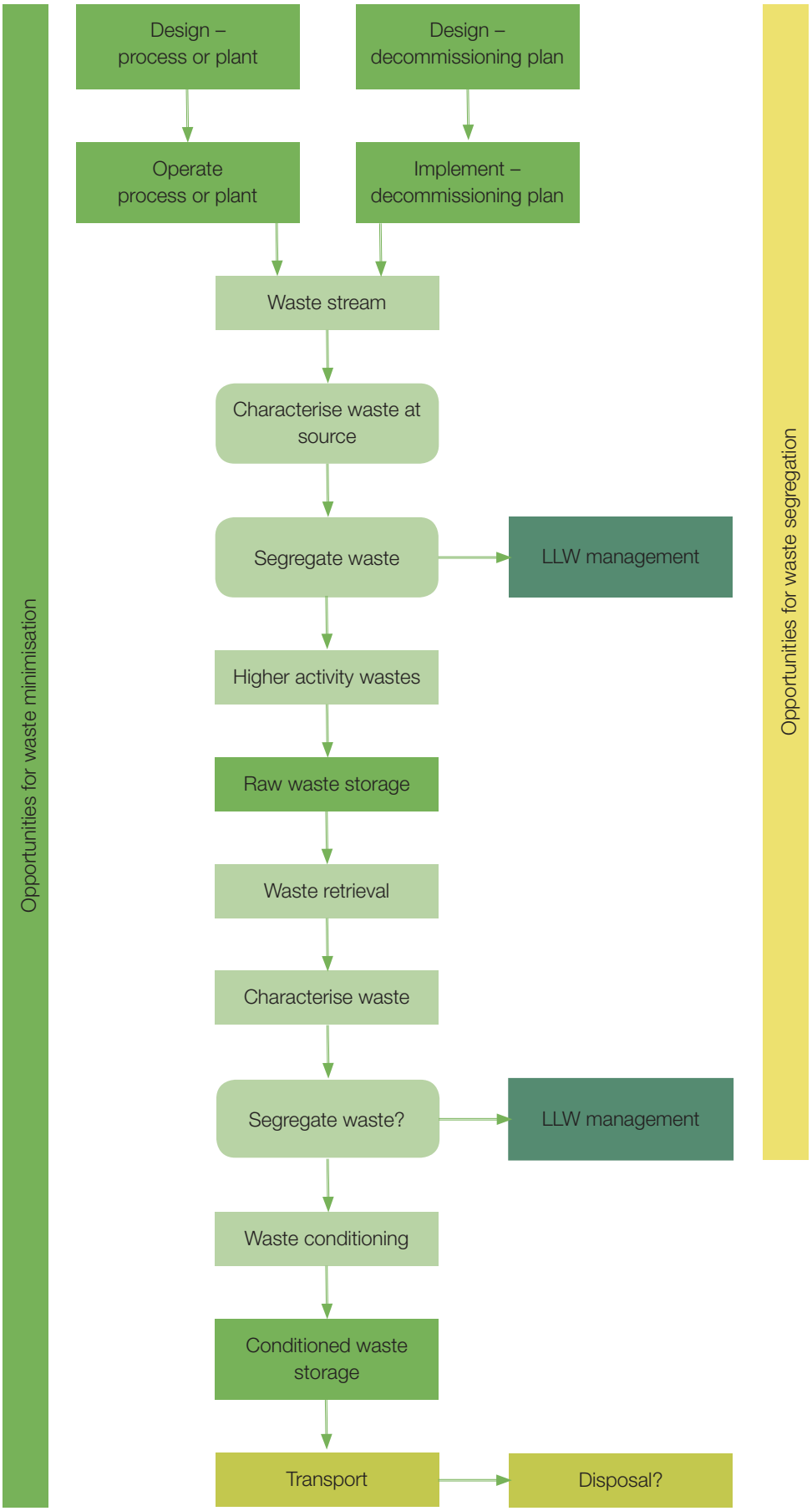

Figure 1 Opportunities for waste minimisation, segregation and characterisation

Waste minimisation

Radioactive waste should not be unnecessarily created, and generation and accumulation of radioactive waste should be minimised

34 Waste minimisation is central to Government radioactive waste management policy[10] and is recognised in international guidance as a fundamental principle of radioactive waste management.[19] Waste minimisation is also a regulatory requirement:

- Licence Condition 32 requires adequate arrangements for minimising so far as is reasonably practicable the rate of production and total quantity of radioactive waste accumulated on site; and
- RSA93 standard authorisation conditions require wastes to be minimised.

Waste minimisation is a fundamental principle of radioactive waste management

35 Steps should be taken to avoid the unnecessary creation of radioactive waste and to minimise the production and accumulation of those wastes that are created, in terms of both the activity and volume. Minimising the generation of waste contributes to effective waste management and reduces the risks arising from such waste.

36 Waste minimisation and control of waste should be taken into account at all stages in the lifecycle of a facility, starting at the planning and design stage through operation, decommissioning and site clearance. This will require developing commissioning, operational and decommissioning arrangements that avoid the creation of radioactive waste or reduce to the minimum radioactive waste generated during the lifetime of the facility.

37 Useful strategies for waste minimisation include:

- reducing the volume of radioactive waste to be managed, by adequate segregation and by keeping non-radioactive material out of controlled areas to prevent contamination;
- the proper planning of activities and the use of adequate equipment for handling waste so as to control the generation of secondary waste;
- the decontamination of material, together with the control of secondary waste arising from decontamination; and
- the recycling and reuse of materials and structures, systems and components.

38 Radioactive waste should be reduced at source as the most efficient method for waste minimisation. Consideration should be given to the design of the facility and to operational features for waste minimisation, including the following aspects:

- the careful selection of materials, processes and structures, systems and components for the facility;
- the selection of design options that favour waste minimisation when the facility is eventually decommissioned;
- the use of effective and reliable techniques and equipment;
- the containment and packaging of radioactive material to maintain its integrity;
- the decontamination of zones and equipment and the prevention of the spread of contamination.

Waste management hierarchy

Operators should manage their waste in accordance with waste management hierarchy principles

39 The waste hierarchy is a stepwise approach to achieving waste minimisation and to promote sustainability that considers the lifecycles of both the processes that create waste and the waste that is produced from them. The hierarchy, as set out in the latest draft European Directive on Waste[20] encourages the adoption of options for managing waste in the following order of priority:

- **Prevention:** Creation of waste should be prevented, or reduced at source, as far as possible to secure the conservation of nature and resources, in particular waste that cannot be managed using current techniques, or techniques under current development.
- **Preparing for reuse:** Where waste cannot be prevented, waste materials or products should, where appropriate, be reused directly or refurbished then reused.
- **Recycling:** Waste materials should then be recycled or processed into a form that allows them to be reclaimed as a secondary raw material, where appropriate.
- **Disposal:** Only if waste cannot be prevented, reclaimed or recovered, should it be disposed of into the environment and this should only be undertaken in a controlled and authorised manner.

40 A further option – 'other recovery (eg energy recovery)' – is included in the standard waste hierarchy. This is rarely an option in dealing with radioactive wastes and has not, therefore, been included in the list above. However, if this option is applicable in any particular case, it should be considered.

41 When applying the waste hierarchy, options should be selected that deliver the best overall outcome. This may require specific waste streams departing from the hierarchy where this is justified by lifecycle thinking on the overall impacts of the generation and management of such waste.

42 The waste management hierarchy principles are central to the latest European Directive on Waste[20] and UK Government policy of LLW management.[21] These should be considered and applied during the planning, design, construction, manufacture, commissioning, operational and decommissioning stages of a facility. Applying the waste management hierarchy to radioactive waste generally requires:

- not creating waste where practicable (ie 'avoidance');
- reducing waste arisings (both by activity and by mass) to the minimum through the appropriate design and operation of processes and equipment and making effective use of techniques such as waste characterisation, sorting and segregation, volume reduction and surface contamination removal;
- otherwise minimising quantities of radioactive waste requiring disposal through decay storage, reuse and/or recycling, and incineration (under appropriately regulated circumstances); and
- disposal.

43 The objective should be to deal with potential arisings at the highest practicable level of this hierarchy. Avoiding the creation of radioactive waste in the first instance and, secondly, minimising the generation of unavoidable waste is one of the foremost principles of good waste management.

44 However, it is recognised that there are limitations to the application of the waste hierarchy in the management of legacy wastes. For example, avoidance of waste creation is less relevant for radioactive wastes that have already been created as a result of historical activities. In such cases, avoidance should be considered in respect of any secondary wastes which might arise during the storage, treatment and conditioning of the legacy wastes.

Generation of primary and secondary radioactive waste should be kept to the minimum practicable, in terms of both its activity and volume

Minimisation of both activity and volume

45 Waste minimisation should take account of the volume and activity of radioactive waste generated and any secondary waste arising from subsequent treatment and conditioning of that waste. Useful strategies for waste minimisation include:

- reducing the volume of radioactive waste to be managed, by adequate segregation;
- planning of activities and the use of adequate equipment for handling waste, so as to control the generation of secondary waste;
- decontamination of material, together with the control of secondary waste arising from decontamination; and
- recycling and reuse of materials and structures, systems and components.

46 Radioactive waste should be reduced at source as the most efficient method for waste minimisation. The chemical characteristics of the waste should also be controlled at the source to facilitate the subsequent processing of the waste and help minimise production of secondary waste. Other factors that should be considered include the magnitude of radiological hazard, the potential for the hazard to be realised, the potential dose uptake and the cost.

47 An operator should demonstrate that the chosen technique, or combination of techniques, for waste minimisation satisfies the optimisation requirements of legislation.

Waste minimisation through continuous improvement

Waste minimisation should be maintained in operating plant through continuous improvement

48 At an operating plant, there remains considerable potential for significant reductions in radioactive waste generation through the application of good waste minimisation practices. It is acknowledged that significant design changes to operating facilities to minimise radioactive waste arisings are not usually a cost-effective option. Nevertheless, reviews of operational processes and implementation of improvements can lead to waste minimisation benefits.

49 Waste minimisation can be achieved through a process of continuous improvement initiated by a commitment from senior management as part of the declared licensee's policy on radioactive waste management. The continuous improvement programme needs to commit adequate resources to waste minimisation, for example, setting up a dedicated trained team with the objectives of identifying and ranking waste generation practices in the licensee's operations and reviewing and feeding back observations and recommendations into operational procedures. This should be linked to objective performance measures and tracking of performance.

Problematic wastes and waste forms

Waste minimisation should be applied to limit the production of problematic wastes and waste forms

50 Wherever practicable, waste minimisation should be applied to ensure that production of problematic wastes and waste forms are kept to a minimum. Problematic wastes and waste forms might include, for example, wastes that have no obvious disposal route or are difficult to convert to a passively safe form for storage due to a high reactive organic or reactive metal content.

Record keeping

Good record keeping should aid demonstration of waste minimisation

51 Recording quantities and activities of different waste streams provides the basis for monitoring the effectiveness of radioactive waste minimisation measures. Trends in radioactive waste generation should be monitored and the effectiveness of applied waste minimisation measures demonstrated. There should be reviews of opportunities for further reduction of radioactive waste arisings.

Environmental management system

Waste minimisation should be part of an environmental management system

52 Waste minimisation forms part of the objectives of an environmental management system. Accreditation to ISO 14001[22] may be used as an indication of commitment to waste minimisation.

Waste characterisation

A quality assured framework for characterisation

Waste should be characterised within a quality assured framework using the best available technologies

53 A systematic approach to waste characterisation should be adopted, which results in the acquisition of data that are sufficient to support waste management decisions. This might be achieved, for example, by adopting an approach based on data quality objectives, which define the quality and quantity of data that are required in the decision context. (For example the data quality objectives process, developed by the US Environmental Protection Agency,[23] provides a systematic, stepwise approach to the collection of data to support waste management decisions and has been applied in waste characterisation programmes.)

54 An important aspect is finding the balance between the impacts and cost of data gathering and the effects of uncertainties in data on the resulting decisions. It is particularly important to ensure that the commitment of resources, which may result in worker dose uptake and/or the production of secondary wastes, is only undertaken in situations where the output will provide net benefits to support a defensible decision.

55 A strategy for waste characterisation covering the stages from raw waste retrieval to the production of conditioned waste for storage and disposal should be developed by the waste producer. The characterisation programme should be supported by a suitable waste sampling plan that is designed to provide a statistically robust data set, where practicable. Where comprehensive sampling and characterisation is not practicable (eg on optimisation grounds), this must be justified and arguments should be presented as to why any alternative approach is appropriate and supportable in the decision context.

56 Appropriate quality assurance arrangements should be adopted throughout the waste characterisation process and beyond to ensure records retention and knowledge management.[4] This should encompass appropriate method development and documentation, staff training, and verification and validation of measurements. Ultimately the aim should be to ensure that all resulting characterisation data are fully traceable and underpinned.

57 A wide range of approaches to waste characterisation are possible and use should be made of appropriate industry codes of practice that are endorsed by the regulators. In general, preference should be given, where practicable, to direct measurement and determination of waste characteristics. This might be achieved, for example, using destructive and/or non destructive techniques, applied either in-situ or using retrieved waste samples.

58 Where practicalities dictate, reliance may also be necessary on other lines of evidence, such as knowledge of the provenance and history of the raw waste (where supported by records), knowledge of waste evolution during storage, the use of simulants and modelling techniques. Whatever approach is adopted, it must provide corroborated data with suitable uncertainty bounds that are sufficient to demonstrate that the waste meets the relevant waste acceptance criteria. The waste characterisation approach and procedures should appropriately documented

and subject to checking via an independent party (eg audits of operator arrangements, accreditation of operator methods, independent check monitoring).

59 Characterisation information generated by the waste producer may be used by other organisations which subsequently handle, treat, store, transport or dispose of the waste and the associated regulatory bodies. Therefore any characterisation data and any associated records should be suitably documented and robust (see *Managing information relating to radioactive waste in the United Kingdom*[4]) and in a format that is acceptable to the recipient.

Characterisation for subsequent management and disposal

60 Development of an integrated waste strategy is contingent upon the availability of information relating to the nature and quantity of wastes. The radiological, physical, chemical and biological properties of waste must be known in sufficient detail as to provide a sound foundation for its safe and effective management from generation through to disposal. Waste characterisation will be required, for example, to properly inform decisions about the design, operation, maintenance and decommissioning of facilities; handling, storage, processing and transport of radioactive wastes; remediation of contaminated land; and the disposability of wastes.

Waste should be characterised so as to properly inform decisions about its subsequent management and disposal

61 Waste characterisation information will be required at an early stage to support any optioneering studies and to ensure that the waste management hierarchy can be applied appropriately. The characterisation challenge for a given waste stream may vary depending on the nature of the waste and the waste conditioning method that is selected. Characterisation requirements might usefully discriminate between options for the future management and disposal of that waste.

62 While adequate waste characterisation is essential, unnecessary over characterisation resulting in additional cost and unjustifiable occupational radiation exposure must be avoided. Provision should be made at the earliest stage for identifying, assessing and dealing with radioactive waste that does not meet existing process specifications or disposal criteria.

Inventory

63 An inventory should be established and properly documented for each waste stream. Inventory data should be reviewed periodically and kept up to date.

Radioactive waste should be identified and an appropriate inventory established, properly documented and maintained

64 The establishment and maintenance of a radioactive waste inventory by waste producers is required for a number of reasons, in particular:

- to assist the waste producer in planning waste management by providing underpinning data for lifetime plans and integrated waste strategies;
- to assist in the maintenance of a UK radioactive waste inventory[24] which can be used by those Government departments and agencies involved in radioactive waste management strategy and regulation and NDA, which is responsible for the development of long-term management solutions for these wastes; and
- to assist the UK in fulfilling its requirements under the *Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management*.[25]

65 Waste producers may find it convenient to report information on a waste stream basis.

Characterisation from generation through to disposal

Waste should be characterised at appropriate stages from generation through to disposal

66 Characterisation should be carried out:

- where there is a lack of sufficient information or knowledge to support the waste management safety case and where further information is required to support subsequent phases of management;
- where information might be out of date or where the properties of the waste have changed to such an extent as to invalidate any relevant safety case considerations;
- for quality assurance or checking; and
- at stages when useful information can be obtained that might otherwise be lost.

67 Characterisation data may be gathered on a progressive basis through the relevant stages of waste management, but there must be sufficient confidence at each stage to support decisions. Characterisation opportunities are perhaps greatest at the time of raw waste generation (ie characterisation at source). Characterisation opportunities may be limited for existing wastes, although opportunities may arise at the time of raw waste retrieval for subsequent conditioning.

68 Where waste is being conditioned, it should be sufficiently characterised to properly inform subsequent decisions about its suitability for disposal. Detailed characterisation is likely to be problematic following waste conditioning, at which point non-destructive techniques may be of limited utility. Significant package reworking may be required if detailed characterisation is required following waste conditioning and such situations should be avoided.

Radiological, physical, chemical and biological properties

Radioactive waste should be appropriately characterised in terms of its radiological, physical, chemical and biological properties

69 Waste characterisation should yield sufficiently accurate and precise information with regards to the radiological, physical, chemical and biological properties of radioactive wastes as to support the waste management safety case, including the anticipated requirements for transport and disposal in so far as these are known.

70 Waste characterisation information should encompass the following:

Radioactivity

71 The radioactivity content of the waste should be known with sufficient accuracy and precision as to meet any limits defined within the relevant waste management safety case, such as to meet any existing waste acceptance criteria and those of any facilities to which the waste will be directed, in so far as these are known.

72 As a minimum, the radioactivity content of the waste should be known to the extent that it can be robustly classified in terms of the waste category (ie as very low-level waste (VLLW), low-level waste (LLW), intermediate-level waste (ILW) or high-level waste (HLW)). The radioactive properties of the waste should be known to the extent that it is possible to assess whether decay to a lower waste category is possible within a reasonable timescale, and hence to inform decisions on its future management and disposal.

73 The requirements may extend to defining the activities of specific radionuclides that are significant to the safety case, either at the individual package or waste stream scale. At the time of waste transport and disposal, knowledge of the radioactivity content of individual waste packages will need to be sufficient to meet the appropriate safety case requirements and waste acceptance criteria for the disposal facility.

Dose rate

74 Dose rates should be known in sufficient detail to indicate compliance with the waste management safety case. Package external dose rates should be known so that compliance with the limits for facilities and equipment in which they will be handled, stored and/or transported can be demonstrated. Where shielding has been identified as a means of restricting dose, it should be effective under all operating conditions.

Surface contamination

75 For conditioned wastes, the amount and extent of any non-fixed surface contamination should be known. Suitable and sufficient decontamination provisions should be provided to meet the relevant safety case requirements. Transferable radioactive contamination on the exterior of the waste packages should be maintained within limits established for the storage, transportation, and packaging facilities where wastes are to be handled.

Fissile content

76 For fissile wastes the nature and quantity of any fissile materials, and any other waste components that may influence the neutron reactivity of the system, should be known in sufficient detail to enable assessment of the criticality hazard and to facilitate safe management, safeguards and disposal arrangements. Waste package fissile limits are discussed specifically and in greater detail in the guidance on waste conditioning.[3]

Chemical properties

77 The bulk composition and chemical properties of the waste should be understood to the extent that any chemical hazards or challenges posed by the waste can be assessed. Specific information with regards to the following will be required, where applicable:

- organic components: this should include organic components that present a hazard based on their inherent toxicity, might degrade to yield gases (such as carbon dioxide, hydrogen and methane), might be radioactive, explosive or present a flammability hazard, might influence the neutron reactivity of the system (eg effective neutron moderators) or which might degrade to form species which can enhance or promote the mobility of radionuclides in the disposal environment;
- reactive components: any waste components that might be expected to react within the waste matrix or with the container should be identified, such that any threat posed to the integrity of the conditioned waste can be assessed. Reactive components might include metals that can react with the waste matrix to form expansive reaction products and gases which may be radioactive and/or flammable, ion exchange resins that may react expansively with the waste matrix, graphite which may have associated Wigner energy, materials which may significantly influence the pH of the waste form and any materials that may challenge the integrity of the waste container via chemical reactions in the long term;
- explosive, flammable, combustible, corrosive and pyrophoric materials: any components that might represent an explosive, flammability, combustion, corrosion or pyrophoric hazard should be identified. This extends to any waste components which might evolve to form materials with such properties in the long-term; and
- the presence of any materials that would be classed as dangerous good for transport purposes or material covered under the Special Waste Regulations.[26]

Physical properties

78 The bulk physical properties of the waste should be understood to the extent that any risks posed by the waste can be assessed and such that compliance with any related safety case limits can be demonstrated. Such information might be required, for example, to support any waste handling and stacking operations.

79 Knowledge of the following physical properties might be required:

- physical dimensions and weight of the waste;
- the physical form of the waste (eg homogeneity, morphology, grain size), its mechanical properties, strength, dimensional stability and resistance to physical stress (eg impact resistance);
- the presence of any mobile, volatile, readily dispersible, leachable or respirable fractions;
- the presence of any free liquids or pressurised gases;
- the thermal power output of the waste (including any radiogenic and chemical heat) and its thermal properties (eg thermal conductivity) and thermal resistance (eg fire resistance, freeze/thaw stability);
- radiation dose rates and radiation damage resistance/stability.

Biological properties

80 The biological properties of the waste should be understood in terms of:

- the presence of substrates within the waste, which through microbial degradation might result in the production of significant volumes of gas and/or acidic species. This would extend to the presence of any significant quantities of putrescible matter;
- the possibility that the waste will promote and/or support microbial-induced corrosion of metallic containers;
- any specific biological hazards, such as might occur via the presence of pathogenic or infectious species. This is likely to be relevant only to contaminated medical wastes.

Waste segregation

81 Segregation of radioactive waste involves accumulating together those materials with similar characteristics, and avoiding mixing wastes with different characteristics. The *IAEA Safety Glossary*[27] defines segregation as 'An activity where waste or materials (radioactive and exempt) are separated or are kept separate according to radiological, chemical and/or physical properties which will facilitate waste handling and/or processing.'

So far as is reasonably practicable, radioactive waste should be segregated to facilitate subsequent safe and effective management

82 Emphasis should be placed on the segregation of different types of waste to reduce the volume of radioactive waste and facilitate its management and eventual disposal. Specific drivers for waste segregation might include:

- facilitating application of the waste management hierarchy by enabling free-release, reuse, recycling or reclassification to more easily disposed radioactive waste;
- removal of items which need special treatment;
- removal of items that do not conform to waste acceptance criteria for those facilities where the waste is to be managed or disposed;
- separation of waste materials that may react together to significantly challenge the integrity of the wasteform or container;
- categorisation of waste into various waste streams, which are similar in terms of their properties, conditioning requirements and/or management arrangements; and
- simplification or facilitation of particular waste management operations.

Early and appropriate segregation can contribute significantly to the safe and effective management of radioactive waste

83 Segregation is most efficient if it is taken into account at the process design stage and the opportunities for waste segregation should be an important consideration within any waste strategy. Waste segregation should be performed as close to the point of generation as is reasonably practicable. Early and appropriate segregation can contribute significantly to the effective and safe management of radioactive waste.

84 There may be cases in which waste segregation may offer potential benefits but is not pursed in practice. This might be based, for example, on the grounds of it being impractical and/or disproportionably costly. In such cases, the radioactive waste management case should justify why waste segregation is not being pursued.

85 Mixing of wastes need not be precluded where this can be shown to provide net benefits in terms of health, safety and environment. Dilution solely for the purposes of re-categorisation to a lower category, however, should be avoided (eg deliberate mixing of ILW with inactive or lower activity waste to yield a larger volume of LLW).

86 Where segregation is to be pursued, the radioactive waste management case should demonstrate provision of suitable and sufficient design features, locations, equipment and arrangements to support segregation operations.

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Glossary

Where possible standard definitions have been used and these are indicated with:

[27] IAEA (from the *IAEA Safety Glossary)*
[21] UK LLW Policy (*Policy for the Long Term Management of Solid Low Level Radioactive Waste in the United Kingdom*)

ALARP as low as reasonably practicable.
as low as reasonably practicable (ALARP) see 'optimisation'.
avoidance (waste) the first step of the waste hierarchy, which states that waste should be prevented, in particular waste that cannot be managed using current techniques or techniques under current development.

best available technique (BAT) see 'optimisation'.
best practicable environmental option (BPEO) see 'optimisation'.
best practicable means (BPM) see 'optimisation'.

characterisation determination of the nature and activity of radionuclides present in a specified place.[27] Characterisation of radioactive waste involves determining its physical, chemical and radiological properties. It may be carried out in association with several of the other basic steps. It may be required for record keeping, moving waste between steps and also to determine the best method of managing waste.
conditioning those operations that produce a waste package suitable for handling, transport, storage and/or disposal. Conditioning may include the conversion of the waste to a solid waste form, enclosure of the waste in containers and, if necessary, provision of an overpack.[27]
Conditioning involves transforming radioactive waste into a form suitable for handling, transportation, storage and disposal. This may include immobilisation of radioactive waste, placing waste into containers and providing additional packaging. Common immobilisation methods include solidification of LLW and ILW liquid radioactive waste, for example in cement, and vitrification of HLW in a glass matrix. Immobilised waste may be placed in steel drums or other engineered containers to create a waste package.

disposal emplacement of waste in an appropriate facility without the intention of retrieval.[27] Disposal may also include discharging radioactive wastes such as liquid and gaseous effluent into the environment and transfer from one site to another.

exempt (from regulatory control) waste below the lower activity limit for LLW, below which waste is not required to be subject to specific regulatory control is:

- for certain natural radionuclides in the uranium and thorium decay chains, the levels specified in Schedule 1 of RSA93, below which the substances are outside the scope of the Act; or
- for other artificial or man-made radionuclides, the levels laid down in the current suite of Exemption Orders issued under RSA93, below which controls additional to those specified in the Exemption Order are not required. The most notable of these is the Substances of Low Activity (SoLA) Exemption Order. This specifies a level for exemption from regulatory control of 0.4 becquerels (Bq)/g for wastes which are substantially insoluble in water. (Different exemption thresholds may apply for the transport of radioactive waste.)

higher activity radioactive waste all radioactive waste other than:

- low-level radioactive waste which will be disposed of promptly at the Low Level Waste Repository near Drigg or to its successor facility; and

- very low-level radioactive waste which will be disposed of promptly at suitably authorised disposal facilities; and
- radioactive wastes exempted under the provisions of any relevant exemption order.

'Promptly' means as soon as is reasonably practicable after waste generation. Both categories require there is no need for any treatment other than basic segregation, sorting and compaction to make it suitable for its intended disposal route.

high-level or heat-generating waste radioactive waste that is sufficiently radioactive that the decay heat significantly increases its temperature and the temperature of its surroundings. Typical characteristics of high-level waste are thermal power above about 2 kW/m^3. The radioactive liquid containing most of the fission products and actinides present in spent fuel – which forms the residue from the first solvent extraction cycle in reprocessing – and some of the associated waste streams; this material following solidification; spent fuel (if it is declared a waste); or any other waste with similar radiological characteristics.[27]

HLW high-level or heat-generating waste.

HSE the Health and Safety Executive.

IAEA International Atomic Energy Agency.

ILW see 'intermediate level waste'.

intermediate-level waste wastes with radioactivity levels exceeding the upper boundaries for low-level wastes, but which do not require heating to be taken into account in the design of storage or disposal facilities. IAEA guidance is that ILW thermal power is below about 2 kW/m^3.

integrated waste strategy An IWS is an overview of the approach to the current and future management of all wastes generated on or received by sites. It should integrate and optimise all waste-related activities on a site ranging from operational activities through to decommissioning activities and wastes arising from contaminated land management. This includes demonstration that the waste can be appropriately managed at the time and rate at which it will arise.

IWS integrated waste strategy.

licensed nuclear site a site for which a licence had been granted under the Nuclear Installations Act 1965 (as amended).

LLW low-level waste.

low-level waste radioactive waste having a radioactive content not exceeding four gigabecquerels per tonne (GBq/te) of alpha or 12 GBq/te of beta/gamma activity.[21]

minimisation the process of reducing the amount and activity of radioactive waste to a level as low as reasonably achievable, at all stages from the design of a facility or activity to decommissioning, by reducing waste generation and by means such as recycling and reuse, and treatment, with due consideration for secondary as well as primary waste.[27] Minimisation of waste is fundamental good practice in radioactive waste management. It should be considered during the design of facilities and applied during all of the basic steps. Effective methods of minimising the accumulation of radioactive waste include the clearance of waste that is exempt from regulatory control and the reuse or recycling of radioactive material.

NDA Nuclear Decommissioning Authority.

NDA(RWMD) the Radioactive Waste Management Directorate of NDA.

Nuclear Decommissioning Authority a non-departmental public body set up, under the Energy Act 2004, by the Government in 2005 with a vision to ensure the safe, accelerated and affordable clean up of the UK's civil nuclear legacy.

optimisation the process by which the management option is selected, and the practices applied, that best meet the full range of relevant health, safety, environmental, and security (including safeguards) principles and criteria taking into account all relevant (eg social and economic) factors. Different regulatory regimes use different terminology and have their own guidance on this topic, ie reducing

risks as low as reasonably practicable (ALARP),[28–32] best practicable environmental option (BPEO),[18] use of best practicable means (BPM)[20] and use of best available techniques (BAT). (In draft statutory guidance[14] the Environment Agency is required to ensure that BAT are applied in place of the current techniques of best practicable means (BPM) and best practicable environmental option (BPEO). It also states that operators who currently meet the requirements of BPM and BPEO will satisfy the current requirements of BAT.) However, all of the above involve the same process, ie making a judgement between options by comparing benefits in terms of safety, environmental protection etc and costs in terms of time, effort or money.

passive safety providing and maintaining a safety function by minimising the need for active safety systems, monitoring or prompt human intervention.

radioactive waste management all administrative and operational activities involved in the handling, pre-treatment, treatment, conditioning, transport, storage and disposal of radioactive waste.[27] For the purposes of this guidance only, radioactive waste management does not include its disposal.
radioactive waste management case comprises document(s) that demonstrate the longer-term safety and environmental performance of the planned management of specific wastes from their generation to their conditioning into the form in which they will be suitable for storage and (in England and Wales) eventual disposal. It should provide a complete picture of the management of waste streams that cannot necessarily be seen from examination of the individual plant safety cases.
RWMC radioactive waste management case.

SAPs Safety Assessment Principles.
segregation an activity where types of waste or material (radioactive or exempt) are separated or are kept separate on the basis of radiological, chemical and/or physical properties, to facilitate waste handling and/or processing.[27]
SEPA the Scottish Environment Protection Agency
storage the holding of radioactive sources, spent fuel or radioactive waste in a facility that provides for their/its containment, with the intention of retrieval.[27] Storage of radioactive waste may take place at any stage in the radioactive waste management process and aims to isolate the radioactive waste help protect the environment and make it easier to control its disposal. Storage may be used to make the next step in the management process more straightforward, or to act as a buffer between or within steps. Waste might be stored for many years before it undergoes further processing and disposal. Some storage facilities are located with a nuclear power plant or a licensed disposal facility, others are separate facilities.

treatment operations intended to benefit safety and/or economy by changing the characteristics of the waste. Three basic treatment objectives are:

- volume reduction;
- removal of radionuclides from the waste; and
- change of composition.[27]

Typical treatment operations include incineration or compaction of dry solid waste or organic liquid wastes (volume reduction), filtration or ion exchange of liquid waste (radionuclide removal) and precipitation or flocculation of chemical species (change of composition).

very low-level waste a sub-category of LLW.
VLLW very low-level waste:

- In the case of low volumes (‘dustbin disposal’), this is categorised as low-volume VLLW:Radioactive waste which can be safely disposed of to an unspecified destination with municipal, commercial or industrial waste (‘dustbin disposal’), each 0.1 m^3 of waste containing less than 400 kilobecquerels (kBq) of total

activity or single items containing less than 40 kBq of total activity. For wastes containing carbon-14 or hydrogen-3 (tritium):
  - in each 0.1 m^3, the activity limit is 4000 kBq for carbon-14 and hydrogen-3 (tritium) taken together; and
  - for any single item, the activity limit is 400 kBq for carbon-14 and hydrogen-3 (tritium) taken together.
- Controls on disposal of this material, after removal from the premises where the wastes arose, are not necessary.
- Bulk disposals are categorised as high-volume VLLW: Radioactive waste with maximum concentrations of 4 Megabecquerels per tonne (MBq/te) of total activity which can be disposed of to specified landfill sites. For waste containing hydrogen-3 (tritium), the concentration limit for tritium is 40 MBq/te. Controls on disposal of this material, after removal from the premises where the wastes arose, will be necessary in a manner specified by the environmental regulators.[21]

waste container the vessel into which the waste form is placed for handling, transport, storage and/or eventual disposal; also the outer barrier protecting the waste from external intrusions. The waste container is a component of the waste package.
waste form waste in its physical and chemical form after treatment and/or conditioning (resulting in a solid product) prior to packaging. The waste form is a component of the waste package.[27]
waste generation occurs during the operation and decommissioning of nuclear facilities. Waste generation can give rise to solid, liquid and/or gaseous wastes.
waste management hierarchy (waste hierarchy) the waste management hierarchy[20] encourages the adoption of options for managing waste in the following order of priority: avoid; prepare for reuse; recycle; other recovery (eg energy recovery); dispose.
waste package the product of conditioning that includes the waste form and any container(s) and internal barriers (eg absorbing materials and liner), as prepared in accordance with requirements for handling, transport, storage and/ or disposal.[27]

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