Nuclear Decommissioning Authority

Radioactive Waste Management Directorate

Packaging Options for Sellafield SIXEP Sand, Clino and Sludge

(Conceptual stage)

Summary of Assessment Report

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Introduction

Sellafield Ltd has sought Conceptual stage endorsement of options proposed for packaging sand, clinoptilolite and sludge waste from the Site Ion Exchange Effluent Plant (SIXEP) at Sellafield.

This Assessment Report summarises the conclusions of the assessment by NDA Radioactive Waste Management Directorate (hereafter RWMD) of the Conceptual stage submission for SIXEP sand, clino and sludge waste. The assessment has been carried out as part of the Letter of Compliance process, whereby RWMD examines the disposability of the proposed waste packages by assessment against ILW packaging standards and specifications and the Geological Disposal concept. Further information on the Letter of Compliance process is available elsewhere[1].

Background

The SIXEP plant has operated since 1985, reducing radionuclide discharges from the Sellafield site to the Irish Sea. Radioactivity is captured using a sand bed filter to capture sludge solids, and an inorganic ion exchange media (Clinoptilolite, or 'clino' - a naturally occurring zeolite from Mud Hills in the USA) to remove radioactive caesium and strontium from solution.

The particulate solids removed by the sand bed filter are periodically back-washed from the sand bed into a Bulk Storage Tank (BST) and allowed to settle. The supernatant is transferred back into the SIXEP feed and the settled solids stored in the BST. Sludges arising from legacy and current Magnox fuel storage ponds have also been transferred to SIXEP for storage. The clino bed removes predominately caesium and strontium, but also traces of other elements. Every few months, the clino requires changing for fresh material and the used clino is transferred to a storage tank. Spent clino is stored in BSTs and the Medium Active Solid Waste Export Plant (MASWEP) storage vessels.

The SIXEP sludge waste stream is a major waste stream for the Sellafield site, containing large quantities of fission products and alpha-emitters. The SIXEP sand and clino waste stream is also a major waste stream, for example containing up to 20% of the caesium inventory for deep disposal of ILW. The waste addressed by these proposals comprises 700m^3 of stored sludge (with 450m^3 future arisings) and 700m^3 of sand and clino mixture (with 1800m^3 future arisings).

[1] *Guide to the Nirex Letter of Compliance Process*, Nirex Document WPS/650, June 2006.

In 2000, the Nuclear Installations Inspectorate issued Licence Instrument 326(a) which specifies that “at least 80% of the total volume of all Intermediate Level Waste sludges originating from operations prior to 1st August 2000 and which have been accumulated as radioactive waste shall be stored in a safe passive form by 1st August 2020". Note that the “sludge” referred to in the Licence Instrument also includes sand and clino waste. The current SIXEP Wastes Process (SWP) project target is to treat 100% of the material stored in BST’s prior to 1/8/2000 within a three year period from ~2017, when the packaging plant(s) are planned to become fully operational.

Scope of the proposals

Sellafield Ltd has several options for the processing of the wastes. The Lifetime Plan baseline envisages the hydraulic transfer of waste from SIXEP, resulting in dilute slurry. This slurry would be concentrated in the Solids-Liquid Separation process and solidified in a waste immobilisation process. It is proposed that the two waste types (sand & clino and sludge streams) would be treated separately. The immobilisation processes have not been chosen at this stage, and could utilise new or existing packaging plant.

Sellafield Ltd has requested RWMD to assess three basic immobilisation media:

- cement grout

  Cement grout is used extensively within the nuclear industry for the immobilisation of sludges.

- geopolymer

  Geopolymers are made by adding aluminosilicates to concentrated alkali solutions and heating up to 80°C for polymerisation. In theory, this allows products to exhibit the most ideal properties of rock-forming elements, i.e. hardness, chemical stability and longevity.

- high temperature treatment process for vitrification/ceramification

  Waste would be mixed with glass or ceramic- forming components at elevated temperatures, which on cooling, would form a solid monolith showing properties typical of glass or relevant ceramic materials.

For the cement grout and geopolymer options, a number of potential variants based on different mixing and infiltration processes are presented. A ‘puck and grout’ option with wastes compacted to form ‘pucks’ is also identified.

Sellafield Ltd has not decided upon the container type to use, but has proposed the following options:

- 500-litre Drum;
- corner lifting $3m^3$ Box, with single or double skin as required;
- corner lifting $3m^3$ Box modified for in-drum mixing;
- a 1.7 m^3 liner, filled and placed in a $3m^3$ Box.

The volume of waste is expected to give rise to between 500 and 2000 packages of waste (based on the use of $3m^3$ Boxes), depending on the wasteform conditioning option chosen. The radionuclide inventory of the waste is consistent with packaging and disposal as ILW.

The assessment has considered the compatibility of the proposed packages containing SIXEP sand, clino and sludge with the requirements for safe long-term management, including storage, transport, emplacement underground, and disposal.

This report represents RWMD advice as to the disposability of the proposed waste packages based upon the standards and specifications developed from the Geological Disposal concept. In producing the Assessment of Disposability, due consideration has been given to safety and environmental protection requirements for transport, handling and disposal of the waste. RWMD expects the assessment of disposability to contribute to the licensee's Radioactive Waste Management Case as required by regulatory guidance, and specifically to the reasoned judgement that the conditioned waste will meet the anticipated requirements for acceptance from the potential disposal site operator.

Technical Evaluation

Even though this assessment is based on comparatively good quality data for legacy wastes obtained through the sampling and analysis of BSTs in the 1990's, there are a number of limitations and uncertainties.

To enable endorsement of a geopolymer product at the Conceptual stage, evidence to support its viability is required. Sellafield Ltd are requested to provide some demonstration that a geopolymer can be produced, and that it has the capability to produce a solid product with SIXEP waste materials, which has a good chance of meeting RWMD disposal criteria through subsequent development work.

Attempts to pressure infiltrate a particulate waste with cement grout have failed historically (e.g. pressure infiltration of a simulated AW500 zeolite skip), due to solid/liquid phase separation of the grout. To enable endorsement of a pressure infilled product at the Conceptual stage, evidence to support the viability of this approach is required. Sellafield Ltd are requested to provide some demonstration that SIXEP wastes can be pressure infilled, and that the approach has the capability to produce a solid product which has a good chance of meeting RWMD disposal criteria through subsequent development work.

Conditioning options utilising cement grout, compact and grout, and high temperature processes are relatively more mature and experience of implementation in waste treatment applications is available.

Assessment of Disposability

The acceptability of the proposed packages (conservatively based on the use of a Sellafield $3m^3$ single skin ILW Product Container) has been assessed against criteria established for the Geological Disposal concept and associated GWPS.

The Assessment of Disposability is based upon a set of radionuclide inventories derived by RWMD using a series of assumptions of waste composition. Sellafield Ltd will be required to confirm that these derived inventories are suitably representative of the SIXEP wastes.

Transport Safety

The assessments of transport safety show that it should be possible for packages containing SIXEP wastes to comply with all relevant criteria if transported in an IAEA Type B transport container with 285 mm thick steel walls, such as the Standard Waste Transport Container (SWTC-285). The most significant issue is the requirement to produce a package-specific criticality safety assessment for SIXEP sludge to demonstrate that the proposed package loadings would be acceptable.

With respect to the fissile material limits, the preliminary conclusion is that the proposed packages containing sand and clino could be considered to be fissile excepted, since there is less than 5g of fissile material in any ten litres of wasteform. For the sludge wastes, it was found that the maximum inventory cemented sludge case for a $3m^3$ box was not compliant with the transport Design Safety Report (DSR). Considering that the sludge waste is based on irradiated natural uranium, it has been judged that such an assessment could be produced and this should be provided at the Interim stage.

Operational Safety

The performance of waste packages under accident conditions is quantified as a set of Release Fractions (RF) that express the fraction of a package radionuclide inventory that could be released. The expected RF values for the packages containing SIXEP wastes have been evaluated through a comparison with existing data for generic and analogous waste packages to quantify the expected releases. For most waste streams, the analysis confirms that even under the most severe accident conditions affecting packages, doses to workers and the public would not approach significant levels.

Post-Closure Safety

Overall, the post-closure safety assessment has revealed no significant areas of concern that should prejudice disposal of packages containing SIXEP wastes. However, in the case of a vitrified wasteform, the impact of the potential reaction of the silica content of the glass with the cementitious backfill material and the resulting effect on pH buffering provided by the backfill must be considered. The assessment has concluded that the SIXEP wastes themselves do not raise any specific issues but the form of conditioned product might do. In the case of glass and possibly ceramic wasteforms the pH buffering can be negatively impacted by the chemical interactions between wasteform and cementitious backfill. As a result it will not currently be possible to endorse packaging of SIXEP wastes using these wasteform production processes. There are a number of options which could be considered by RWMD to progress vitrification packaging options, for instance disposal options with revised designs of disposal vault. It is recommended that Sellafield Ltd liaises closely with RWMD and the regulatory bodies during process de-selection work for SWP. Wasteforms making use of cementation or 'puck and grout' do not raise the same issues and are expected to be compatible with the post-closure safety assessment.

The sludge waste stream contains large amounts of fissile material, albeit as irradiated natural uranium of low enrichment. The existing generic criticality safety assessment for irradiated natural uranium is expected to cover packages of cemented sand and clino. However, a package-specific criticality safety case would need to be undertaken if the cementitious wasteform is chosen for SIXEP sludge.

The existing generic criticality safety assessment is only relevant to the cementitious waste forms. If Sellafield Ltd proceeds with vitrification/ceramification technology for packaging sand and clino or sludge, a package-specific criticality safety case will be required.

In summary, the Assessment of Disposability has concluded that a Radioactive Waste Management Case ultimately could be made for packages containing SIXEP wastes. The vitrified wasteform is expected to exhibit a number of advantages over the alternatives considered (e.g. volume reduction, destruction of organic species), however further work is required to demonstrate compatibility with the current geological disposal concept. Therefore at this stage the Radioactive Waste Management Case would needs to be based on the cementitious and/or 'puck and grout' conditioning options.

Requirements for further development work

The Conceptual stage submission, and the resulting assessment by RWMD, has been based upon a number of outline proposals for the packaging of SIXEP wastes.

At the Conceptual stage, further work is required to support proposals for vitrified/ceramic, geopolymer and pressure infilled wasteforms. If geopolymers are to be pursued, Sellafield Ltd need to demonstrate that a geopolymer can be produced, and that it has the capability to produce a solid product with SIXEP waste materials and which has a good chance of meeting disposal criteria through subsequent development work. If pressure infilling is to be pursued, Sellafield Ltd need to demonstrate that there is potential for a successful infilling process.

If vitrified/ceramic products are to be pursued, RWMD will need to address the potential conservatism in the simple models used to determine repository backfilling requirements or alternative options such as new disposal vault design to suit this type of wasteform.

At the Interim stage RWMD would expect to see the details of packaging proposals, whichever option or options are selected, developed and substantiated through the provision of evidence in the following general areas:

- a strategy for derivation and justification of assessment inventories applicable to future stages of assessment and the timing of future waste sampling from the current waste storage locations, taking account of the uncertainties and the potential consequences for waste package, in particular the chloride inventory of the sand and clino;
- selection of the wasteform(s) and development of an appropriate wasteform formulation and demonstration that the proposed formulation is robust to potential variations in the waste and process;
- selection of the waste container(s), and confirmation of details of the container and container design, including internal fittings and furniture and sacrificial containers if required;
- development of appropriate data recording proposals, including provision of a data recording methodology describing the packaging process and how data will be obtained and recorded;
- development of the draft Waste Product Specification(s);
- development of criticality safety assessments or arguments to show compatibility with the generic criticality safety assessment for Irradiated Natural Uranium or the criticality safety assessment for SDP packages, and development of Criticality Compliance Assurance Documentation.

Conclusions

The Conceptual stage packaging options proposed for SIXEP sand, clinoptilolite and sludge waste by the SWP project have been assessed.

It has been concluded that the following wasteform options can be endorsed at the Conceptual stage:

- a cementation process;
- a puck and grout process.

It has not been possible to endorse a geopolymer wasteform at this stage. Even though such a product(s) may in theory have some advantages over the other wasteform options, there is no definition of the type of geopolymer system to be developed or existing wasteform analogue or evidence to give confidence that such a system has potential to meet disposal requirements. The option of pressure infilling has not been endorsed at this stage, mainly due to concern from previous studies suggesting that such a process will not succeed using a cement grout as the infilling medium. A number of Action Points have been raised which will require to be addressed to allow further consideration for endorsement of geopolymer or pressure infilled wasteform options.

The vitrified/ceramic wasteform is expected to be robust and to provide advantages in terms of volume reduction. The disposal of these packages however has the potential to impact on the pH of the near-field in the current disposal concept and it may be necessary to consider alternative vault designs and backfill for such packages. Should it become necessary to modify the disposal system to accommodate vitrified/ceramic products, RWMD will need to undertake the necessary development work.

It has been concluded that standard waste container options which meet the requirements for disposal, as specified in the Generic Waste Package Specification, can be endorsed at the Conceptual stage. From the information provided in the submissions, these are to be based on the 500-litre drum and corner lifting $3m^3$ Box standards. It has been assumed that container internal fittings will be provided to suit the waste packaging process, and details of their design will be assessed at the Interim stage Letter of Compliance submission.

Endorsement of the Conceptual stage proposals will be based on the data provided by the submission, and it has been assumed that future arisings of waste will be consistent with the origins and content of current stocks of sand, clino and sludge. Sellafield Ltd are requested to work with RWMD to agree an appropriate strategy for derivation and justification of assessment inventories applicable to future stages of assessment and the timing of future waste sampling, taking account of the uncertainties and the potential consequences for waste package design.

A number of Action Points have also been raised which will require to be addressed as part of any Interim stage Letter of Compliance proposals for a selected packaging option(s).

The proposals to package SIXEP sand, clino and sludge have been judged against the regulatory guidance[2] and the view of RWMD is that they be considered as HIGH priority for regulatory scrutiny. The principal reasons for this judgement are the potential novelty of some wasteform options and the significant radionuclide inventory. Sellafield Ltd is advised to seek the necessary interaction with regulators to confirm this position.

[2] *The Management of Radioactive Waste on Nuclear Licensed Sites – Part 1: The Regulatory Process*, Guidance from the Health and Safety Executive, the Environment Agency and the Scottish Environment Protection Agency to nuclear licensees, December 2007.