Radioactive Waste Management

WPS/926/02

Geological Disposal:

Guidance on the use of polycarboxylate ether superplasticisers for the packaging of low heat generating wastes

October 2019

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Waste Package Specification And Guidance Documentation

Guidance on the use of polycarboxylate ether superplasticisers for the packaging of low heat generating wastes

This document forms part of the Waste Package Specification and Guidance Documentation (WPSGD), a suite of documents prepared and issued by Radioactive Waste Management Ltd (RWM). The WPSGD is intended to provide a 'user-level' interpretation of the RWM packaging specifications, and other aspects of geological disposal, to assist UK waste packagers in the development of plans for the packaging of higher activity waste in a manner suitable for geological disposal.

Key documents in the WPSGD are the Waste Package Specifications (WPS) which define the requirements for the transport and geological disposal of waste packages manufactured using standardised designs of waste container. The WPS are based on the high level requirements for all waste packages as defined by the Generic Waste Package Specification (GWPS) and are derived from the bounding requirements for waste packages containing a specific category of waste, as defined by the relevant Generic Specification.

This document provides guidance on the use of polycarboxylate ether superplasticisers for the packaging of low heat generating wastes, in such a form as to render them suitable for geological disposal.

The WPSGD is subject to periodic enhancement and revision. Users should refer to RWM website to confirm that they are in possession of the latest version of any documentation used.

WPSGD Document Number WPS/926 – Version History		
Version	**Date**	**Comments**
WPS/926/01	March 2017	Based on 2010 DSSC and NDA Report No. NDA/RWMD/068.
WPS/926/02	September 2019	Amended to reflect updated position on the use of PCE superplasticiser based on new R&D.

List of Contents

Abbreviations and acronyms used in this document

CSH	Calcium silicate hydrate
DSSC	Disposal System Safety Case
EBS	Engineered barrier system
GDF	Geological disposal facility
GGBS	Ground granulated blast-furnace slag
GWPS	Generic Waste Package Specification
ILW	Intermediate level waste
LHGW	Low heat generating wastes
LoC	Letter of Compliance
NDA	Nuclear Decommissioning Authority
OPC	Ordinary portland cement
PCE	Polycarboxylate ether
PFA	Pulverised Fly Ash
RWM	Radioactive Waste Management Limited
WPS	Waste Package Specification
WPSGD	Waste Package Specification and Guidance Documentation

1. Introduction

The Nuclear Decommissioning Authority (NDA), through Radioactive Waste Management Ltd (RWM), is responsible for implementing UK Government policy for long-term management of higher activity radioactive wastes, as set out in *Implementing Geological Disposal - Working with Communities* [1], in England and *Geological Disposal of Higher Activity Radioactive Waste: Working with Communities* [2], in Wales. These policy documents outline a framework for managing higher activity radioactive waste in the long term through geological disposal, which will be implemented alongside the ongoing interim storage of waste packages and supporting research.

RWM produce packaging specifications as a means of providing a baseline against which the suitability of plans to package higher activity waste for geological disposal can be assessed. In this way RWM assist the holders of radioactive waste in the development and implementation of such plans, by defining the requirements for waste packages which would be compatible with the anticipated needs for transport to and disposal in a geological disposal facility (GDF).

The packaging specifications form a hierarchy which comprises three levels:

— *The Generic Waste Package Specification* (GWPS) [3]; which defines the requirements for all waste packages which are destined for geological disposal;

— *Generic Specifications;* which apply the high-level packaging requirements defined by the GWPS to waste packages containing a specific type of waste; and

— *Waste Package Specifications* (WPS); which apply the general requirements defined by a Generic Specification to waste packages manufactured using standardised designs of waste container.

The WPS, together with a wide range of explanatory material and guidance that users will find helpful in the development of proposals to package waste, make up a suite of documentation known as the *Waste Package Specification and Guidance Documentation* (WPSGD). For further information on the extent and the role of the WPSGD, all of which can be accessed via the RWM website, reference should be made to the *Introduction to the RWM Waste Package Specification and Guidance Documentation* [4].

This guidance has been produced to provide advice on the use of superplasticisers for the packaging of low heat generating wastes (LHGW), in order to assist waste packagers in the development of packaging strategies. Its principal aims are to inform waste packagers of RWM's position on the use of superplasticisers, discuss the superplasticisers that can be accepted for use by waste packagers and discuss the controls on the use of these superplasticisers.

The remainder of this document is structured in the following manner:

- Section 2 provides background information on the manner in which RWM defines the requirements for waste packages, and the role that packaging specifications play in assessing the suitability of proposed waste packages for geological disposal.
- Section 3 describes the technical evidence underpinning of the use of polycarboxylate ether superplasticisers in the packaging of LHGW. This section presents the experimental research that has been undertaken to investigate the potential impact of superplasticisers on the mobility of radionuclides in a post-closure GDF environment.
- Section 4 presents RWM's position on, and the safety arguments for, the use of polycarboxylate ether superplasticisers in the packaging of LHGW.

2. Background

2.1 The concept of geological disposal

Whilst the precise manner in which geological disposal would be implemented in the UK is not yet defined, RWM envisages that any approach to long-term management of waste (including disposal) would comprise a number of distinct stages which could include:

— the manufacture of passively safe and disposable waste packages;

— a period of interim surface storage, usually at the site of waste arising or packaging;

— transport of the waste packages to a GDF;

— transfer of waste packages underground and emplacement in the disposal facility;

— back-filling of the disposal areas; and

— eventual sealing and closure of the facility.

The exact nature, timing and duration of each stage would depend on a number of criteria, including the geographical location and host geology of a GDF, as well as the disposal concept selected for implementation for each distinct category of waste.

2.2 The role of the waste package in geological disposal

The waste package provides the most immediate barrier to the release of radionuclides and other hazardous materials from the waste it contains both during interim storage, transport and when it forms part of a multiple barrier geological disposal system. It can also play a role in protecting individuals from the radiation emitted by the radionuclides it contains during interim storage, transport and the GDF operational period.

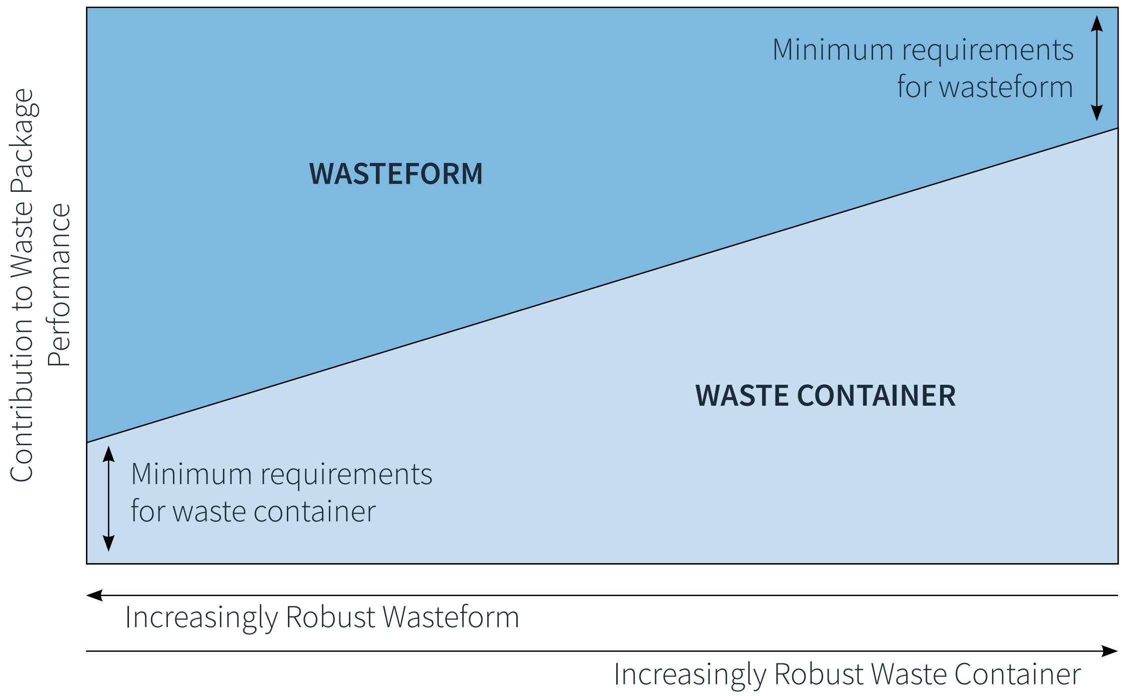
The barrier provided by a waste package can be considered to comprise two components, each of which can act as a barrier in its own right as part of an overall engineered barrier system (EBS):

- The waste container, which provides a physical barrier and also enables the waste to be handled safely during and following waste package manufacture. Containers can be manufactured from a range of materials with designs selected to suit the requirements for the packaging, transport and disposal of the wastes they contain.
- The wasteform, which can be designed to provide a significant degree of physical and/or chemical containment of the radionuclides and other hazardous materials associated with the waste. The wasteform may comprise waste which has been 'immobilised' (e.g. by the use of an encapsulating medium such as cement) or that which may have received more limited pre-treatment prior to packaging (e.g. size reduction and/or drying).

It is the performance of the barrier(s) provided by the waste package that packaging specifications seek to address, by defining requirements for waste packages which have been derived from the needs relating to their long-term management.

Both the waste container and the wasteform can contribute to the achievement of the required performance of a waste package, the relative importance of each generally depending on the robustness of the former. This is illustrated in Figure 1 which shows in stylised form how the use of a more robust waste container can reduce the required contribution of the wasteform to overall waste package performance. Figure 1 also shows that for all waste packages both the waste container and the wasteform will be required to play some role. It should also be noted that it is the overall performance of the waste package, rather than that of its two components, that is the governing factor in judging its disposability.

Figure 1: Relative contribution of the waste container and the wasteform to waste package performance



2.3 The assessment of packaging proposals

RWM has established the Letter of Compliance (LoC) Disposability Assessment process [5] to support waste producers in the development of plans to package higher activity wastes. Specifically, the Disposability Assessment process is used by RWM to demonstrate that proposals to package waste would, if implemented, result in 'disposable' waste packages. In this context a disposable waste package is one that is compliant with all of the relevant regulations and safety cases for transport to and disposal in a GDF, and in line with regulatory expectations for the long term management of the waste [6].

The Disposability Assessment process also plays an important role in underpinning the generic *Disposal System Safety Case* (DSSC) [7] by providing confidence that the safety cases for the transport and disposal of waste, which are based on generic assumptions regarding the wastes that are anticipated to be accommodated by a GDF, are compatible with the 'real' waste packages that are being manufactured. The performance of disposability assessments also helps us to show that the disposal concepts considered within the generic DSSC will be appropriate for the wastes they will be expected to cover, as well as identifying wastes that could challenge current disposal concepts and allow early consideration of what changes may be required to these concepts to permit these wastes to be accommodated.

Guidance is available on the manner by which waste packagers should prepare submissions for the disposability assessment of packaging proposals [8].

3. Underpinning the use of polycarboxylate ether superplasticisers

3.1 Introduction

Superplasticisers belong to a group of cement additives known as High Range Water Reducers. These high molecular weight, water miscible organic polymers have been used as chemical admixtures in the production of concretes and mortars in the civil construction industry for the last four decades [9]. They are used as dispersants to prevent premature particle agglomeration in cementitious mixtures. The addition of superplasticisers to these mixtures allows for a reduction of the water to cement ratio, increasing the early strength of the concrete whilst improving the flow characteristics (rheology) of the mixture.

The use of superplasticisers in cementitious mixtures has been identified as a key enabler by waste packagers for the packaging of LHGW, due to the operational advantages identified above (e.g. reduced water content and increased fluidity in cementitious mixtures), which results in an extension of the working time of the mixtures and potentially advantageous wasteform properties such as greater waste infiltration. Additionally, the reduced water content in a grout mixture could aid in reducing the potential for bleed water formation during wasteform setting. This would reduce the need for treatment of effluents as secondary wastes.

Specifically, waste producers may wish to use superplasticisers for addition to:

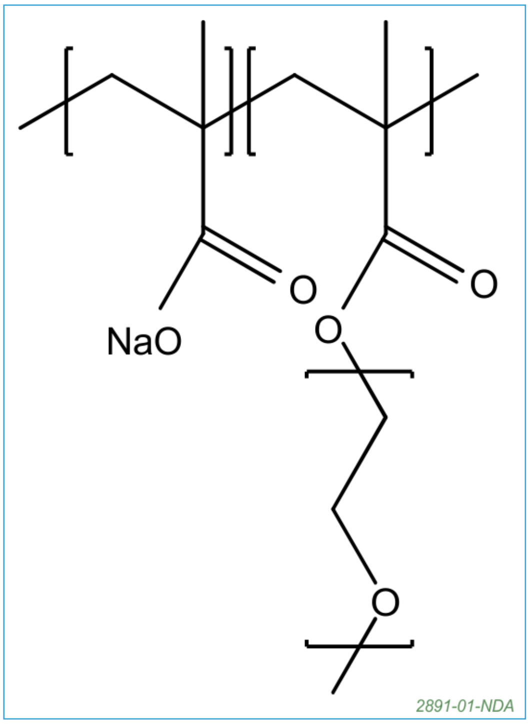
— grout mixtures used for the encapsulation of wastes; and

— concrete mixtures used in the manufacture of waste packages (e.g. concrete containers and cement-based bunds).

3.2 Polycarboxylate ether superplasticisers

Several chemical classes of superplasticisers have been developed over the decades. The main class of superplasticisers currently available to the civil construction industry are polycarboxylate ethers (PCE), also known as comb polymers due to the polyethylene oxide graft side chains which are perpendicular to the backbone (forming the teeth of the comb). These polymer structures typically have molecular weights in the tens of thousands. A general PCE superplasticiser chemical structure is provided in Figure 2.

Figure 2: General chemical structure of a PCE superplasticiser



The mode of action of PCE superplasticisers is to act as dispersants where rheology enhancement is achieved by both electrostatic repulsion and steric hindrance effects between cement particles as the superplasticiser is adsorbed onto the surface of the cement particles. These effects prevent premature agglomeration of the cement particles leading to a rapid dispersion of the individual cement particles and improvements in both fluidity and subsequent hydration.

PCE is the main class of superplasticier currently considered by waste producers. The remainder of this guidance document applies only to the use of PCE type superplasticiers.

3.3 Experimental research into the behaviour of PCE superplasticisers

Despite the potential benefits of the use of PCE superplasticisers, research has demonstrated that the concentration of certain radionuclides in free aqueous solution can be increased by several orders of magnitude in the presence of PCE superplasticisers. The presence of a typical PCE superplasticiser (at 1% concentration) has been shown to increase the concentration of uranium and plutonium in sodium hydroxide and calcium hydroxide solutions by up to four orders of magnitude [10]. Similar results have been observed for americium and thorium in the presence of the same superplasticiser at lower concentrations of 0.1% and 0.01% [11]. This increase is attributed to the formation of complexes between PCE superplasticisers and radionuclides, resulting in increased solubility of the radionuclides in solution.

A potential implication of the observed increase in radionuclide solubility in free aqueous solution was that this behaviour could also result in increased mobility of radionuclides post GDF closure. Consequently, RWM identified that further work was required to improve understanding of the impact of PCE superplasticisers on the mobility of radionuclides in a GDF post-closure environment and to support any endorsement of their use in waste packaging. A number of subsequent research studies have been undertaken (see [12] for a summary of the results of these studies). These studies focussed on the release of radionuclides from cement materials. This was due to RWM acknowledging that the solubility increases observed in free aqueous solution was likely to represent a pessimistic view of the potential impact of PCE superplasticisers in a GDF post-closure environment. In hardened cement and concrete, PCE superplasticisers will be associated with the cured cementitious structures (e.g. grouted wasteforms, the concrete walls of waste containers). They would only become available to potentially increase the solubility of radionuclides, as demonstrated by the free solution trials conducted, once they begin to be released from cured cementitious structures into the surrounding cement porewater. Therefore arguments for the effects of PCE superplasticiser on post-closure radionuclide behaviour should not be made based on free solution solubility experiments alone. In addition, the concentrations of superplasticisers used in the free solution trials are not deemed representative of the concentrations which will be present within cementitious systems in a GDF post-closure environment (~0.5% superplasticiser by weight of dry cement powders would represent the expected typical concentration within a wasteform).

The results from one study, in which the grout samples incorporated a typical PCE superplasticiser at a concentration of 0.5% by weight of dry cement powders, showed negligible leaching for nickel, uranium(VI) and thorium [13]. NDA/ RWM subsequently undertook work to investigate the leaching of ^{63}Ni, ^{241}Am, ^{239}Pu and total U from grout samples containing a number of bespoke PCE superplasticiser mixtures [14]. This work also showed negligible leaching of radionuclides, suggesting that PCE superplasticisers may become associated with cementitious grouts and have limited availability to promote the mobility of radionuclides in a GDF post-closure environment. This suggested that the impact of PCE superplasticiser may not be as significant as initially thought.

Based on the research to date, RWM published Issue 1 of this guidance document in 2017 and concluded that the use of PCE superplasticiser in the production of selected waste packages (e.g. concrete boxes) did not present a significant risk to the post-closure safety of a GDF. This conclusion reflected the technical understanding that significant complexation of actinides would only occur when freely available actinide species were able to interact with the PCE superplasticiser during the liquid phase of cement preparation. The guidance therefore focussed on the control of the actinide content of the waste and the accessibility of the actinide content during the liquid/ curing stage.

Uncertainty remained on the impact of superplasticiser on the binding and incorporation of radionuclides into cement phases. This uncertainty was significant because increased radionuclide solubility, coupled with decreased uptake to cement phases could increase radionuclide mobility and therefore present a risk to post-closure safety. In addition, under post-closure GDF conditions, there is potential for the PCE superplasticiser to degrade. It is also important to understand the impact of any degradation products formed to assess the implications for radionuclide mobility as the engineered barriers evolve with time.

To address these remaining uncertainties, RWM commissioned an experimental programme to:

— investigate whether the presence of PCE superplasticiser impacts on the uptake of plutonium onto cement phases and the magnitude of any effects on plutonium concentration in solution,

— investigate whether PCE superplasticiser and plutonium are leached from cement phases over long timescales and whether the rate of plutonium leaching is affected by the presence of PCE superplasticiser,

— investigate PCE degradation under GDF-relevant conditions and the effect of degradation products on the solubility of plutonium and it's uptake onto cement phases.

Plutonium was selected for the study because as well as being a key actinide of importance in the post-closure safety assessment, it has a low solubility under alkaline conditions and its concentration in solution is particularly sensitive to the effect of complexants. The full experimental programme is reported in a recently published report [15]. Key findings are:

— Uptake of PCE superplasticiser to cement surfaces is strong and re-mobilisation is limited.

— Consistent with previous observations, PCE superplasticiser is capable of increasing the concentration of plutonium in cement equilibrated water over several orders of magnitude. However, plutonium uptake to cement materials is strong, with the PCE superplasticiser having little effect at 0.01 and 0.1% concentration. At 1% PCE concentration, the effect on plutonium uptake was slightly greater, with a reduction in uptake by approximately a factor of 5 (under 10kDa filtration).

— No measurable difference was observed in the release of plutonium from crushed samples of cementitious grout that were prepared with and without PCE superplasticiser. In addition, total organic carbon analysis, used to measure PCE release, did not show any detectable increase above background.

— PCE superplasticiser uptake to C-S-H gel with a Ca/Si ratio of 1.65 (representing 'fresh' C-S-H phases) was greater than uptake to C-S-H gel with a Ca/Si ratio of 0.83 (representing more aged and Ca2+ depleted C-S-H phases). However, the observed difference in PCE uptake did not make a significant difference to the uptake of Pu to both of the C-S-H gels.

— PCE superplasticiser remained unchanged under the alkaline and thermal degradation conditions considered. Gamma irradiation to a total dose of 200 kGy (a conservative but potential estimate of the total dose that could be received by the PCE within a waste package) produced an 80% drop in measured total organic carbon and a decrease in the average molecular weight. Degradation products could not be reliably identified by gel permeation chromatography, therefore an empirical approach was adopted to understand any effect of PCE superplasticiser degradation products on plutonium behaviour.

- Plutonium concentrations in a 1% irradiated PCE superplasticiser solution were comparable to that in fresh unirradiated 1% solutions. However, in ten and one hundred fold dilutions of the 1% irradiated solution, the plutonium solubility was significantly lower.
- The effect of irradiated PCE superplasticiser on the uptake of plutonium to cement materials was reduced compared to the (already small) effect of the fresh unirradiated superplasticiser.

4. RWM position on the use of PCE superplasticisers

4.1 Technical understanding of the impact of PCE superplasticisers

Using the results of the experimental research on PCE superplasticisers undertaken to date, the following evidence can be derived which supports the use of PCE superplasticisers:

- **Results of leaching studies:** The results from radionuclide leaching studies from intact cementitious grouts containing PCE superplasticisers suggest there is no measurable release of radionuclides over the timescales of the experiments [13,14]. Experiments where a plutonium-containing waste simulant was mixed with cement materials representative of a wasteform grout, cured and then crushed prior to leaching found no measurable difference in plutonium release from samples prepared with or without PCE superplasticiser. Concentration of PCE superplasticiser in leachates measured by total organic carbon showed no detectable release above background [15].
- **Mechanism of interaction of superplasticisers with cement matrices**: C-S-H will be subject to long-term evolution, eventually leaching from cementitious matrices (e.g. wasteforms) in a GDF environment over timescales of up to tens to hundreds of thousands of years. PCE superplasticiser uptake to calcium silicate hydrate (C-S-H) phases representative of both fresh C-S-H (Ca/Si ratio of 1.65) and older, Ca^{2+} depleted C-S-H (Ca/Si ratio of 0.83) has been demonstrated. Uptake of PCE superplasticiser was greater to C-S-H with a Ca/Si ratio of 1.65 than the C-S-H with a Ca/Si ratio of 0.83 [15]. This is consistent with a greater interaction of the negatively charged polymer with the Ca^{2+} ion rich C-S-H [16]. Whilst PCE superplasticiser uptake was stronger to C-S-H with a higher Ca/Si ratio, this was not observed to make a significant difference to the uptake of plutonium to the C-S-H gels, thus a step change in plutonium release as the cementitious materials evolve and the Ca/Si ratio of the C-S-H decreases is unlikely.
- **Interaction of radionuclides with PCE:** Whilst PCE superplasticiser has been shown to be capable of increasing the concentration of plutonium in high pH solution over several orders of magnitude, plutonium uptake to cement phases under the similar conditions remains relatively strong

(R_D values greater than 10^2 cm^3 g^{-1}). In addition, as stated above, in crushed grout leaching experiments, no measurable difference in plutonium release from samples prepared with or without PCE superplasticiser was observed. Total organic carbon analysis of PCE leached from crushed grout showed no detectable levels above background, although measurement of plutonium solubility in this leachate indicates some presence of PCE, with the plutonium concentration slightly higher (less than one order of magnitude) than baseline values [15].

— **Superplasticiser degradation:** Degradation of PCE superplasticiser under post-closure relevant conditions has demonstrated that PCE superplasticiser remained unchanged under the alkaline and thermal degradation conditions considered. Under gamma irradiation to a total dose of 200 kGy, a decrease in the average molecular weight and total organic carbon in solution was observed, consistent with radiation induced chain scission of the polymer chains. Plutonium solubility in a 1% irradiated PCE superplasticiser solution was comparable to that in fresh unirradiated 1% solutions. However, in ten and one hundred fold dilutions of the 1% irradiated solution, the plutonium solubility was significantly lower. In addition, there was less effect of irradiated PCE superplasticiser on plutonium uptake to cement materials compared to the (already small) effect of the unirradiated PCE superplasticiser.

— **Superplasticiser dosage:** Formulation trials by waste packagers have demonstrated that a low dosage of superplasticisers (i.e. 0.5% or less by weight of cement powders) is required to produce the plasticising effect, (i.e. improved rheology of the cementitious mixture). On the basis of a SP dosage of 0.5% of which the SP components and additives typically constitute ca. 25% of the mixture (with the remaining ca. 75% being water), this leads to a weight for weight ratio of 1.25 mg of SP component and additives for every 1 g of cement.

4.2 Arguments in support of packaging proposals

— For waste packages in which there are no freely available actinides or actinides are effectively absent, the use of PCE superplasticisers need not be restricted.

— Where PCE superplasticisers are incorporated into cementitious material without prior contact with actinides (e.g. pre-fabricated concrete containers), subsequent detrimental effects would be limited to the potential for low concentrations of PCE superplasticiser, or degradation products, to be released from the cement structure over long timescales and to become available in GDF pore-water. In practice, the experimental evidence indicates that such concentrations would not have a significant effect on post-closure safety.

— For waste packages in which freely available actinides would be expected to interact with the PCE superplasticiser during the liquid phase of cement preparation, experimental evidence suggests that whilst PCE superplasticiser has the ability to increase the concentration of radionuclides in high pH solution, a negative impact on the incorporation of radionuclides within the cement matrix is not anticipated. Limited leaching of plutonium from crushed wasteform grouts was observed with no significant difference between crushed grout prepared with or without PCE superplasticiser. PCE superplasticiser uptake to cementitious grout and specifically C-S-H phases of varying Ca/Si ratio is strong with experimental evidence suggesting that reversibility is limited. Although PCE superplasticiser uptake to the higher Ca/Si ratio C-S-H was greater, this was not observed to make a significant difference to the uptake of plutonium to both the C-S-H gels, thus a step change in plutonium release as the cementitious materials evolve and the Ca/Si ratio of the C-S-H decreases is unlikely.

— Degradation under GDF-relevant conditions has demonstrated that PCE superplasticiser is relatively stable to alkaline hydrolysis and thermal effects. PCE superplasticiser has been shown to undergo a decrease in molecular weight under irradiation. The degradation products have been shown to have either a comparable or lesser effect on both the solubility and uptake behaviour of plutonium to cement materials and are therefore not considered to pose any additional risk compared to the fresh polymer.

In conclusion, based on the arguments presented, RWM has concluded that the use of PCE superplasticisers in the packaging of low heat generating waste does not present a significant risk to the maintenance of post-closure safety for a GDF. In practice, the use of PCE superplasticiser in the production of waste packages would be subject to formal assessment and endorsement via the RWM Disposability Assessment Process. The endorsement of the use of any PCE superplasticiser would be subject to the provision of adequate information about the PCE superplasticiser. In order to undertake a disposability assessment, waste packagers would be asked to provide the following information:

— confirmation that the superplasticiser is a PCE type;

— the brand name of the PCE product;

— any associated Material Safety Data Sheets provided by the manufacturer for the product;

— the percentage breakdown of the product components, i.e. % PCE polymer, % of other additives (e.g. biocide, defoamer, etc.), % base carrier (e.g. water or solvent); and

— the dosage proposed to be used in the concrete or grout formulation (and the manufacturers recommended product dosage range).

Additionally, any information about the ability of the PCE polymer to complex with metals species or information on the degradation of the polymer under alkaline conditions and under radiolysis would aid the assessment of the proposals.

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Glossary of terms used in this document

agglomeration
A mass or collection of things.

barrier
A physical or chemical means of preventing or inhibiting the movement of radionuclides.

container
The vessel into which a wasteform is placed to form a waste package suitable for handling, transport, storage and disposal.

containment
The engineered barriers, including the waste form and packaging, shall be so designed, and a host geological formation shall so be selected, as to provide containment of the waste during the period when waste produces heat energy in amounts that could adversely affect the containment, and when radioactive decay has not yet significantly reduced the hazard posed by the waste

disposability
The ability of a waste package to satisfy the defined requirement for disposal.

disposability assessment
The process by which the disposability of proposed waste packages is assessed. The outcome of a disposability assessment may be a Letter of Compliance endorsing the disposability of the proposed waste packages.

disposal
In the context of solid waste, disposal is the emplacement of waste in a suitable facility without intent to retrieve it at a later date; retrieval may be possible but, if intended, the appropriate term is storage.

disposal facility (for solid radioactive waste)
An engineered facility for the disposal of solid radioactive wastes.

disposal system
All the aspects of the waste, the disposal facility and its surroundings that affect the radiological impact.

electrostatic repulsion
Refers to the force existing between two particles of the same charge that drive away each other.

geological disposal
A long term management option involving the emplacement of radioactive waste in an engineered underground geological disposal facility or repository, where the geology (rock structure) provides a barrier against the escape of radioactivity and there is no intention to retrieve the waste once the facility is closed.

geological disposal facility (GDF)
An engineered underground facility for the disposal of solid radioactive wastes.

higher activity radioactive waste
Generally used to include the following categories of radioactive waste: low level waste not suitable for near surface disposal, intermediate level waste and high level waste.

intermediate level waste (ILW)
Radioactive wastes exceeding the upper activity boundaries for LLW but which do not need heat to be taken into account in the design of storage or disposal facilities.

Letter of Compliance (LoC)
A document, prepared by RWM, that indicates to a waste packager that a proposed approach to the packaging of waste would result in waste packages that are compliant with the requirements defined by relevant packaging specifications, and the safety assessments for transport to and disposal in a GDF, and are therefore deemed 'disposable'.

Nuclear Decommissioning Authority (NDA)
The NDA is the implementing organisation, responsible for planning and delivering the GDF. The NDA was set up on 1 April 2005, under the Energy Act 2004. It is a non-departmental public body with designated responsibility for managing the liabilities at specific sites. These sites are operated under contract by site licensee companies (initially British Nuclear Group Sellafield Limited, Magnox Electric Limited, Springfields Fuels Limited and UK Atomic Energy Authority). The NDA has a statutory requirement under the Energy Act 2004, to publish and consult on its Strategy and Annual Plans, which have to be agreed by the Secretary of State (currently the Secretary of State for Trade and Industry) and Scottish Ministers.

post-closure period (of a disposal facility)
The period following sealing and closure of a facility and the removal of active institutional controls.

radioactive waste
Any material contaminated by or incorporating radioactivity above certain thresholds defined in legislation, and for which no further use is envisaged, is known as radioactive waste.

Radioactive Waste Management Limited (RWM)
A wholly owned subsidiary of the NDA, established to design and build an effective delivery organisation to implement a safe, sustainable and publicly acceptable geological disposal programme. Ultimately, RWM will evolve under the NDA into the organisation responsible for the delivery of the GDF. Ownership of this organisation can then be opened up to competition, in due course, in line with other NDA sites.

radioactivity
Atoms undergoing spontaneous random disintegration, usually accompanied by the emission of radiation.

radionuclide
A radioactive form of an element, for example carbon-14 or caesium-137.

rheology
Describes the flow and shape of matter, primarily in a liquid state.

safety case
A 'safety case' is the written documentation demonstrating that risks associated with a site, a plant, part of a plant or a plant modification are as low as reasonably practicable and that the relevant standards have been met. Safety cases for licensable activities at nuclear sites are required as license conditions under NIA65.

steric hindrance
The prevention or retardation of inter- or intramolecular chemical interactions as a result of the spatial structure of a molecule.

waste container
Any vessel used to contain a wasteform for disposal.

wasteform
The waste in the physical and chemical form in which it will be disposed of, including any conditioning media and container furniture (i.e. in-drum mixing devices, dewatering tubes etc) but not including the waste container itself or any added inactive capping material.

waste package
The product of conditioning that includes the wasteform and any container(s) and internal barriers (e.g. absorbing materials and liner), as prepared in accordance with requirements for handling, transport, storage and/or disposal.

waste packager
An organisation responsible for the packaging of radioactive waste in a form suitable for transport and disposal.

Certificate No LRQ 4008580

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