NATIONAL NUCLEAR LABORATORY

GAMECHANGERS
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Challenge: Alternative materials for encapsulation of nuclear waste in a net zero world

Cement is used extensively in the encapsulation of nuclear waste. The National Nuclear Laboratory (NNL) are seeking alternatives to cement-based solutions, with considerably reduced environmental impact more suitable for our net zero future.

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Introduction

Ordinary Portland Cement (OPC), pulverized flue ash (PFA) and blast furnace slag (GBFS, also known as GGBS) are used extensively for the encapsulation of a wide variety of low and intermediate level radioactive wastes. However lower alkalinity alternatives are being explored to reduce corrosion of encapsulated metals; these alternatives also offer environmental benefits due to their lower carbon footprint. Additionally, alternatives to PFA and GBFS (key components of the cement mix) are being sought as security of supply becomes an issue. PFA, for example, is a by-product from coal-fired power stations and UK production ceased in early 2021, whilst GBFS is a waste material from steel production, and is similarly under threat due to the reduction in steel production overall in the UK as well as changes to methods of production.

Current Portland cement-based systems require considerable energy to produce and release CO_2 in their production. In light of the UK Net Zero 2030 targets, there is a requirement to be even more ambitious, and seek game changing encapsulation solutions that are more fitting for a future Net Zero World.

More sustainable solutions presenting a lower environmental impact may include (but are not limited to):

- Novel materials and alternatives to Portland cement-based systems
- Materials or strategies already in use within other sectors that could be adapted for use in the nuclear sector
- Replacements to cement for encapsulation and/or replacement to current waste containers and/or removing the requirement for a waste container at all

Given the long term nature of nuclear decommissioning and waste management of existing and future nuclear programmes it is important that the solution is not reliant on secondary materials from another process or industry where security or longevity of supply may become an issue. However, reuse or recycling of materials may present an opportunity to considerably reduce environmental impact.

Current practice

The nuclear waste market in the UK is several thousand tonnes of waste per year. This is likely to increase as decommissioning of legacy power plants increases. An encapsulant material is required for both Low level Waste (LLW) and Intermediate Level Waste (ILW). These waste materials (from nuclear operations) might be liquids and solids, as well as sludge mixtures, ranging from paper and Personal Protective Equipment to metals from dismantled equipment, machinery, reactor parts or tools. At present, the waste is treated (e.g. through compaction, by being settled/dewatered or chemically modified) to make it suitable for encapsulation within a specified combination of OPC, PFA and GBBS and then transported to interim and longer-term storage facilities.

The nuclear industry pays a substantial premium for cement powders that meet its higher, bespoke specification powders over current construction standard powders, to ensure consistency in the encapsulation process and making sure waste packages meet high quality assurance standards for storage and transport. Alternative materials could therefore lead to cost savings, but equally may provide additional benefits that the nuclear industry is prepared to pay premium rates for.

The potential market for novel materials is likely to extend to the wider construction sector, who are seeking increasingly ‘greener’ cement materials. This challenge is not however limited to devising greener cement-based materials.

Challenge aims

The principle aim of this challenge is to identify materials which can be demonstrated to encapsulate nuclear waste and will be reliably available over the next 100 years and beyond, to support current nuclear decommissioning and future requirements.

The anticipated timescale for the introduction of new materials is 5-10 years.

An encapsulant is required for both Low level Waste (LLW) and Intermediate Level Waste (ILW) with the latter having a higher performance requirement. The wastes are liquids and solids, as well as sludge mixtures. A key requirement

of the encapsulant is to be compatible with a broad range of metals in the waste (notably steel, uranium, magnesium and aluminum) ensuring that corrosion rates are low and that metal containers are passivated.

The encapsulant needs to make a waste-form with intrinsic strength and dimensional stability, which evolves in a controlled, predictable manner. The waste package should be suitable for extended (~150 years) above ground interim storage and eventual placement in a future underground Geological Disposal Facility. UK regulations require a total lifetime of approximately 500 years. In addition, following closure of the Geological Disposal Facility (GDF) the encapsulant material needs to be compatible with the chemistry of the GDF backfill material (likely grout) and environment.

Technological solutions could initially be demonstrated with non-radioactive targets. The ability to characterise targets, including the precise measurement of the mass of the material deposited, is a key requirement.

Benefits to the challenge owner

- Increased sustainability of operations through reduced environmental impact
- Longer term security of supply of material for waste encapsulation
- Cost effective in terms of both process and performance
- Lower volume of encapsulated products (via materials which incorporate greater volumes of waste than the existing cement systems)
- Lower variability in material or performance (improved quality assurance)
- Fewer additives or other impurities
- Guaranteed performance over centuries – interim storage and final disposal

Constraints and functional requirements

A novel encapsulant material must have the following properties:

- Minimal bleed
- The materials used must be highly fluid such that they can easily penetrate around complex shaped waste
- Resistance to external heat sources; it is desirable that the encapsulation process itself should be undertaken at room temperature
- Compatible with the waste (to avoid the risk that the waste could prevent the encapsulant from setting or otherwise degrade it)
- Low residual water content (so as not to lead to corrosion of metals)
- Porosity: sufficiently gas permeable to allow gases to escape but sufficiently impermeable to stop water leaching in
- Compressive strength sufficient to ensure the package is robust and can be handled or transported and placed in stores and/or disposal sites

What next?

Game Changers are hosting an online briefing webinar for this challenge. Details of the webinar are available on the Game Changers website www.gamechangers.technology.

If you have new ideas or innovations which can be applied to address this challenge, we invite you to join us. If you'd like more information about the funding available through the Game Changers programme, please visit Our Funding Process (gamechangers.technology)

The deadline for applications for this challenge is **31st January 2022 at 12 noon.**

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Twitter @GC_Innovators
email: apply@gamechangers.technology