It has been shown that the HIP process can produce dense, physically robust wasteforms with large volume reductions from 100 % waste

Hot isostatic pressing can substantially reduce the volume of nuclear waste

A graduate from the University of Sheffield, **Dr Paul Heath** of GeoRoc Ltd has a PhD in the application of hot-isostatic pressing (HIPing) technology to challenging and diverse radioactive waste streams. He currently leads GeoRoc Ltd's research on HIPing of nuclear waste streams from the Sellafield site.

The UK will spend around £117 billion on nuclear decommissioning within the next century. Of this, around 70% of the financial expenditure is predicted to be focused on Sellafield, the site of many ground-breaking nuclear developments in the 20th century. Having successfully delivered concept and early design projects based on Sellafield waste streams, Dr Paul Heath and the team at GeoRoc are working on an innovative new technology, based on a hot-isostatic pressing technique (HIPing). This technology could save up to £950 million in waste management and packaging costs and reduce the volume of sludge and slurry radioactive waste in repositories by up to 90%.

CURRENT WASTE TREATMENT

In England and Wales, Intermediate Level Waste (ILW) and High Level Waste (HLW) (wastes exceeding 4 GBq / tonne α or 12 GBq / tonne β/γ) arising from current and historic nuclear operations, are to be disposed of at a single geological disposal facility, or repository. Prior to deposition, wastes are processed in order to be deemed passively safe using existing waste treatment methods, including cementation and melting into a glass wasteform (vitrification).

ILW is typically treated via cementation, which encapsulates the waste products within a cement matrix to contain the radioactive products. However, this process typically increases waste volumes by up to 400%, taking valuable repository space which may be costed by volume, and incurs additional waste transfer liabilities. The process is not ideally suited for all waste streams, for example the presence of reactive metals such as uranium may destabilise the cement, leading to reduced stability and durability.

Vitrification is the preferred option for high level wastes (HLW). It typically involves calcining the waste materials and melting with additives in order to immobilise radionuclides and chemotoxic elements within a boro-silicate based glass. Vitrification is also under investigation as a method for the treatment of ILW. Although vitrification offers a significantly reduced waste volume when compared to encapsulation, it is a complex process which requires exact control of process parameters such as the melt viscosity, crystallisation and conductivity, which are dependent on waste-stream composition. In addition, the processes involved may lead to greater radioactive volatile losses, more complex off-gas systems and additional secondary wastes.

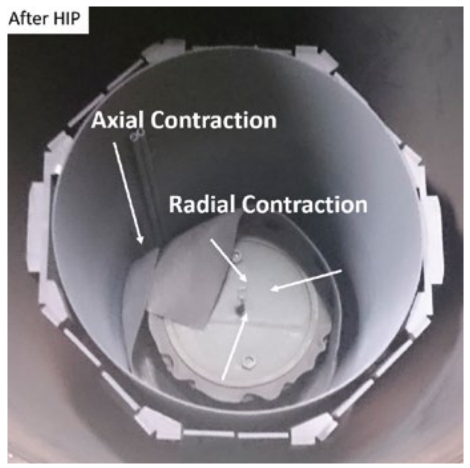
HOT-ISOSTATIC PRESSING

GeoRoc's Hot-Isostatic Pressing (HIPing) technology is potentially an exciting alternative treatment option for ILW wastes. HIPing is an existing method used to densify and consolidate materials by applying isostatic pressure at an elevated temperature in a pressure vessel. An inert gas, typically argon, is used to pressurise the heated vessel. For radioactive waste treatment, the waste is sealed inside a specially designed canister before HIPing. As the temperature and pressure inside the vessel increases, the materials placed in the canister react and densify to produce stable, volume reduced wasteforms.

THE BENEFITS

GeoRoc have been investigating how the HIP process could be used to treat approximately 5000 m^3 of wastes (primarily magnesium hydroxide sludges from Magnox fuel elements and clinoptilolite slurries from SIXEP plant operations) from the Sellafield site in the North West of England. The selection of a baseline treatment option for these sludge and slurry wastes is currently under review by Sellafield Ltd.

GeoRoc's work to date has shown that the HIP treatment method is commercially feasible. A conceptual plant design detailing the treatment philosophy of these wastes has been delivered to Sellafield, supported by a trial demonstrating that over 160 L of sludge can be processed in a single waste package. This trial processed over 160 L of sludge into a single 40 L HIP package. Following



The work performed by GeoRoc pushes the boundaries of HIP technology for waste treatment, successfully processing the largest demonstration wasteform to date

the success of these two projects, GeoRoc's process has become a viable alternative, under consideration for the treatment of ILW streams.

The advantages of this technology over existing practices include increased wasteform stability, significant waste volume reductions and minimised secondary or operational wastes. This aligns with the Nuclear Decommissioning Authority's (NDA) Research and Development 5 Year Plan to establish alternative waste treatments with a particular focus on volume reduction.

As a number of these wastes are poorly characterised, Dr Heath and the team needed to understand the flexibility of the HIP process and, specifically, its capacity to accommodate the physical and chemical variations within the waste stream and the properties of uranium-doped radioactive samples. This further research will demonstrate the feasibility of using GeoRoc's technology to treat these highly variable waste-streams.

UNDERSTANDING THE ISSUES: THREE KEY PHASES

Using simulants of the Magnox sludge and SIXEP sand/clinoptilolite slurry currently at Sellafield, the first stage investigated the science and reaction of the materials during processing, selecting a suitable combination of additives and processing parameters. Subsequently, samples were loaded with non-radioactive caesium (Cs) and a range of additives to simulate the complex chemistry of the sludge wastes and their effect on processing was determined.

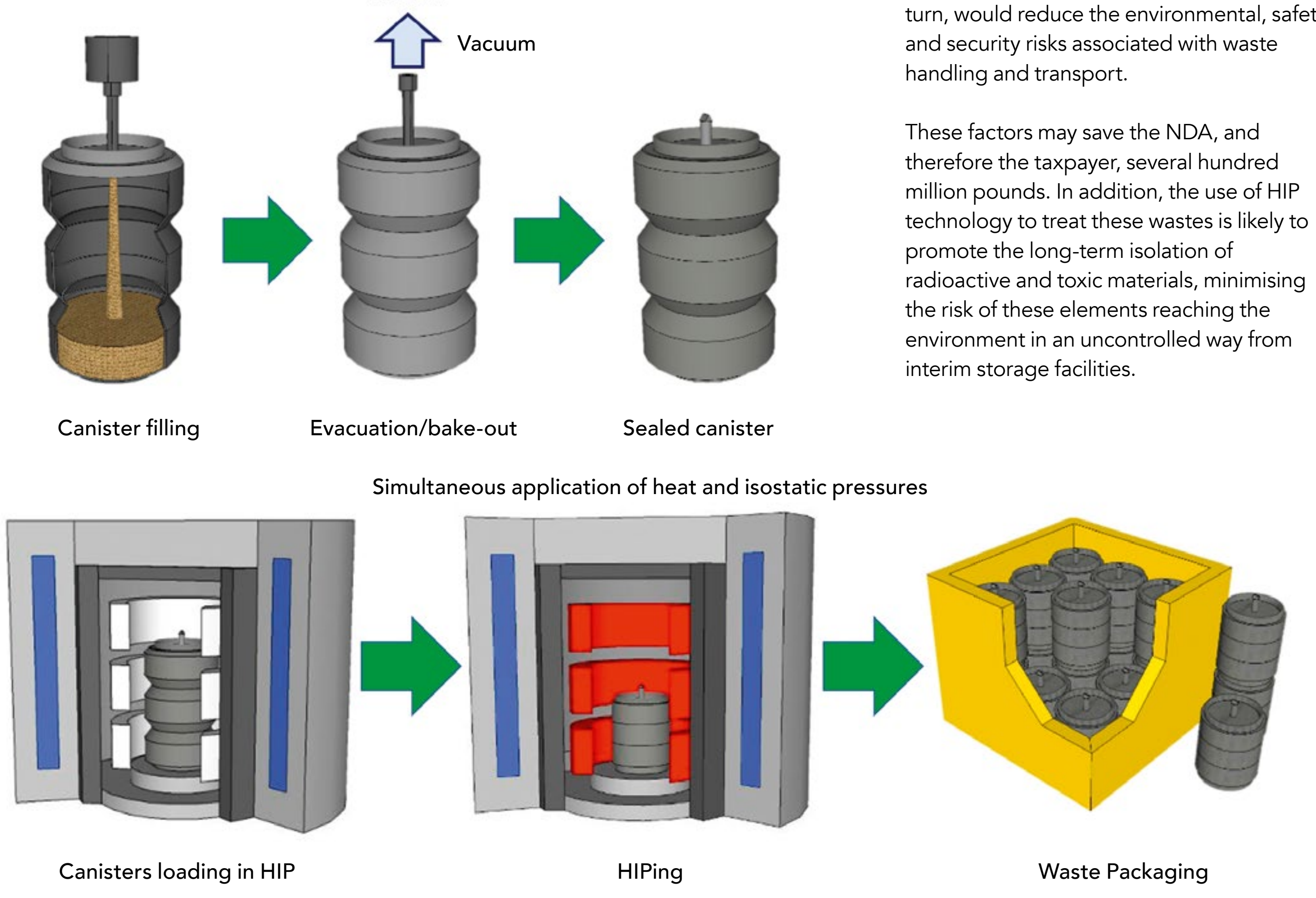
The next phase looked at the extremes of Sellafield's waste inventory. By evaluating the effect of varying particle size, carbonate content, organic content, reactive metal content and total waste loading, it was determined that suitable wasteforms could be produced across the expected range of sludge and slurry waste streams using identical process parameters.

Finally, the project will produce and analyse uranium-doped HIP samples. The samples will be based on the Magnox sludge composition and will characterise the behaviour of radioactive material during processing. This will provide information on the speciation, wasteform quality and technical feasibility of uranium inclusion within the HIP process.

THE FUTURE OF NUCLEAR WASTE TREATMENT

GeoRoc's technology has the potential to significantly reduce the lifetime waste management costs for radioactive waste liabilities. Savings could be made through the production of fewer packages, a smaller repository and simplified logistics. This, in turn, would reduce the environmental, safety and security risks associated with waste handling and transport.

These factors may save the NDA, and therefore the taxpayer, several hundred million pounds. In addition, the use of HIP technology to treat these wastes is likely to promote the long-term isolation of radioactive and toxic materials, minimising the risk of these elements reaching the environment in an uncontrolled way from interim storage facilities.

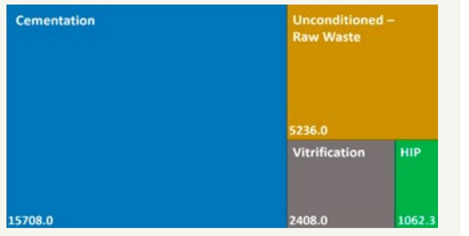


Q&A

As the simulants for the feasibility studies are based on Magnox sludge waste, will additional studies need to be completed at other sites?
As the primary focus of all UK nuclear operations is public safety, research into the treatment of each waste-stream is typically undertaken to ensure the process is suitable, whatever the proposed treatment methodology. The highly variable physical, chemical and radioactive properties of wastes around the world means no one solution is able to safely and effectively treat all wastes. Thermal treatment of wastes, such as HIP, offer significant improvements, ensuring radioactive waste is treated safely by reducing the volume and increasing the long-term stability of the waste materials.

Can this technology be applied to wastes from other industries e.g. oil, gas, and mining?
Yes, one of the major benefits of HIP technology in the treatment of radioactive wastes is the flexibility to produce a range of materials using the same processing equipment. This is equally true of other wastes, especially heavy and toxic metals produced from drilling and mining operations. HIP technology processes waste in a sealed canister, which means the critical treatment parameters (e.g., temperature, pressure, time) are independent of the waste-stream properties. This allows the same equipment to be used to design and produce metallic, ceramic, glass or glass-ceramics materials at high waste-loadings, based on the chemistry and physical properties of the waste.

Having demonstrated the viability of HIP for the treatment of Sellafield sludge and slurry wastes, what is the next step for full commercialisation of the technology?
GeoRoc have designed a functional pilot plant. This facility will be the world's first integrated and flexible demonstration of HIP technology for the treatment of waste materials. The pilot facility has been designed to process wastes at a commercially relevant scale (~1/10 – full scale depending on waste stream) and will be made available to trial problematic wastes. We believe the operation of this pilot facility will provide a step change in the acceptance of HIP as an option for treatment of the world's most problematic legacy wastes.



Comparison of waste volumes produced if Sellafield's ILW sludge and slurries were treated by a variety of potential options (m^3)

Can HIPing be applied to existing cemented waste packages?
While theoretically possible, it would require some development effort with some front-end processing. There would also have to be a cost benefit assessment undertaken by the waste owners to see if there was any value in further treating these packages. The packages are therefore not a current target for us. GeoRoc is focusing its development efforts on the higher hazard, untreated wastes, such as the Magnox sludges.

One potential issue with decommissioning is the unavailability of historical operational data. Does this limit waste treatment options?
The complexity and cost of obtaining representative data for certain waste streams can severely limit their waste treatment options. This is why the flexibility afforded by HIP treatment and the research we have been performing on the waste envelope is so important to supporting the commercial implementation of this technology. For example, it has been shown that the HIP process does not need to accurately meter chemical additives as it has a broad chemical process window and can produce dense, physically robust wasteforms using 100 wt% waste. This is true whether treating magnox sludge, SIXEP sand/clinoptilolite or a combination of the two, all under identical processing conditions.

Detail

RESEARCH OBJECTIVES
Dr Heath's research focuses on the disposal of nuclear waste. His recent research has been related to the application of hot-isostatic pressing in the treatment of UK ILW sludges and slurries.

FUNDING
- Innovate UK
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COLLABORATORS
- Martin Stewart (GeoRoc)
- Sam Moricca (AMEPT)
- Prof Neil Hyatt (ISL – University of Sheffield)
- Dr Sean Morgan (Sellafield Ltd)

BIO

Dr Paul Heath has been leading GeoRoc's Sludge and Slurry Treatment R&D programme for over two years. Since the start of his PhD, his research has focused on the development of treatment options for radioactive wastes. These studies have aimed to combine advanced, passively safe wasteforms with industrially relevant processing technologies.

CONTACT
Dr Paul Heath, Materials Engineer,
GeoRoc Ltd
Unit 1 – Building 3
Advanced Manufacturing Park (AMP)
Rotherham
S60 5WG
UK

T: +44(0)7939 889 726
E: paul.heath@georoc.co.uk
W: www.georoc.co.uk

GeoRoc Limited