Strategic Options For The Management Of Waste Irradiated Graphite - 9456

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ABSTRACT

World-wide there are over 230 000 tonnes of irradiated graphite that will ultimately require the identification of treatment, management and/or disposal options. This legacy has arisen predominantly from the use of graphite moderated reactors for base-load generation. The UK is one of several countries that have an irradiated graphite waste legacy; some of these countries have combined to address this future waste management problem. This paper describes how this consortium (CARBOWASTE) will evaluate and analyse graphite management options.

INTRODUCTION

Across the world graphite has been used extensively as a reflector and moderator in over a hundred nuclear power plants, research reactors and plutonium production reactors. Indeed according to the IAEA [1] there are over 230 000 tonnes of radioactive graphite which will ultimately need to be managed as radioactive waste. A significant portion of this irradiated graphite is located in Europe.

The major challenge with this material is related to the presence of both long lived isotopes such as radiocarbon (C-14) and chlorine (Cl-36) and also shorter lived ones such as cobalt (Co-60). Notably the shorter lived isotopes can influence decisions regarding the timing and method of dismantling reactors and the longer lived isotopes influence disposal options.

CARBOWASTE

The UK's National Nuclear laboratory is one of 28 partners in a European Atomic Energy Community [EURATOM] funded collaborative project, 'Treatment and Disposal of Irradiated Graphite and other Carbonaceous Waste (CARBOWASTE)' that addresses the waste management of irradiated graphite. These materials that will arise from the decommissioning of a variety of graphite moderated reactors in EU Member States. The project commenced in April 2008 under the 7th EURATOM Framework Programme and will continue for four years. The aim of the project is to develop best practices in the retrieval, treatment and disposal of irradiated graphite, addressing both existing legacy waste as well as waste from graphite-based nuclear fuel resulting from a new generation of nuclear reactors (e.g. V/HTR).

The wide range of levels of radioactivity and quantities of graphite in different countries coupled with international variations in both legislation and approach mean that the most appropriate approach to recovery, treatment and end point may vary from country to country and potentially from site to site. The challenge for the CARBOWASTE project is to build a harmonised ‘toolbox’ of techniques, methodologies and best practices for decommissioning and waste management of irradiated graphite, that can be applied to address a range of requirements and conditions.

The CARBOWASTE project therefore considers the life cycle of irradiated graphite from its in reactor state through to ultimate disposal or re-use. The project is broken down into six technical work packages (WPs);

- integrated waste management approach (WP 1)
- retrieval and segregation (WP 2)
- characterisation and modelling (WP 3)
- treatment and purification (WP 4)
- recycling and new products (WP 5)
- disposal behaviour (WP 6)

An overview of the project and the individual work packages has recently been published [3].

This paper focuses on Work Package 1 – the Integrated Waste Management Approach. This package is central to the overall project, aiming to develop a true definition of the problem of irradiated graphite management, developing methodologies for evaluating strategic options for waste management. A major step in this process was the development of an irradiated graphite route map.

IRRADIATED GRAPHITE ROUTE MAP

The first stage in the process was to develop a framework in which to consider the management of irradiated graphite and identify the questions that need to be addressed in order to develop an integrated approach to this waste.
The National Nuclear Laboratory had previously developed an irradiated graphite waste management road map that identified key stages, end-points and parameters that need to be considered to reach appropriate end-points. This road map was specifically developed for irradiated graphite from UK Magnox reactors, but would potentially accommodate the UK’s Advanced Gas Cooled Reactor (AGR) fleet.

However this existing approach was not sufficiently flexible to accept other reactors such as HTRs, and RBMKs. In addition to these other reactor types, the CARBOWASTE project also aims to consider a broader range of treatment, re-use, waste management and disposal options. This road map has therefore been upgraded to a route map which defines how different approaches to graphite management may be considered.

The route map considers waste management of irradiated graphite in six key areas as illustrated in Figure 1, and identifies the issues that need to be considered in each area in order to develop an integrated waste management solution. This will ultimately be used to inform the research programmes to be carried out by partners within the consortium. The route map considers the interim storage, treatment, recycle/re-use, treatment and disposal of graphite.

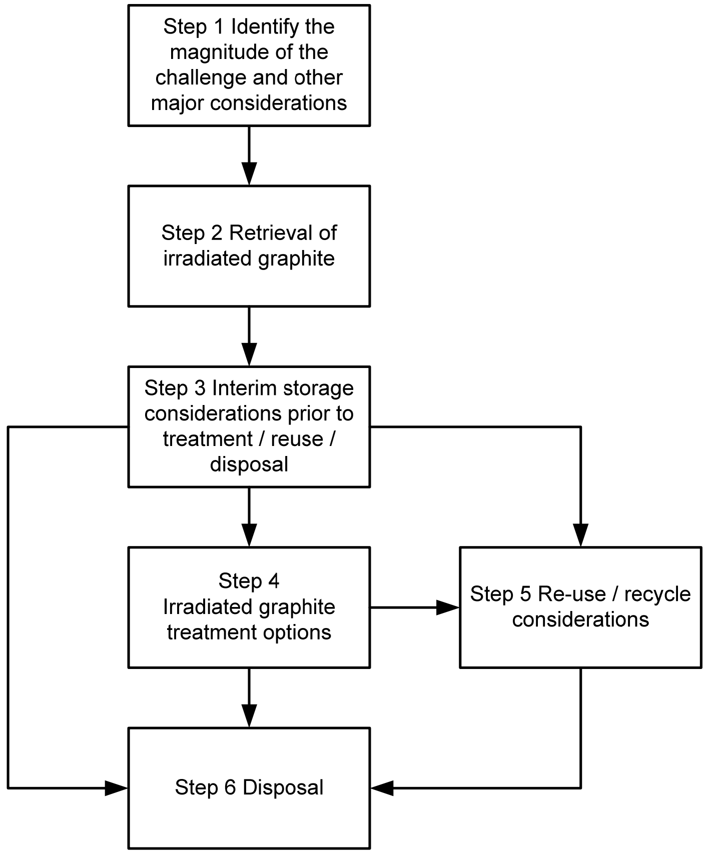

Figure 1 Irradiated graphite route map overview

Step 1 – The Challenge

The first step requires a comprehensive understanding of the irradiated graphite problem, notably in terms of inventory. Acquiring the following information is paramount to selecting appropriate downstream options:

- Reactor type
- Quantity of irradiated graphite
- Disposition of irradiated graphite
- Irradiation history
- Storage period

This above information is needed in order to understand how much graphite is to be managed and the nature of the associated radioactivity. These factors influence all subsequent steps in the route map. The radioactive inventory is particularly important in terms of determining the most significant radionuclides particularly in terms of dismantling, treatment, disposal and identifying any potential for re-use/recycle. For example the radionuclides H-3, C-14 and Cl-36 will have major implications for selecting the most appropriate irradiated graphite disposal options, whilst Co-60 and other neutron activation products will influence the start date of graphite retrieval and/or the mode of retrieval.

This information is being collated as part of a review of existing knowledge and will ultimately be supplemented by results of characterisation and modelling research to be carried out as part of the CARBOWASTE project (WP3).

Step 2 Retrieval of graphite

In order to evaluate options for the retrieval of graphite a variety of information is required; including

- Radioactive inventory
- Physical/ chemical nature of the graphite
- The configuration of the reactor core
- The presence of other materials, such as securing wires, thermocouples
- Design of the reactor in terms of access and integrity

These factors will ultimately influence the choice of retrieval method for graphite. The current world-wide experience is limited to knowledge gained from dismantling of three graphite based reactors Fort St Vrain (USA), GLEEP (UK) and WAGR (UK) each which has used a different approach relevant to their individual circumstance. In the USA the graphite was retrieved under water which is different from the UK experience on GLEEP and WAGR.

One further consideration in this area is the timing of retrieval. Some countries currently have a policy of prompt dismantling whereas others utilise a safestore period and delay retrieval to take advantage of the decay of short lived radionuclides.

A range of options for retrieval and segregation of graphite waste will be investigated as part of the overall CARBOWASTE programme, based on these considerations.

Step 3 Interim Storage

It may be necessary for retrieved graphite to be stored on an interim basis in order to facilitate efficient dismantling. Key factors affecting retrieval also impact on this stage, notably form and inventory of the graphite. Additionally the throughput capacities for retrieval and subsequent downstream availability/capacity for ‘processing/disposal’ will impact on the size of any facility.

If required interim storage would allow subsequent characterisation of graphite.

Step 4 Treatment of Graphite

This stage of the route map focuses on issues surrounding treatment technologies for irradiated graphite. Treatment may be required in order to achieve disposal or re-use/ recycle of the graphite. A range of treatment options including physical, chemical and microbiological techniques are being evaluated as part of the CARBOWASTE programme. These processes will be evaluated in the context of the following key considerations;

- Ability to achieve the required decontamination factor
- Ability to industrialise commensurate with the quantities of graphite
- Secondary waste generation
- Overall environmental impact
- Cost
- Maturity and flexibility

Step 5 Re-use and Recycle

The re-use or recycle of graphite, or some portion of the graphite is being considered within the CARBOWASTE project. Consideration is being given to the use of irradiated graphite in terms of new products, isotope separation and market potential. The key issues in this stage will be in understanding the market potential and achieving acceptable product forms.

Step 6 Disposal

There are many factors influencing disposal options that must be considered including;

- Socio political factors – (e.g. public acceptance)
- Availability of disposal facility
- Volume of waste
- Radioactivity
- Package design
- Requirements for immobilisation
- Wasteform / repository interactions

The CARBOWASTE project (Work Package 6) aims to provide a “disposal point of view” on best practices for graphite carbonaceous waste management.

The previous sections have given an overview of some of the key factors that will influence the determination of an integrated approach to the management of irradiated graphite. One benefit of the development of this approach has been the ability to identify the key data needed to inform decision making.

Evaluating the Current Knowledge Base on Irradiated Graphite

A detailed international review is being conducted to consolidate the current knowledge base on irradiated graphite, building on previous work by IAEA [1,2] and others. This has focussed on individual reviews of inventory, status of irradiated graphite, management options and disposal across a range of countries. Once completed, this review will be compared with the data requirements identified in the route map and any gaps will be identified. This analysis of data requirements will inform other CARBOWASTE work packages.

Strategic Options

The review of the existing graphite knowledge base will identify strategic options for the management of irradiated graphite. As the CARBOWASTE research progresses, variations on these options and potentially alternative technologies will emerge. The requirements of the route map will be used to define options to a point where they can be evaluated and compared, on a consistent basis. A Multi–Criteria Decision Analysis technique will be developed as part of the CARBOWASTE toolbox to aid evaluation of options.

Multi-Criteria Decision Analysis

Questions concerning sustainable management of nuclear waste are characterized by contrasting economic, environmental, social, technical, and ethical objectives. It is difficult to arrive at a logically robust solution without the assistance of one or more decision support tools that provide for the transparent integration and structuring of complex information.

Multi-criteria decision tools have been found to be useful to support decision making under such conditions; see for example [4] and [5]. Criteria can be assessed on both quantitative and qualitative scales. An example of such an approach is Multi-Criteria Decision Analysis (MCDA), which serves as an aid to the analysis and decision-making process of an expert assessment group through the deployment of one or more techniques. A typical MCDA approach is illustrated in Figure 2.

A suitable MCDA methodology is now being prepared as part of the project. The approach needs to be flexible enough to address a wide range of irradiated graphite challenges under different socio-political and environmental conditions, whilst facilitating a robust and transparent analysis of the available data. Initial work will focus on the development of the objective and value measures to support the decision making process.

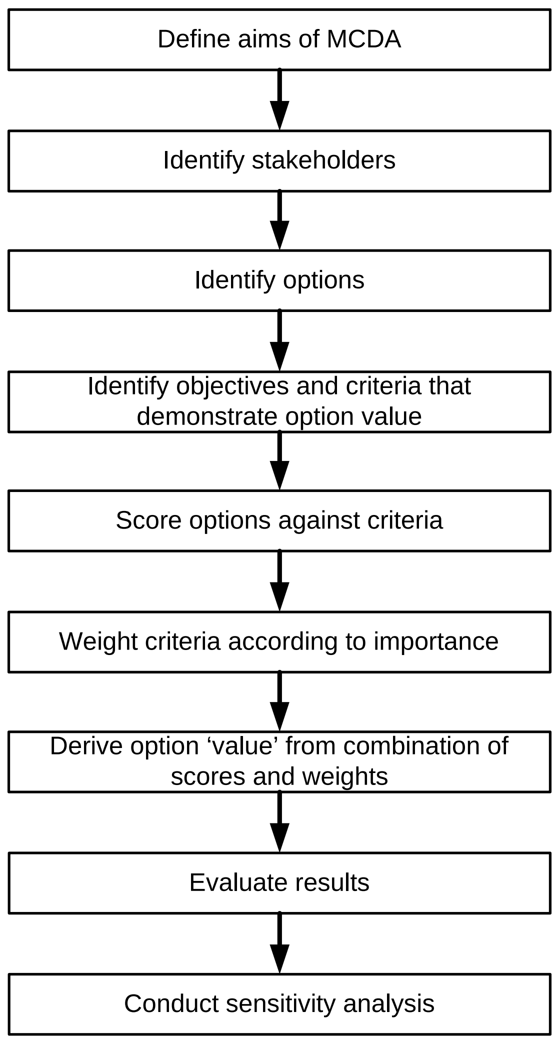

Figure 2 Typical MCDA approach to decision support

CONCLUSIONS

Internationally there is a significant legacy of irradiated graphite, and a significant portion of this is European. Twenty eight international partners are now working together, through the CARBOWASTE project to identify best practices in retrieval, treatment and disposal of irradiated graphite.

A central part of the CARBOWASTE project is the development of an integrated approach to this waste management challenge, through the development of a route map identifying the key issues, the development of strategic options / end points and the development of an MCDA framework for systematic evaluation of options.

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