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CARBOWASTE

Treatment and Disposal of Irradiated Graphite and Other Carbonaceous Waste

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WP 1 Irradiated Graphite Route Map

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Document title
Irradiated Graphite Route Map
Executive summary
This report presents the irradiated graphite route-map document developed under task 1.2 of the CARBOWASTE project. This route map is a hierarchical document that identifies the key stages and key issues that need to be considered in the development of an informed waste management strategy for irradiated graphite.

History /Revisions

Rev.	Date	Short description	Lead Author	Internal Review	Task Leader	WP Leader
	7-09-08	First issue for Comment	H Eccles	NNL team review meeting		
	16-02-09	Presentation to WP 1 Workshop 16 Feb 09	H Eccles	AW Banford		
	04-03-09	Draft issued to WP1 participants updated following WP 1 workshop	H Eccles	Reviewed at WP 1 workshop by WP1 participants		
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1 Introductory Notes

This route map is a hierarchical document that identifies the key stages and issues that must be considered to enable an informed irradiated graphite waste management option to be selected.

This route map is specific for i-graphite management and therefore is only one contribution to the process of decommissioning nuclear reactors.

It is a route map has several ways or 'roads', that can achieve the required end-points[1] as show in Figure 1.

Information, data and knowledge will be required for each key step. Some of this will be generic[2] for all key steps whilst other information will be specific[3] for the particular step.

Some key steps may require a lower tier road map to be developed to collect all of the options/considerations. These will be provided later.

It is conceivable that some key steps can be by-passed as the disposal options can accommodate this approach.

It is essential to identify the disposal options and then consider upstream stages.

This route map is not a stand alone decision making activity. It needs to be used in conjunction with Multiple Criteria Decision Analysis (MCDA) and the review paper from WP 1. Together, the review and the route map will be used to identify the key factors and information that will influence any waste management strategy for irradiated graphite and to identify key gaps in knowledge that will be researched by other participants in the project. The MCDA will identify the most appropriate options.

[1] End-points are criteria such decommissioning policy, radiological considerations that affect decisions/considerations; for example decommissioning policy that requires reactors to be fully decommissioned in 25 years.
[2] Generic considerations would include environmental, social and economic considerations.
[3] Specific information would include for example market opportunities for re-use/recycle step.

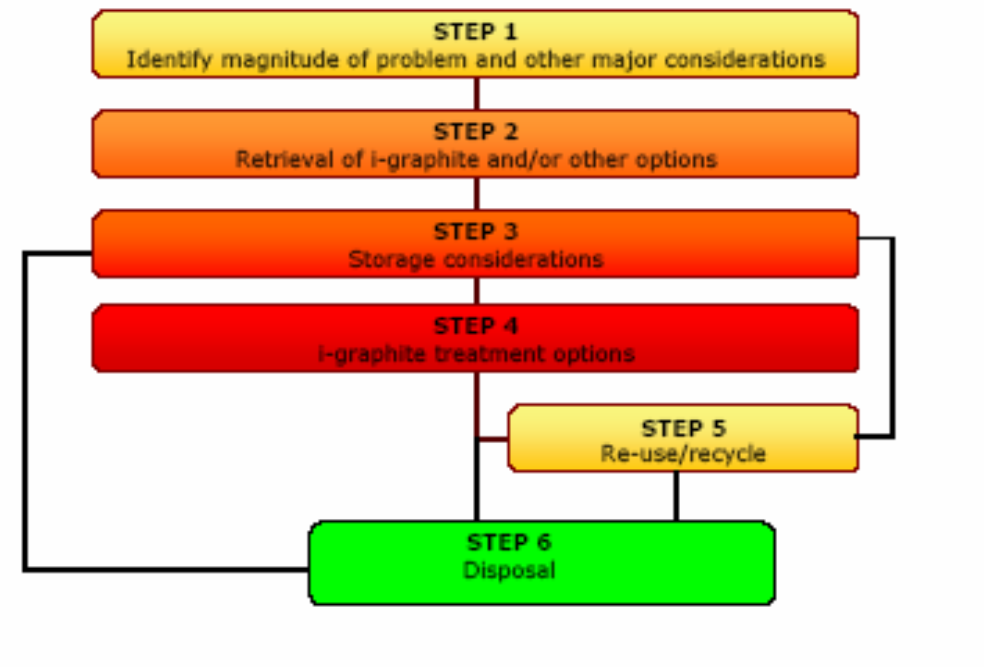

Figure 1 Irradiated Graphite Route Map – level 1

2 Identify magnitude of problem and other major considerations

STEP 1
Identify magnitude of problem and other major considerations

INTRODUCTION

This information is fundamental to all key stages of the route map.

INFORMATION

Reactor/Graphite history	Offending radionuclides	Other considerations
1 Quantity of graphite involved 2 Disposition 3 Closure date of reactor 4 Decay period 5 Graphite irradiation history 6 PIE data 7 Origin of graphite 8 Reactor type 9 Reactor operational history 10 Fuel failures and other reactor perturbations 11 Reactor operational atmosphere	1 Nuclides that will impact on: [a] storage in-situ/ex-situ [b] retrieval/removal [c] treatment [d] recycle issues [e] disposal	Non radioactive species Organic mater Wigner energy

CONTRIBUTIONS

Information needed to allow:

1 estimate of degree of radioactivity of graphite
2 neutron activation products based on original impurities levels
3 residual activity due to delayed storage

The above will impact on decommissioning strategy, radiological, environmental considerations and cost.

H-3, C-14 and Cl-36 will have major implications to disposal options
Other neutron activation products such as ^{60}Co, depending on delay storage option (25, 50 or 75 years) will impact on decommissioning options.
Other isotopes resulting from fuel manufacturing routes for HTRs will also need consideration for decommissioning stages.

OUTPUTS

Understanding the importance and quality of the information/data available and knowledge gaps that need to be addressed before the next step in the routes map can be considered.
Waste disposal options.

3

3 Retrieval of i-graphite and/or other options

STEP 2
Retrieval of i-graphite and/or other options

INTRODUCTION

Information from the previous step and considerations here will allow various options including retrieval to be examined.

INFORMATION

Contributory impacts

1 Physical/chemical properties of i-graphite from other materials
2 Potential methods of removal
3 Other materials e.g. thermocouples, securing wires

4 Implications of reactor design on graphite retrieval

Confirm major issues

1 Reactor and graphite core designs and other relevant design/construction details

2 Need to segregate i-graphite
3 Agree mode of dismantling

4 Consider radiological implications, time constraints, and costs etc
5 Waste arisings
6 Examine environmental impact

CONTRIBUTIONS

During this step major radiological and physical/mechanical graphite properties will have been considered and their impact on selection of graphite retrieval from the reactor or other options. Radiological and environmental impact assessments will have been undertaken.

OUTPUTS

Candidate retrieval and/or other options identified.

4 Storage considerations

STEP 3
Storage considerations

INTRODUCTION

Storage covers both buffer storage prior to treatment or other options and as an interim strategy prior to final disposal. The buffer store will allow any fluctuations in treatment to be accommodated. It will also allow treatment options to be considered (desk-top studies) prior to making preliminary selection or even if treatment is the preferred option. Interim storage may be needed if i-graphite has been removed from the reactor before a final disposal route is available.

INFORMATION

Agree environmental targets/end points

1 Identify environmental thresholds for waste options e.g. vLLW, LLW, ILW
2 Correlate threshold values with quantity
3 Examine current routes for disposal
4 Determine excess quantity requiring treatment
5 Climate change implications on decommissioning
6 Duration of material storage

Assess decontamination factors required for various end-points

1 Calculation of DF values needed to achieve the various disposal options for C-14 and other radionuclides

Other considerations (storage)

1 store boundaries
2 graphite/container interactions

CONTRIBUTIONS

Process technology evaluations will prioritise options most appropriate for further consideration
The determination of DF values will provide an indication of efficiencies required and whether the task appears practical.

OUTPUTS

Boundary conditions of potential C-14 decontamination processes identified.
Boundary conditions for storage.

5

5 I- graphite treatment options

STEP 4
i-graphite treatment options

INTRODUCTION

The treatment options will have to satisfy numerous criteria not least cost, environmental impact and socio-political considerations. Treatment and final disposal of secondary wastes/effluents generated from the i-graphite treatment process will be crucial to its acceptability.

Review technologies capable of achieving required DF[4]

1 Consider if proven technologies can achieve the required DFs
2 Subsequent considerations of experimental/novel techniques
3 Consideration of timeframes for technology implementation

Identify key issues of candidate technologies

1 Identify waste/effluent arisings from candidate processes
2 Consideration of other process considerations such as:
- manpower needs
- radiological considerations
- energy requirements
- modular technology
- footprint
- other environmental issues
- flexibility of process

Secondary waste treatment options

1 select treatment with:
[a] no/low waste generation
[b] high efficiency
[c] flexibility
[d] proven technology

Waste arisings from candidate option

1 Identify all final wastes/ effluents
2 assessment of volumes/ quantities
3 prioritise severity of wastes
4 opportunities for recycle

Environmental impact assessment

1 environmental assessment of all waste/ effluent arisings from candidate process

INFORMATION

CONTRIBUTIONS

The evaluation of current proven separation technology can be undertaken using calculated DF values. If existing technology is not capable of achieving the DFs required with single/dual pass system then novel/experimental stage technology could be considered. In this case risk, time to demonstrate and cost of commercialisation need to be considered.

Assessment of waste/effluents and their degree of treatment difficulty will be paramount to the final selection of the candidate treatment process

Treatment of wastes/effluents arising from the treatment of i-graphite will contribute to sustainable solution

OUTPUTS

[4] DF is the ratio of C-14 present in graphite to the quantity acceptable for disposal

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6 Re-use/recycle

STEP 5
Re-use/recycle

INTRODUCTION

Re-use/recycle may complement disposal. This will depend on the market opportunities for re-use/recycle and on the radioactivity that can be accommodated by users. Other issues such as cost of re-use/recycle etc will need consideration.

INFORMATION

Major considerations

1 Market potential i.e. more than one user
2 Usage i.e. tes/annum
3 Radioactivity
4 Other properties that will influence costs of re-use/recycle

CONTRIBUTIONS

OUTPUTS

Market survey indicating re-use/recycle graphite is acceptable

7 STEP 6 Disposal

STEP 6
Disposal

INTRODUCTION

The disposal option will need to consider both treated and untreated i-graphite, residues from recycle and re-use options and potential wastes/residues arising from the treatment option.

INFORMATION

Waste form optimisation

Optimise with respect to:
1 activity category
2 volume
3 package size
4 treatment and encapsulation requirement
5 waste/container interactions
6 wasteform/repository interactions
7 location transport
8 public acceptance
9 national/local agreement

Disposal design

1 Near-field[1] behaviour of i-graphite
2 Radiological assessment
3 Geosphere requirements
4 Design options
5 Location geology
6 Location transport
7 Public acceptance
8 National/local agreement
9 Climate change
10 Retrievability of waste

CONTRIBUTIONS

Disposal options and final waste categories to be considered through retrieval, treatment and storage stages e.g. retrieval processes need to consider suitability of powdered graphite and impact on volume minimisation, activity segregation, treatment options, radionuclide behaviour in waste form and repository

OUTPUTS

Upper level conditions for acceptance for graphite
National variations
Sustainable waste management option for i-graphite

[1] IAEA definition of near field – the excavated area of a repository near or in contact with the waste packaging, including filling or sealing materials, and those parts of the host medium rock whose characteristics have been or could be altered by the repository or its contents.