Engineering and Innovation Research Studentship 2025/2026

Project title:	**Modelling nuclear graphite waste smouldering: A novel approach to managing a highly challenging waste stream**
Discipline	Environmental Engineering
Key words:	Numerical modelling, Thermochemical, Carbon, Nuclear graphite
Supervisory team:	Dr. Gareth Neighbour, Dr. Tarek Rashwan
URL for lead supervisor's OU profile	https://www.open.ac.uk/people/gbn9

Project Highlights:

- Expand understanding of key chemistry dynamics in an emerging energy-efficient environmental treatment method to support safe disposal of nuclear graphite waste.
- Conduct laboratory experiments for validation purposes.
- Acquire industry-relevant skills through presenting research findings at international, industry-led forums.
- Enhance an existing numerical model to explore key dynamics in applied smouldering systems across scales.

Overview:
The UK's fleet of Advanced Gas-cooled Reactors (AGRs) utilises graphite moderator bricks, which become radiologically contaminated – primarily with Carbon-14 (C-14) and other radionuclides such as Co-60 – through transmutation over decades of operation. In addition, the graphite bricks are subject to degradation through radiolytic oxidation and irradiation, causing significant cracking. As the reactors are decommissioned, managing this graphite waste presents a significant technical and environmental challenges due to its condition as well as the long half-life of C-14 (~5,730 years) and other radionuclides, the volume of waste, and other persistent residual risks. Novel environmental technologies are needed to manage challenging nuclear graphite waste.

This project will focus on exploring a novel method using applied smouldering combustion to reduce nuclear graphite bricks to ash. This processes will use a self-sustaining thermal approach where the energy contained within the graphite will destroy itself [1]. Smouldering is emerging as an energy-efficient alternative thermal technique that has been used to successfully manage similar non-volatile carbon-based wastes commercially, e.g., spent granular activated carbon (GAC) from per- and polyfluoroalkyl (PFAS) treatment systems [2, 3].

Smouldering combustion is a low-temperature, flameless form of combustion – commonly seen as the glowing surface of a charcoal barbecue. The key advantage for smouldering non-volatile waste treatment compared to traditional combustion processes – e.g., flaming combustion that is used in most incinerators – is that smouldering is driven by oxygen transfer directly to the condensed phase fuel (waste) [1]. That is, the key exothermic chemical reactions in smouldering systems are driven by heterogeneous processes rather than homogeneous processes in flaming systems. In many cases, smouldering systems can operate in a self-sustaining manner after ignition, i.e., without significant external energy inputs.

While smouldering systems demonstrate unique benefits in treating non-volatile wastes – such as nuclear graphite waste – the chemical degradation dynamics within these systems are complicated and poorly understood.

This project seeks to better understand the fundamental chemical dynamics relevant to graphite waste smouldering systems. Through leveraging both experimental and numerical modelling methods that are established at the Open University (OU).

Methodology:
This research will build upon established smouldering numerical methods to explore the smouldering dynamics, e.g., [4-8]. This project will also include experiments using (*i*) thermogravimetric analysis paired with differential scanning calorimetry (TGA-

DSC) and (*ii*) laboratory-scale smouldering column experiments to generate key validation data for the numerical model development.

This project will leverage existing expertise related to GAC smouldering [4, 5, 7-11] (i.e., a waste stream similar to graphite waste), and use descriptions of semi-global carbon oxidation to understand the roles of various carbon oxidation steps in smouldering graphite waste systems [12-16].

This project is expected to both (*i*) improve the fundamental understanding of chemistry dynamics within smouldering systems and (*ii*) provide insight into a novel energy-efficient approach to managing a challenging waste stream.

Altogether, this project will support an international effort to optimise applied smouldering environmental treatment systems to enhance waste management sustainability globally and improve UK's nuclear graphite waste management capabilities.

References & Further reading:

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[2] Fournie T, Rashwan TL, Switzer C, Gerhard JI. Smouldering to treat PFAS in sewage sludge. Waste Manage. 2023;164:219-27.
[3] Duchesne AL, Brown JK, Patch DJ, Major D, Weber KP, Gerhard JI. Remediation of PFAS-Contaminated Soil and Granular Activated Carbon by Smoldering Combustion. Environ Sci Technol. 2020;54(19):12631-40.
[4] Wang J, Zanoni MAB, Rashwan TL, Torero JL, Gerhard JI. Smoldering ignition of wet combustible materials. Proc Combust Inst. 2024;40(1):105448.
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[6] Miry SZ, Zanoni MAB, Rashwan TL, Kinsman L, Torero JL, Gerhard JI. Fuel mobility dynamics and their influence on applied smouldering systems. Combust Flame. 2024;270:113789.
[7] Miry SZ, Zanoni MAB, Rashwan TL, Torero JL, Gerhard JI. Investigation of multi-dimensional transfer effects in applied smouldering systems: A 2D numerical modelling approach. Combust Flame. 2022;246:112385.
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[13] Shaddix CR, Hecht ES, Gonzalo-Tirado C, Haynes BS. The effect of bulk gas diffusivity on apparent pulverized coal char combustion kinetics. Proc Combust Inst. 2019;37(3):3071-9.
[14] Shaddix CR. An improved semi-global intrinsic kinetics model for high temperature carbon oxidation. Proc Combust Inst. 2024;40(1):105339.
[15] Murphy JJ, Shaddix CR. Combustion kinetics of coal chars in oxygen-enriched environments. Combust Flame. 2006;144(4):710-29.
[16] Geier M, Shaddix CR, Holzleithner F. A mechanistic char oxidation model consistent with observed CO2/CO production ratios. Proc Combust Inst. 2013;34(2):2411-8.

Further details:

The ideal candidate will have a background in mechanical, chemical, or environmental engineering and exhibit strong independence and initiative. Previous numerical modelling experience, particular on thermochemical systems, will be considered a strong asset, but not essential. This project can be tailored to the specific background and interests of the successful applicant.

For further information, please contact Dr. Gareth Neighbour (gareth.neighbour@open.ac.uk)

Applications should include:

- A 1000 word cover letter outlining why the project is of interest to you and how your skills match those required
- an academic CV containing contact details of three academic references
- an Open University application form, downloadable from: http://www.open.ac.uk/postgraduate/research-degrees/how-to-apply/mphil-and-phd-application-process
- IELTS test scores where English is an additional language

Applications should be sent to **STEM-EI-PhD@open.ac.uk by 31.01.2025**