Engineering and Innovation Research Studentship 2024/2025

Project title:	**Numerical modelling of key dynamics in applied smouldering waste-to-energy systems**
Discipline	Environmental Engineering
Key words:	Numerical modelling, Thermochemical, Process scale-up, Porous media
Supervisory team:	Dr. Tarek Rashwan, Dr. James Bowen
Advisory Collaborators:	Dr. Marco Zanoni (The University of Western Ontario), Dr. Gavin grant (Savron)
URL for lead supervisor's OU profile	https://www.open.ac.uk/people/tr829

Project Highlights:

- Explore a novel, waste-to-energy method to support net-zero targets within a circular economy.
- Acquire industry-relevant skills through collaboration with an international industry leader in an emerging area of science and technology.
- Develop a numerical model to explore key dynamics in applied smouldering systems across scales, from the laboratory to commercial application.

Overview:

Smouldering combustion has demonstrated many benefits as a novel and valuable engineering tool towards environmentally beneficial purposes such as: (*i*) resource recovery/generation, (*ii*) improved sanitation in the developing world, (*iii*) brownfield site remediation, and (*iv*) wastewater sludge treatment [1]. However, many physical and chemical dynamics within these systems are complicated and poorly understood.

Smouldering combustion is a low-temperature, flameless form of combustion – commonly seen as the glowing surface of a charcoal barbecue. The key advantage of smouldering compared to traditional combustion processes, e.g., flaming combustion, as used in incineration, is that smouldering exhibits slow combustion timescales [2]. These slow timescales foster efficient energy recycling that can treat wastes with challenging properties, e.g., with low volatility and/or high moisture content. In many cases, smouldering systems can operate in a self-sustaining manner after ignition, i.e., without external energy input. Moreover, depending on the waste, smouldering can be used for resource recovery/generation [3]. In all cases, excess energy can be recovered for waste-to-energy purposes. Therefore, smouldering is a novel, sustainable waste-to-energy method that is highly compatible with a circular economy and net-zero targets [1].

Many applied smouldering systems require the waste be mixed within inert porous media (e.g., sand) to facilitate the necessary conditions for self-sustained smouldering – e.g., good air permeability, high surface area for reaction, and heat retention. Therefore, heat and mass transfer in porous media is central to smouldering system operation [2]. While recent numerical modelling research efforts have elucidated many key aspects of smouldering systems in laboratory-sized systems, full-scale systems remain challenging to model.

This proposal seeks to better understand the heat and mass transfer dynamics in smouldering systems via numerical modelling. This project will investigate: (*i*) alternative formulations of the system boundary conditions, (*ii*) the use of simplified models to predict airflow patterns based on temperature dynamics, and (*iii*) methods for energy recovery relevant to full-scale smouldering systems.

This project will leverage existing commercial smouldering results for model calibration and validation. This project is expected to improve the fundamental understanding of heat and mass transfer dynamics within these systems to support the design of efficient energy recovery methods from smouldering systems.

Methodology:

This research will build upon established smouldering numerical methods to explore the smouldering dynamics relevant towards energy recovery, e.g., [4-6]. Existing data from experiments performed across scales – from laboratory to commercial application – will be used for model validation [7-11]. Novel energy recovery methods will be explored via this validated numerical model.

References & Further reading:

[1] Gerhard JI, Grant GP, Torero JL. Chapter 9 - Star: a uniquely sustainable in situ and ex situ remediation process. In: Hou D, editor. Sustainable Remediation of Contaminated Soil and Groundwater: Butterworth-Heinemann; 2020. p. 221-46.

[2] Torero JL, Gerhard JI, Martins MF, Zanoni MAB, Rashwan TL, Brown JK. Processes defining smouldering combustion: Integrated review and synthesis. Prog Energy Combust Sci. 2020;81:100869.

[3] Wyn HK, Konarova M, Beltramini J, Perkins G, Yermán L. Self-sustaining smouldering combustion of waste: A review on applications, key parameters and potential resource recovery. Fuel Process Technol. 2020;205:106425.

[4] Zanoni MAB, Torero JL, Gerhard JI. Delineating and explaining the limits of self-sustained smouldering combustion. Combust Flame. 2019;201:78-92.

[5] 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.

[6] Miry SZ, Zanoni MAB, Rashwan TL, Torero JL, Gerhard JI. Investigation of applied smouldering in different conditions: The effect of oxygen mass flux. Fuel Process Technol. 2023;250:107849.

[7] Rashwan TL, Fournie T, Torero JL, Grant GP, Gerhard JI. Scaling up self-sustained smouldering of sewage sludge for waste-to-energy. Waste Manage. 2021;135:298-308.

[8] Rashwan TL, Torero JL, Gerhard JI. The improved energy efficiency of applied smouldering systems with increasing scale. Int J Heat Mass Transfer. 2021;177:121548.

[9] Rashwan TL, Zanoni MAB, Wang J, Torero JL, Gerhard JI. Elucidating the characteristic energy balance evolution in applied smouldering systems. Energy. 2023;273:127245.

[10] Sims AW, Sabadell GP, Lam CW, Segal DC, Bireta P, Thomas D. Self-sustaining smouldering combustion for the treatment of industrial oily waste. Waste Manage Res. 2022;0(0):0734242X221123145.

[11] Solinger R, Grant GP, Scholes GC, Murray C, Gerhard JI. STARx Hottpad for smoldering treatment of waste oil sludge: Proof of concept and sensitivity to key design parameters. Waste Manage Res. 2020;38(5):554-66.

Further details:

The ideal candidate will have a background in mechanical, chemical, civil, or environmental engineering and exhibit a high degree of independence and initiative. Previous numerical modelling experience, particularly with thermochemical processes, 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. Tarek Rashwan (tarek.rashwan@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 16.02.2024**