Engineering and Innovation Research Studentship 2023/2024

Project title:	**Exploring Biochar Production in Applied Smouldering Systems**
Discipline	Environmental Engineering
Key words:	Carbon sequestration, Thermochemical, Biomass
Supervisory team:	Dr. Tarek Rashwan, Dr. James Bowen
Advisory Collaborators:	Dr. Christine Switzer (University of Strathclyde), Dr. Gavin Grant (Savron, Canada)
URL for lead supervisor's OU profile	https://www.open.ac.uk/people/tr829

Project Highlights:

- Explore a novel, energy-efficient biochar production 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
- Experimentally explore the biochar production and model the process energy balance and carbon sequestration

Overview:

Given the immediate risks of climate change, bold carbon sequestration initiatives are needed. Biochar production has been suggested as one such initiative [1]. Biochar is a carbon-rich by-product of thermal processing biomass, typically via pyrolysis, and its application in agricultural systems has been demonstrated as a viable method to improve soil quality [2]. However, pyrolysis units rely on endothermic reactions and therefore require external energy, which can lead to process complexity.

Applied smouldering is emerging as valuable environmental engineering technology due to its robustness and simplicity. Applied smouldering systems have been demonstrated suitable for a range of applications: e.g., for waste-to-energy, remediation, resource recovery/generation, and off-grid sanitation in low-income countries [3]. Smouldering is a flameless, low-temperature form of combustion that is harnessed in these systems to support a self-sustaining process without the need for external energy. These systems are highly energy efficient and can therefore manage problematic wastes, e.g., with high moisture content or low volatility.

Given the simplicity of applied smouldering systems, they have the potential to be deployed worldwide to produce biochar from biomass wastes for carbon sequestration and soil improvement. Indeed, recent research has demonstrated this potential [4]. However, the processes that lead to biochar production are not yet well-understood. Smouldering systems are dynamic in space and time and support numerous physical and chemical zones [5]. Generally, pyrolysis reactions proceed ahead of combustion reactions, but they also overlap and compete in space. Therefore, improved understanding of how these reactions establish in applied smouldering systems through experimental methods will provide guidance on how to best maximise biochar production in a self-sustaining manner. Moreover, the energy balance and carbon sequestration results from these systems will need to be quantified to model the potential scale-up benefits. Last, it is not clear how beneficial the biochar from smouldering systems is compared to biochar generated from traditional pyrolysis methods.

These are key research questions that limit the development of applied smouldering systems for carbon sequestration.

Methodology:

This research will use established smouldering experimental methods to produce biochar, e.g., [4, 6, 7]. These experiments will investigate strategies to maximise biochar output and quantify the carbon and energy balances, following established methods [8-10].

In addition, biochar formation in controlled pyrolysis units will be completed in-house to provide comparative samples. Biochar samples produced

from smouldering and pyrolysis systems will be compared via surface science analyses.

References & Further reading:

[1] Woolf D, Amonette JE, Street-Perrott FA, Lehmann J, Joseph S. Sustainable biochar to mitigate global climate change. Nature Communications. 2010;1(1):56.
[2] Kamali M, Sweygers N, Al-Salem S, Appels L, Aminabhavi TM, Dewil R. Biochar for soil applications-sustainability aspects, challenges and future prospects. Chem Eng J. 2022;428:131189.
[3] 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.
[4] Wyn HK, Zárate S, Carrascal J, Yermán L. A Novel Approach to the Production of Biochar with Improved Fuel Characteristics from Biomass Waste. Waste Biomass Valorization. 2019.
[5] 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.
[6] Rashwan TL, Fournie T, Green M, Duchesne AL, Brown JK, Grant GP, Torero JL, Gerhard JI. Applied smouldering for co-waste management: Benefits and trade-offs. Fuel Process Technol. 2023;240:107542.
[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] Zanoni MAB, Torero JL, Gerhard JI. Delineating and explaining the limits of self-sustained smouldering combustion. Combust Flame. 2019;201:78-92.
[10] Zanoni MAB, Torero JL, Gerhard JI. Determining the conditions that lead to self-sustained smouldering combustion by means of numerical modelling. Proc Combust Inst. 2019;37(3):4043-51.

Further details:

The ideal candidate will have a background in engineering and environmental sciences and exhibit a high degree of independence and initiative. Previous laboratory experience, particularly with thermochemical techniques, will be considered a strong asset, but not essential. This project can be tailored to the specific background and interests of individual applicants.

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 15.02.2023**