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A Novel Fluidised Bed System for Sustainable Biosolids Management: Development and Scale-Up of PYROCO

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ABSTRACT

Biosolids, the treated organic fraction of sewage sludge, are rich in nutrients (N, P, K, S) and organic matter, making them suitable for land application. However, due to the presence of emerging contaminants such as per- and polyfluoroalkyl substances (PFAS), microplastics, and pharmaceutical residues, along with increasingly stringent regulations, the water sector is keen to explore alternative strategies. Among these, advanced thermochemical processes such as pyrolysis and gasification are gaining traction for their ability to destroy contaminants while producing stable, nutrient-rich biochar.

This study presents the scale-up journey and pilot demonstration of a novel fluidised bed pyrolysis-gasification system, PYROCO, developed by RMIT University in collaboration with South East Water and Intelligent Water Networks. PYROCO was specifically designed to overcome key limitations of conventional large-scale pyrolysis reactors, including uneven temperature distribution, poor heat transfer efficiency, and high operating and maintenance costs. Featuring a fluidised bed heat exchanger configuration, PYROCO achieves high heat transfer coefficients and uniform reactor temperatures without the need for expensive inert gases or mechanically moving parts, enabling improved process efficiency and scalability.

Following the successful operation of the PYROCO Mark 1 pilot unit in 2021 at Greater Western Water's Melton site, a second-generation unit (Mark 2) was developed, incorporating design improvements based on learnings from Mark 1. These included an enhanced reactor configuration and an upgraded gas-cleaning system. In 2023, the Mark 2 unit was operated continuously for 14 days, treating a total of 923 kg (dry basis) of feedstocks, including biosolids, food and garden organics, and canola straw.

The trial demonstrated safe and stable operation across chemically and physically diverse *feedstocks. A comprehensive analysis of all product and waste streams was conducted by an independent NATA-accredited laboratory. PFAS compounds were below detection limits in all biochar, scrubber water, and flue gas samples, with the thermal oxidiser effectively destroying PFAS, dioxins, and furans. The resulting biochar exhibited high carbon stability, retained key nutrients, and displayed favourable agronomic properties. The co-pyrolysis of canola straw and biosolids produced biochar with particularly high nutrient retention and low metal content. The scrubber water met all trade waste limits and was safely discharged into the treatment plant inlet.*

Mass and energy balance data confirmed low external energy input requirements, even for high-ash, low-calorific feedstocks. This study demonstrates the successful scale-up of the PYROCO system and its potential as a next-generation solution for safe and sustainable biosolids management in Australia.

KEY WORDS

Biosolids, pyrolysis, PYROCO, Biochar, pilot trials

BIOGRAPHY

Include a short biographical (100 words) for the presenting author

Dr. Nimesha Rathnayake is a Lecturer in the Department of Chemical and Environmental Engineering at RMIT University, Melbourne, and an early-career researcher with expertise in sustainable waste management. She is an affiliated member of the ARC Training Centre for the Transformation of Australia's Biosolids Resource and an active contributor to the innovative Resources and Waste Technologies (iRWT) research group. Dr. Rathnayake's research focuses on advancing thermochemical technologies for biosolids treatment, including pyrolysis and co-pyrolysis, with a particular emphasis on the fate of per- and polyfluoroalkyl substances (PFAS) during thermal processes.

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