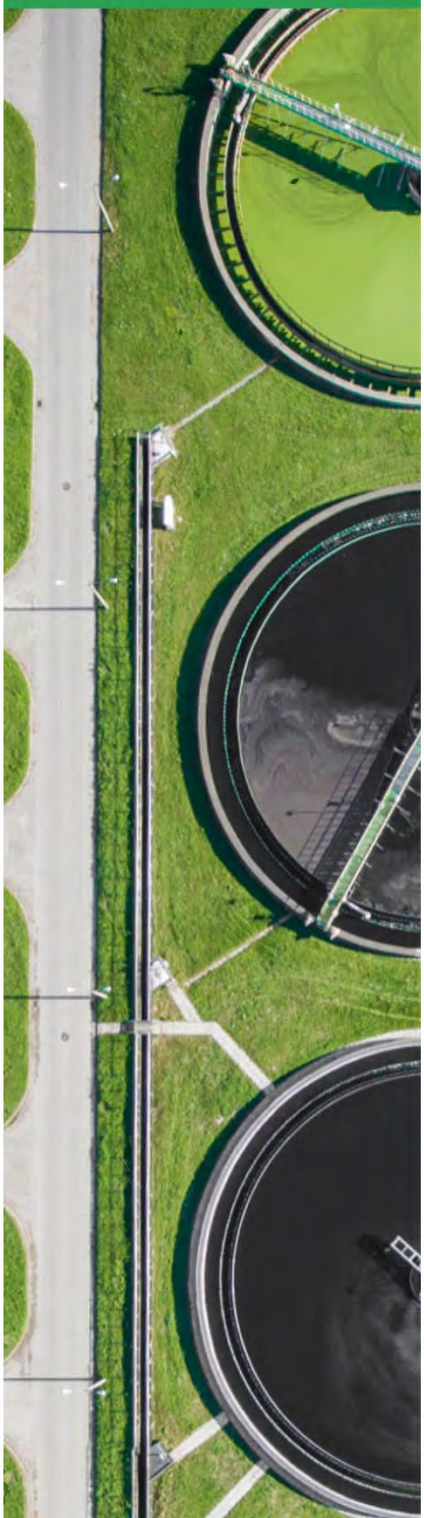
Transforming Biosolids



Enhancing Resource Recovery Through Thermal/Hydrothermal Processing

(Project 1B)

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June 2025

A report of a study funded by the ARC Training Centre for the Transformation of Australia's Biosolids Resource

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About the Centre

The ARC Training Centre for the Transformation of Australia's Biosolids Resource has a primary goal of delivering world-class and innovative technological solutions and knowledge, to train the next generation of biosolids practitioners in cutting-edge, transformational approaches, and to guide best practice in the biosolids sector.

About the Project

This document provides an integrated overview of two major streams of work under Project 1B of the ARC Training Centre for the Transformation of Australia's Biosolids Resource. Appendix 1 presents the industry-oriented outcomes of the **Biosolids Transformation Technology Assessment (BTTAS): A Systematic Approach Involving Selection Criteria and Benchmarking based Analysis**, while Appendix 2 summarises the **PhD-led research on hydrothermal treatment of sewage sludge**. Together, these efforts address key industry priorities: benchmarking of advanced thermal and hydrothermal technologies, assessment of contaminant fate, and development of decision-support tools for utilities.

Outcomes from the BTTAS Project (Appendix 1)

The BTTAS project developed a decision-support tool that integrates mass and energy balances, techno-economic models, and EPA compliance benchmarks into an accessible Excel/VBA platform. Two core modules were created:

- **BTTAS-SC (Selection Criteria):** enables utilities to filter technologies based on customised performance indicators.
- **BTTAS-BM (Benchmarking Module):** provides high-level evaluation of energy balances, costs, emissions, and product yields.

Key outcomes include:

- Benchmarking of pyrolysis, gasification, and hydrothermal processes under Australian conditions.
- Development of correlations for mass and energy balance, calorific value, ash content, organic elements compositions and product yields based on >200 journal sources and in-house experimental data.
- Engagement with regulators (EPA VIC/NSW/QLD, DWER WA) to align outputs with compliance requirements.

- Demonstrations to utilities and presentation at the 4th and 5th ARC Annual Biosolids Symposium in Perth (2024) and Melbourne (2025), respectively.

Publications from BTTAS

- Critical review on Current understanding on the transformation and fate of per-and polyfluoroalkyl substances before, during, and after thermal treatment of biosolids (*Chemical Engineering Journal*, 2024).
- Critical review on Thermal treatment options for biosolids management (*Environmental Science: Water Research and Technology*, 2025).

Outcomes from the PhD Hydrothermal Project (Appendix 2)

The PhD project examined the integration of anaerobic digestion with hydrothermal treatment (HT) of various sludge types (primary, thickened WAS, and digested sludge), including co-processing with alum sludge (AlS) and food and garden organics (FOGO).

Key findings include:

- **Feedstock-specific behaviour:** primary sludge produced superior hydrochar and bio-oil yields compared to TWAS or digested sludge.
- **Co-processing benefits:** addition of AlS improved product properties and reduced heavy metal content, while FOGO enhanced hydrochar's fuel value.
- **Contaminant fate:** PFAS degradation exceeded 99% for PFOA under hydrothermal conditions, though PFOS degradation remained limited (~41%). Heavy metals were redistributed depending on catalytic vs. co-HT conditions.
- **Integration with anaerobic digestion:** highest methane yields achieved when combining primary sludge with liquid fractions from hydrothermally treated TWAS, showing strong potential for energy recovery pathways.

Publications from PhD Project

Five Q1 journal papers have been published to date:

1. Review on PFAS and contaminant fate in hydrothermal treatment (*Current Opinion in Green and Sustainable Chemistry*, 2024).
2. Comparative study of sludge types in HT processes (*Journal of Industrial and Engineering Chemistry*, 2025).
3. Co-processing of sewage sludge with AlS and FOGO (*Journal of Environmental Chemical Engineering*, 2025).
4. Catalytic and co-HT for hydrochar quality and PFAS fate (*Journal of Water Process Engineering*, 2025).
5. Integration of HT with anaerobic digestion in the content of water recycling plants (*Bioresource Technology*, 2025)

Conference presentations include ICOSSE 2025 (Auckland), NextWater 2025 (Melbourne), and multiple ARC Biosolids Symposia, further extending industry engagement

Combined Impact

Together, these projects deliver a comprehensive decision-support tool and evidence base resource recovery solution for water utilities:

- BTTAS provides a practical benchmarking and technology selection tool.
- The PhD project supplies fundamental experimental data on sludge transformation, co-treatment synergies, and contaminant pathways.
- The outputs directly address objectives from the original research plan, including techno-economic feasibility, fate of contaminants (PFAS, heavy metals), and integration of hydrothermal processes with anaerobic digestion