Chemeca2026
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28 – 30 September 2026
Melbourne, Australia

Hazards Australasia 2026

Chemeca 2026 and Hazards Australasia
28 – 30 September, Melbourne, Australia

Development of Porous Amine-Based Absorbents for Direct Air Capture of CO_2

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ABSTRACT

The increasing concentration of atmospheric carbon dioxide (CO_2) has intensified the need for scalable and energy-efficient carbon removal technologies. Direct air capture (DAC) is a promising approach for achieving negative emissions; however, its large-scale application and deployment remain challenging due to the very low concentration of CO_2 in the air (~420 ppm) and the need for adsorbents that perform effectively under variable atmospheric conditions.

This study investigates the development of porous amine-based adsorbents for DAC applications. A range of porous support materials was functionalised with polyamine and systematically evaluated for their suitability for capturing CO_2 from atmospheric air. The materials were characterised using complementary physicochemical techniques, while fixed-bed dynamic breakthrough experiments were conducted under representative DAC conditions to investigate adsorption behaviour, regeneration performance, and cyclic stability.

The results demonstrate that material composition, porous support characteristics, and operating conditions strongly influence CO_2 capture performance. Selected amine-functionalised adsorbents showed effective CO_2 uptake at low concentrations, reversible adsorption-desorption behaviour, and promising performance over repeated cycles. The materials were also evaluated under humid conditions to assess their potential for operation in realistic atmospheric environments.

Overall, this work highlights the potential of porous amine-based adsorbents for direct air capture and provides a basis for further optimisation of material formulation, regeneration conditions, and structured adsorbent design toward scalable DAC systems.

KEY WORDS

Adsorbent, Adsorption, Amine Functionalised Adsorbent, Gas separation, Direct Air Capture, Carbon Capture, Carbon Technology, Cyclic Operation

BIOGRAPHY

Thi Hong Tran is a PhD candidate in Chemical Engineering at Curtin University, specialising in advanced materials for Direct Air Capture (DAC). Her research focuses on the development of 3D-printed, amine-functionalised adsorbents to enhance adsorption efficiency under ambient conditions. She has a background in polymer engineering and experience in various fields, including plastic recycling, chemical process engineering and sustainability practice. Throughout her career, she has consistently promoted sustainable development and addressed the issue of global warming. Hong has also contributed to sustainability initiatives through her work under the United Nations Development Programme in Southeast Asia. Passionate about bridging academia and industry, she aims to develop scalable solutions for climate change mitigation and resource efficiency.

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