INSIGHTS INTO THE HETEROGENEITY OF COAL FLY ASH WASTE

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Master of Science (Major Component Research)

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Thesis submitted in partial fulfillment of the requirements for the degree
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DECLARATION

I declare that this is my own work and this Thesis does not incorporate without acknowledgement any material previously submitted for a Degree or Diploma in any other University or Institute of higher learning and to the best of my knowledge and belief it does not contain any material previously published or written by another person except where the acknowledgement is made in the text. I retain the right to use this content in whole or part in future works (such as articles or books).

Signature: Date: 03 May 2024

The supervisors should certify the Thesis with the following declaration.

The above candidate has carried out research for the Master of Science (Major Component Research) Thesis under our supervision. We confirm that the declaration made above by the student is true and correct.

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ABSTRACT

Coal is a well-known workhorse for power generation, particularly in developing countries, due to its favourable economic benefits such as low cost, wide availability, and minimal infrastructure. However, coal-fired power plants yield a substantial by-product, known as coal fly ash (CFA), with a global annual output of 1 billion tons during combustion. Only 60% of this CFA is presently used, whereas the rest is disposed of in the environment, contributing to severe environmental pollution. In contrast, CFA is a versatile material that can serve as an adsorbent, fertiliser, and in advanced material applications, offering a promising dimension for its use. This study addressed the multifaceted potential of CFA components, by probing its seldom-explored heterogeneity through advanced characterisation techniques. While existing research has predominantly focused on isolated extractions, neglecting broader applications, this study proposes a comprehensive strategy centred on the strategic implementation of washing cycles. Integral to this approach is an extensive characterisation campaign employing multi-modal imaging techniques, such as scanning electron microscopy and energy-dispersive X-ray spectroscopy combined with state-of-the-art deep learning algorithms and digital image processing techniques. Through these methods, this study uncovered and extracted various valuable constituents from CFA, notably cenospheres and materials conducive to zeolite synthesis, demonstrating their potential as effective adsorption agents. Furthermore, this study pioneered a novel methodology that combined X-ray microanalysis with deep learning to precisely classify and characterise cenospheres. This breakthrough facilitated a comprehensive understanding of these hollow structures and allowed quantification of their imperceptible physical structures to modify them as efficient adsorbents. The results of this study significantly contribute to elucidating the capabilities of CFA as a source of high-performance adsorption agents. By leveraging innovative techniques and holistic approaches, this study advances our understanding of CFA, and offers a pioneering methodology for sustainable waste management and resource recovery.

Keywords: Coal fly ash, Cenosphere, X-ray microanalysis, Deep learning

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LIST OF ABBREVIATIONS

Abbreviation	Description
BSE	back-scattered electron
CFA	coal fly ash
CPU	central processing unit
CT	computed tomography
DB	disperse blue
DIP	digital image processing
DO	disperse orange
EC	electrical conductivity
EDS	energy-dispersive X-ray spectroscopy
ENC	entering cell wall
EPMA	Electron probe X-ray microanalysis
EXC	exiting cell wall
GPU	graphics processing unit
IOU	intersection over union
LCA	life cycle assessment
MB	methylene blue
MC	Monte Carlo
MSE	mean squared error
PSD	particle size distribution
REEs	rare earth elements
RMSE	root mean square error
SAM	Segment Anything Model
SD	standard deviation
SE	secondary electron
SEM	Scanning Electron Microscope
SSRs	secondary solid residues
XRD	X-ray diffraction