

Optimization of Adsorption and Multi-Contaminant Removal in Pharmaceutical Wastewater Using Coagulation, Coconut Shell Activated Carbon, and Biochar

By

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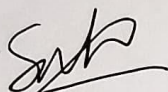


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03 February 2026

STATEMENT BY THE AUTHOR

I hereby declare that this submission is my own work and to the best of my knowledge, it contains no material previously published or written by another person, nor material which to a substantial extent has been accepted for the award of any other degree or diploma at any educational institution, except where due acknowledgement is made in the thesis.



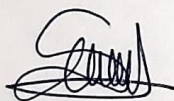
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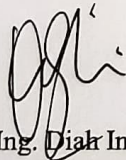


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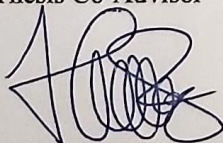


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ABSTRACT

Optimization of Adsorption and Multi-Contaminant Removal in Pharmaceutical Wastewater Using Coagulation, Coconut Shell Activated Carbon, and Biochar

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Pharmaceutical manufacturing effluents typically comprise complex aqueous matrices containing dissolved heavy metal ions and recalcitrant organic pharmaceutical compounds, which present substantial environmental and public health hazards in the absence of adequate remediation. The present investigation evaluated a sequential hybrid treatment system integrating coagulation with poly aluminium chloride (PAC) as a primary unit process, followed by adsorptive treatment employing coconut shell-activated carbon (AC) and thermally-converted animal bone biochar for the simultaneous removal of zinc (Zn^{2+}) cations, calcium cations (Ca^{2+} , serving as an indicator of water hardness), and acetaminophen. Batch-mode experimental protocols were implemented to systemically optimize critical operational parameters, including adsorbent loading rate, solution pH, and solid-liquid contact duration. The coagulation stage functioned as a preliminary treatment operation to facilitate colloidal destabilization and suspended particulate matter reduction, thereby enhancing the mass transfer characteristics and sorption performance of the subsequent adsorption processes.

Under systemically optimized operational parameters (pH 6.5-7.5, contact time of 23 hours, single adsorbent CSAC of 20 grams and also combined biochar of 8.263 grams and CSAC of 20 grams), the integrated coagulation-adsorption treatment system demonstrated removal of paracetamol to 110.6 ppm and zinc to 0.3 ppm.

Keywords: *adsorption; polyaluminium chloride (PAC); activated carbon; biochar; zinc removal; calcium removal; acetaminophen; pharmaceutical wastewater treatment*



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DEDICATION

This thesis is dedicated to the future of sustainable wastewater treatment systems.

To the engineers, scientists, and researchers who continue to believe that clean water is not a privilege, but a universal right.

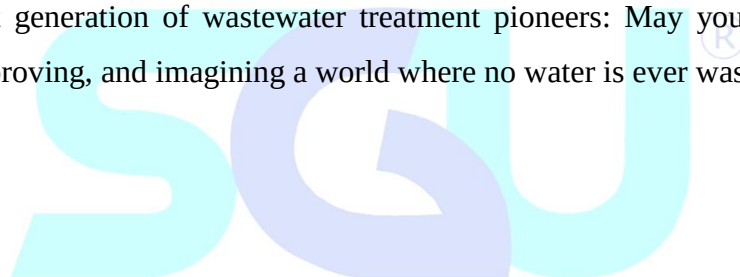
To the innovators who refuse to accept that industrial progress must come at the expense of the environment.

To those who relentlessly pursue solutions – sometimes without recognition, often without certainty – driven only by the belief that every drop of water saved today will matter for future generations.

May this work become a small contribution toward systems that are more efficient, more responsible, and more humane.

May it inspire better decisions, cleaner processes, and technologies that protect both people and the planet.

And to the next generation of wastewater treatment pioneers: May you never stop questioning, improving, and imagining a world where no water is ever wasted.



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First and foremost, I would like to express my deepest appreciation to Silvy Yusri [M.Si](#), my thesis advisor. Thank you for your patience, insightful criticism, and for always challenging me to think deeper and work with integrity. Your guidance has shaped my way of approaching research, and I am truly honored to have learned from you.

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To my dearest Mom and Dad, thank you for your sacrifice, prayer, and unconditional love. Everything I achieve in life is rooted in your patience and guidance. You taught me perseverance, humility, and the value of hard work. I am forever grateful.

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Lastly, I would like to thank my friends, classmates, and everyone in the laboratory and department who has helped, supported, and believed in me. Each of you contributed a piece to this journey, and I carry that gratitude with me.

This thesis is not just a document. It's a testament to every prayer, every sacrifice, every moment of doubt, and every act of kindness I have received along the way.

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