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Transforming local waste into value: Activated carbon from brewery sludge for sustainable phosphate removal

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INTRODUCTION & AIM

Phosphate pollution from industrial wastewater remains a critical threat to aquatic ecosystems due to eutrophication and nutrient imbalance. Addressing this challenge requires sustainable and locally adaptable solutions [1,2].

This study presents an environmentally conscious approach to converting brewery sewage sludge (an abundant local waste in Gondar, Ethiopia) into activated carbon for phosphate removal. The concept integrates waste valorization with circular water management, reducing disposal burdens while producing efficient adsorbent materials.

METHOD

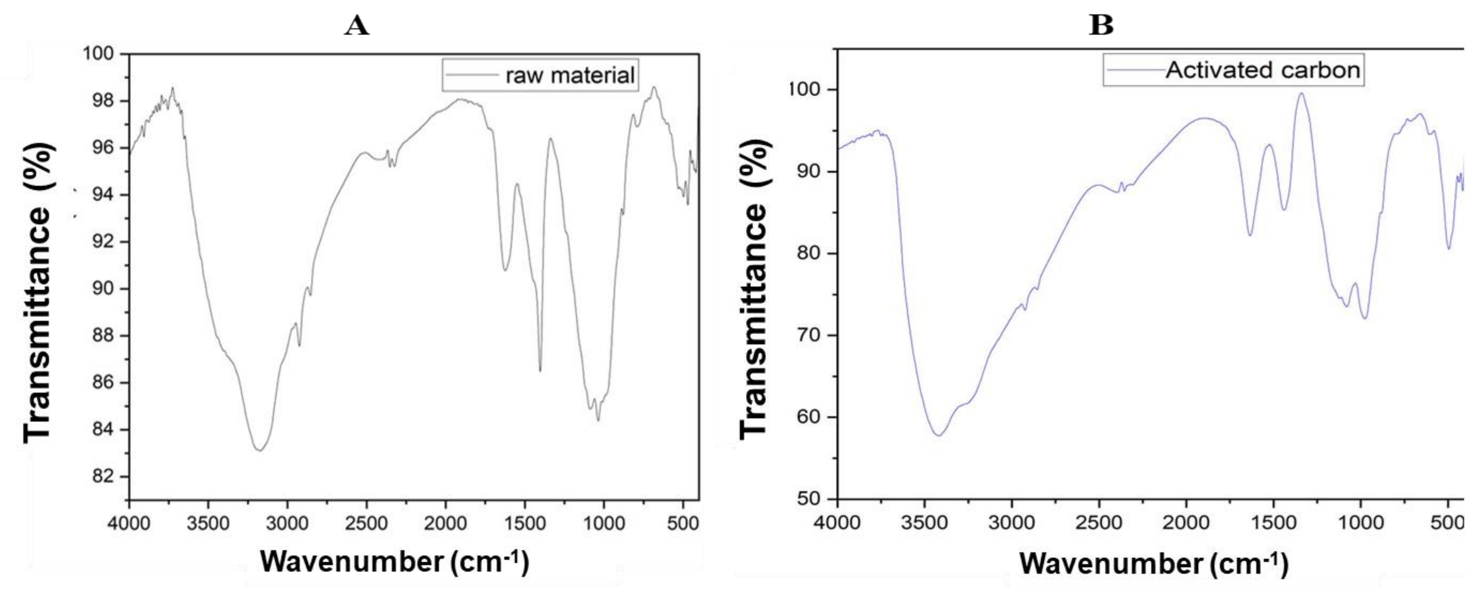
Sewage sludge was chemically activated using phosphoric acid (H_3PO_4) and sodium hydroxide (NaOH), followed by controlled thermal treatment. Physicochemical properties were analyzed using FT-IR, BET surface area, pH_{pzc}, and proximate analysis. Batch adsorption tests were optimized via Response Surface Methodology (Design Expert 13.0.5) under varied pH (3–10), contact time (60–120 min), and adsorbent dosage (1–3 g).

CONCLUSION

- Activated carbon from Dashen Brewery sludge ($NaOH/H_3PO_4$, 400 °C) effectively removed phosphate.
- Efficiency increased with adsorbent dose and contact time, but decreased at higher pH.
- Langmuir isotherm and pseudo-second-order kinetics indicate chemisorption.
- The adsorbent retained >50% efficiency after three regeneration cycles.
- Brewery sludge is a promising low-cost, reusable adsorbent supporting circular economy goals.

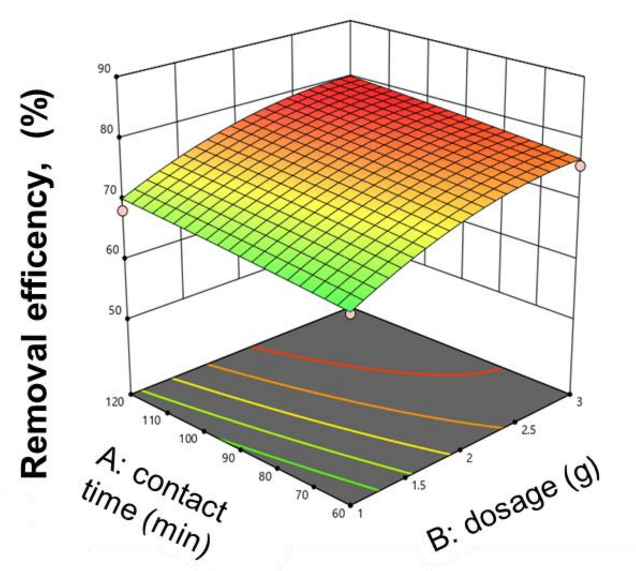
RESULTS & DISCUSSION

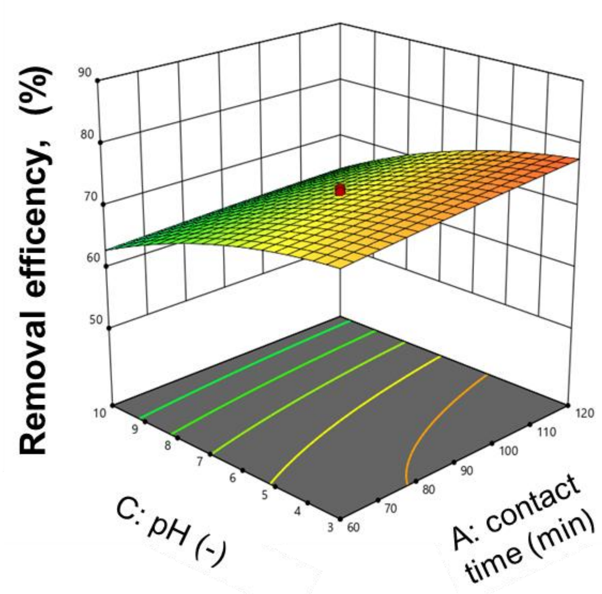
FTIR spectra analysis of raw (A) and activated sludge (B)

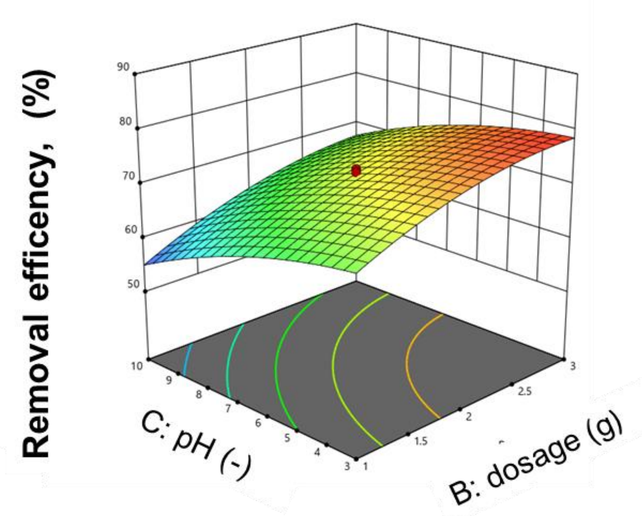


Brunauer-Emmett-Teller (BET) surface area analysis:

- raw sludge: 80.573 m^2/g
- activated sludge: 427.052 m^2/g





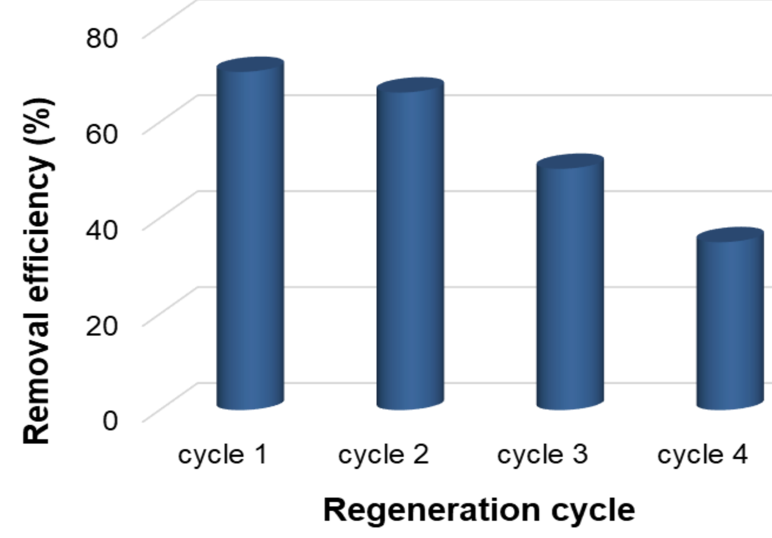


3D surface plot of removal efficiency as a function of: (A) dose and contact time, (B) pH and contact time, (C) pH and adsorbent dose

Summary of isotherms, kinetics constants and R^2 values

Model	Langmuir isotherm			Freundlich isotherm		
Constant	q_m, mg/mg	K_L L/mg	R^2	Kf, mg/g	1/n	R^2
Value	10.13	1.08	0.981	1.3867	0.1897	0.936
Model	pseudo-first-order			second-order		
Constant	q_e, mg/mg	K_1 min^{-1}	R^2	q_e, mg/mg	K_2 $(g/mg)min^{-1}$	R^2
Value	10.13	1.08	0.9257	1.3867	0.1897	0.992

Effect of regeneration cycle on removal efficiency



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