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Title of Thesis: Study on Anaerobic Ceramic Membrane Bioreactor Treating Low Strength Wastewater

Findings

This work assessed the performance of agro-industrial waste sugarcane bagasse ash (SBA)-based ceramic membranes (CMs), i.e., SBA-CMs, in an anaerobic membrane bioreactor (AnMBR) treating simulated low-strength wastewater representing urban drain wastewater (chemical oxygen demand, COD 180-200 mg/L).

The study examined the AnMBR operation in two configurations, continuous and sequential batch reactor (SBR) modes. The hydraulic retention time (HRT) varies from 48 to 10 h accompanied by shutdown periods (1.5-3 months). The results suggest SBR as the optimal reactor configuration for an AnMBR system equipped with waste-derived CMs under studied operational conditions. This study reveals that variations in the HRT and intermittent starvation did not affect the average COD removal, indicating the AnMBR could tolerate unregulated or seasonal influent variations which could aid in designing and maintaining non-automated decentralized treatment setups.

SBR-AnMBR operation at a high target flux of 19.4 L/m^2 h and optimal 18 h HRT achieved an operational flux of 17.8 L/m^2 h, 8% less than the desired flux. However, this was still higher than the other waste-based CMs in MBRs (<15 L/m^2 h). This performance highlights the potential of SBA-CMs as a viable and efficient option for full-scale AnMBR applications.

The study on sludge parameters identifies key membrane foulants and suggests possible fouling mechanisms. The study follows the screening of a suitable SBA-CM out of three (one with no secondary layer and two with a secondary layer) followed by finding the optimal operating mixed liquor suspended solids (MLSS) concentration. After this, the SBR-AnMBR system was operated over 64 days using selected SBA-CM (with no secondary coating) at optimal MLSS

concentration (2.5 g/L). Fouling control strategies, including filtration-relaxation, backflushing and physical cleaning, allowed stable operation at 14.9 L/m^2 h. Analytical techniques such as ATR-FTIR, PSA and SEM were used to investigate the responsible foulants viz., extracellular polymeric substances (EPS), colloids and non-settleable micro-particles. This study offers insights into fouling and effective fouling control strategies, which could facilitate the broader application of these waste-derived membranes in the wastewater sector.

The potential reuse of spent SBA-CMs as media in an upflow biological reactor (UBR) for low-strength wastewater treatment at HRTs ranging from 48 to 6 h was investigated. Optimal performance was achieved at a 12 h HRT, with COD removal efficiency of ~85% and low effluent solids concentration of 6.2 mg/L. Over 163 days of operation, the ceramic media showed minimal porosity reduction (~3%), demonstrating durability and effectiveness. This study highlights the feasibility of reusing SBA-CMs, promoting sustainability and reducing waste in environmental management.

Finally, a cost analysis of SBA-CMs produced at both laboratory and industrial scales was done, followed by an LCC evaluation of a decentralized AnMBR system with a capacity of 50 m^3/d. The analysis revealed that lab-manufactured SBA-CMs cost \$93.6/m^2, significantly lower than conventional CMs (\$350 to \$700/m^2). At an industrial scale, SBA-CMs cost could be further reduced to \$22.3/m^2. The LCC analysis underscored the economic advantages of SBA-CMs, highlighting their potential to significantly lower costs in decentralized wastewater treatment systems while maintaining efficiency and sustainability.