Sewage sludge stabilization through indigenous microalgae promoting growth: performance in a 20L tubular photobioreactor

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Sewage sludge poses a significant environmental challenge in wastewater treatment, requiring sustainable and cost-effective solutions. This study introduces a closed-loop system using native microalgae growth, where microalgae produce oxygen to degrade organic matter through heterotrophic bacteria, while utilizing the bacteria's CO_2 emissions for growth. This self-sustaining system eliminates the need for external oxygen input and minimizes greenhouse gas emissions, offering dual benefits of sludge stabilization and resource recovery.

Building upon prior success in 1L PhotoBioReactors (PBR) where 47.55% volatile solids (VS) reduction, 6.72-log *E. coli* removal, complete Salmonella eradication, and 71.42% settleability improvement were achieved over 20 days (Ben Hamed et al. 2024), we scaled the process to a 20L tubular photobioreactor (Figure 1) for industrial validation.

Figure 1. Photobioreactor used in this study.

Sludge collected from the secondary tank of the wastewater treatment plant (Grosse Batte, Liège, Belgium) was diluted with treated wastewater to reduce opacity and achieve a target solids concentration: 4.5 ± 0.3 g/L. The PBR, equipped with eight cool-white fluorescent lamps (Philips, 12h/12h light-dark cycle) and operated under continuous agitation (70 rpm) at ambient temperature, maintained a closed configuration to maximize microalgae /Bacteria gas exchange efficiency. The treatment process lasted for 20 days.

The results demonstrated significant physicochemical changes during microalgae-assisted sludge stabilization. Notably, the pH increased from 7.08 to 8.56 due to CO_2 uptake by microalgae, peaking at 9.21 on day 14, confirming strong photosynthetic activity on this day. The dissolved oxygen (DO) also increased, reaching 11.5 mg/L due to intense photosynthetic activity by the microalgae. Volatile solids (VS) decreased by 66.9% and surpassed the EU stabilization threshold (38-40%), while total solids (TS) declined by 22.2%, demonstrating an effective sludge mass reduction. Furthermore, indigenous microalgae growth, tracked via chlorophyll (a) concentration, increased 7.6-fold (from 0.236 ± 0.038 to 1.793 ± 0.0107 mg/mL), validated by microscopic observation.

Sludge settleability improved significantly, with a 58.5% reduction in sludge volume index (SVI) from 131 ± 6.10 to 54.39 ± 4.27 mL/g, due to changes in extracellular polymeric substance (EPS) profiles (Ben Hamed et al. 2025)This enhancement supports system scalability. Future bacteriological analyses will assess Salmonella and *E. coli* eradication to validate compliance with agricultural reuse standards.

References

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