Assessment of chemical interactions in anaerobic digester effluent and bio-based strategies for nutrient utilization

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Abstract

Anaerobic digester effluents typically contain high concentrations of C, N and P that contribute to environmental pollution. The aim of this study, being performed on effluent of an Induced Blanket Reactor (IBR, a commercial anaerobic digester system for treating dairy waste) is to: (1) elucidate chemical interactions within the effluent system and, (2) evaluate biological strategies for nutrient utilization and generation of higher value products.

Assessment of Chemical Interactions

Methodology:

The complex interactions of nutrients (especially P) with other chemical species present in anaerobic digester effluent dictates their bio-availability in the medium. Speciation of inorganic components in solid and liquid portions of the IBR effluent (pH = 7.98) was experimentally determined and results were theoretically compared using chemical speciation program GEOCHEM.

Results:

The GEOCHEM model predicts that 98% of inorganic or ortho-P in the medium is insoluble and is precipitated with metals like Ca, Fe, and Zn (Figure 1). Further, GEOCHEM predicts that the insoluble inorganic P can be completely dissolved only when the effluent is diluted by ~250 times or when the pH is lowered to 4.5 or less. This result was experimentally verified (Figure 2) and validates GEOCHEM predictions.

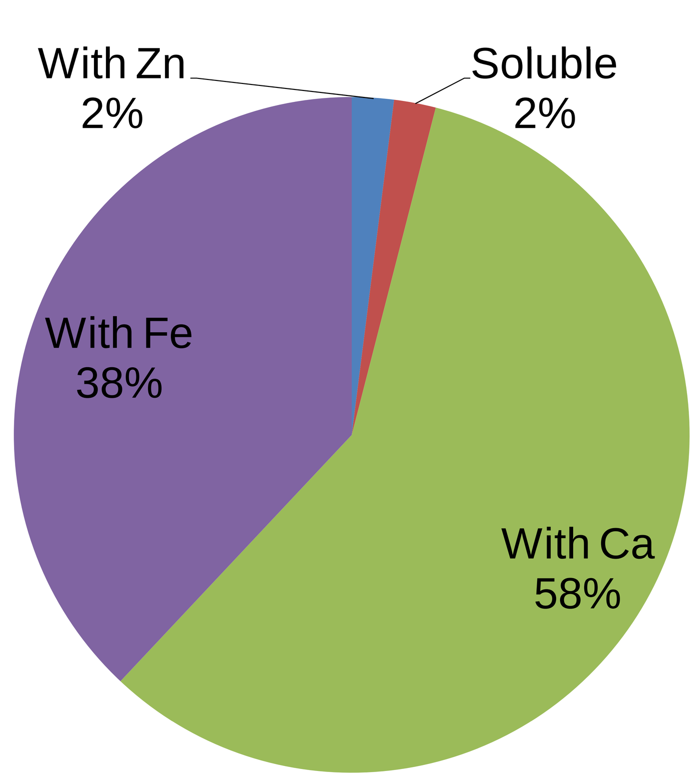

Figure 1: GEOCHEM prediction of ortho-P species in IBR effluent. Majority of the ortho-P is predicted to be insoluble and precipitated with Ca and Fe

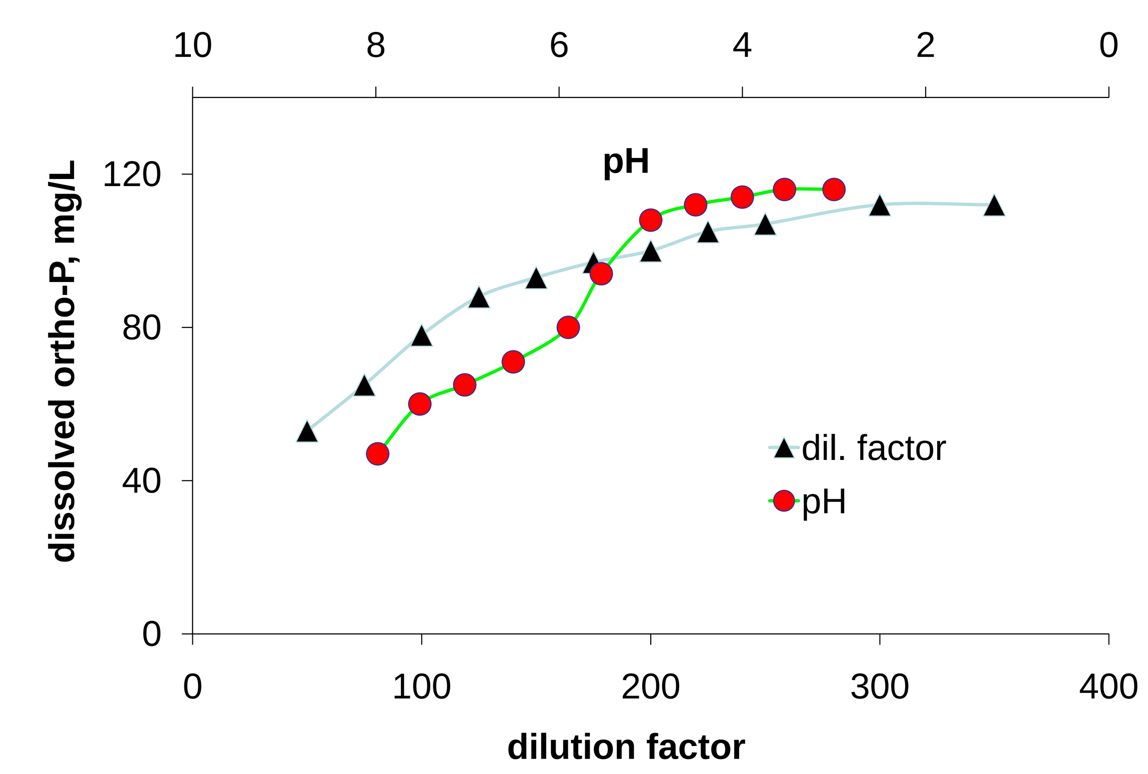

Figure 2: Effect of dilution and pH on ortho-P solubility. Near-complete dissolution is observed at pH < 4.5 or dilution > 250X

Bio-based Strategies for Nutrient Utilization

Methodology:

Two nutrient utilization strategies were studied – (1) Growth of phototrophic microorganisms on nutrients present in the effluent and , (2) Enrichment of native P-accumulating organisms (PAO) by anaerobic – aerobic cycling to perform enhanced biological P removal (EBPR). For phototrophic growth studies, effluent was diluted 40X to increase availability of inorganic P and improve penetration of light for efficient photosynthesis. Three different phototrophic microbial cultures were used - a pure microalgal strain of *Scendesmus sp.*, a pure cyanobacterial culture of *Synechocystis sp.*, and a mixed culture from Logan river. For PAO studies, indigenous microbes were stimulated using intrinsically available short chain fatty acids produced during upstream anaerobic digestion.

Results – Phototrophic growth :

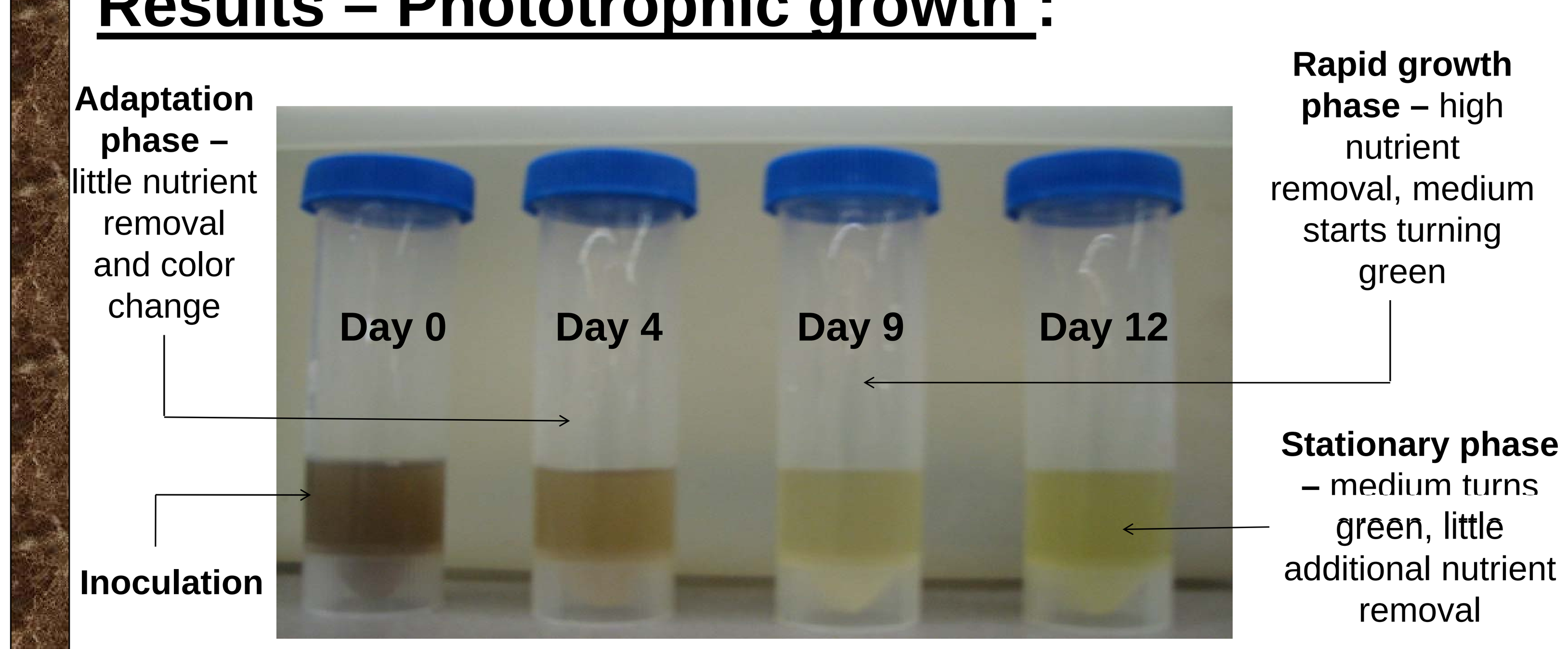

Figure 3: Logan river mixed algal culture growth on 40X diluted IBR effluent.

All three phototrophic cultures grew on IBR effluent and removed N and P, although the mixed culture from Logan river grew most rapidly (Figure 3) suggesting that natural consortia are likely more suitable for nutrient removal due to faster adaptation to the effluent medium. Overall, phototrophic growth was able to achieve up to 79% NH3-N and 55% ortho- P removal (Figure 4)

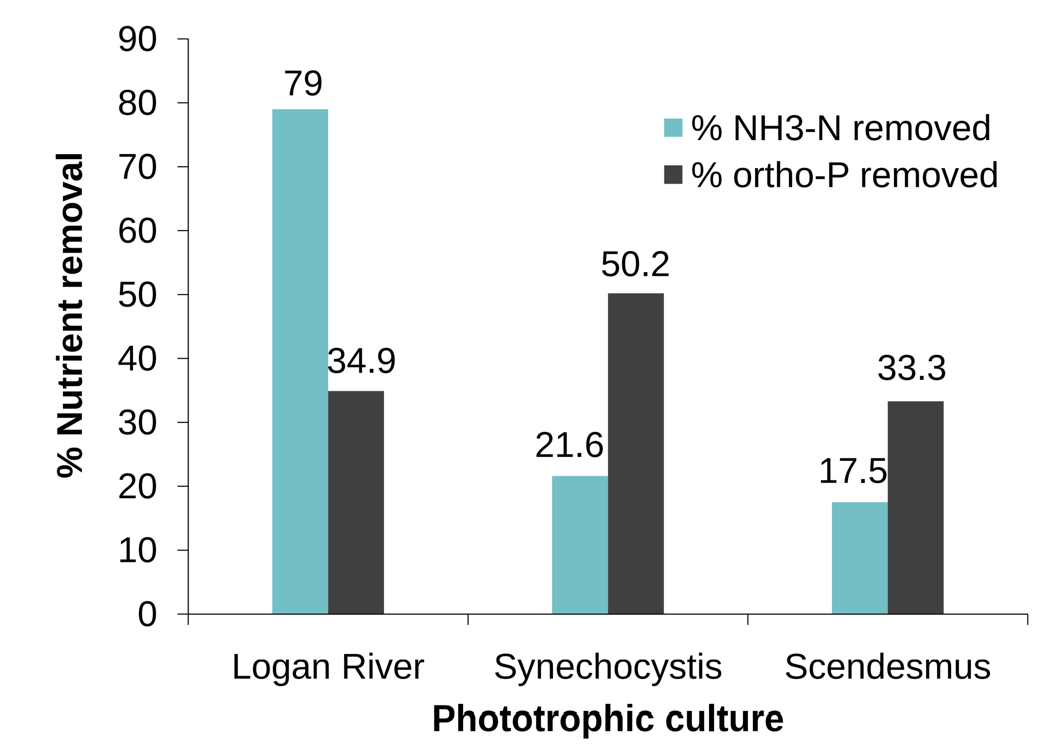

Figure 4: Nutrient removal during phototrophic growth on 40X diluted IBR effluent after 24 days.

Results – PAO growth:

57% of ortho-P was shown to be removed in six days upon aeration of effluent (Figure 5). We hypothesize that PAOs were enriched during this process and experiments involving aerobic-anaerobic cycling to simulate the EBPR process are currently in progress.

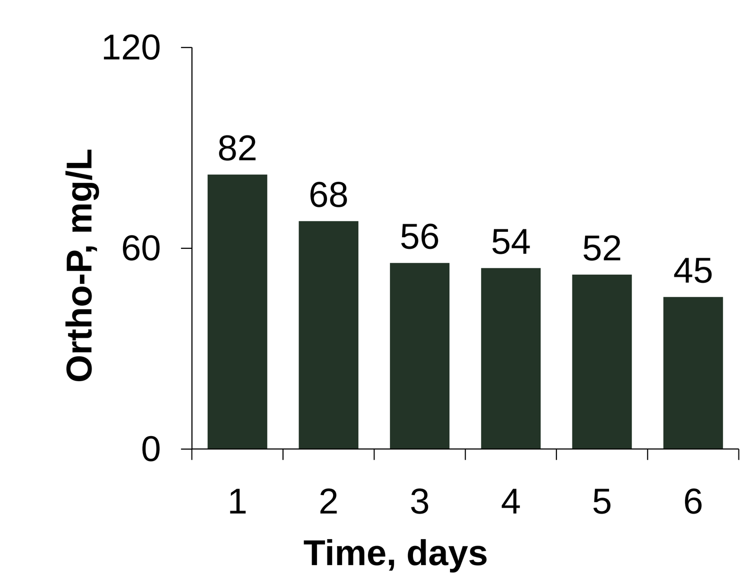

Figure 5: P-removal during aeration of IBR effluent.

CONCLUSIONS

Our results indicate that anaerobic digester effluent is suitable for both algal growth and EBPR and these bio-strategies can be taken further for the production of biodiesel from algae and bioplastics from PAOs performing EBPR. These nutrient utilization strategies not only improve the economic viability of anaerobic digester systems but also increases the energy security and environmental sustainability by production of high value byproducts.

ACKNOWLEDGEMENTS

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