Perspectives and limitations of hybrid osmotic microfiltration bioreactor for nutrients recovery

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INTRODUCTION

Membrane bioreactors (MBR) has become an attractive technology for wastewater treatment as the implementation of a microfiltration (MF) membrane ensures a high effluent quality, reduces footprint and enables independent operation of solid retention time and hydraulic retention time [1]. However, fouling of the membranes is inevitable and increases costs for operation. Therefore, osmotic MBR has been studied, which replaces the MF membranes with forward osmosis (FO) membranes, as FO membranes are less prone to fouling [2]. FO membranes retain and thereby concentrate nutrients, which makes it easier to recover, e.g. ammonia and phosphate by struvite precipitation [3]. However the higher concentration of nutrients and other salts create a high osmotic pressure and a reduced flux. In this study, MF was implemented in the osmotic MBR to make the hybrid osmotic MF MBR (HOM-MBR). By doing this, the phosphorus and ammonia is extracted through MF permeate and the concentration is controlled by the relative amount of water leaving through the FO membrane.

CONCEPT

Wastewater is treated in an MBR with three flows leaving the reactor:

- Water free from nutrients, vira and micropollutants (FO permeate, Q_{FO})
- Concentrated nutrients (MF permeate, Q_{MF})
- Sludge for biogas production (Q_{Excess})

With this configuration there are three operating variables hydraulic, solid and nutrients retention time (HRT, SRT and NRT) for a reactor with volume, V, and inlet flow, Q_{In}:

$$HRT = \frac{V}{Q_{In}} \qquad SRT = \frac{V}{Q_{Excess}} \qquad NRT = \frac{V}{Q_{MF}+Q_{Excess}}$$

Hence, the microbial, filtration and concentration processes can be controlled independently with NRT/HRT being the concentration factor. The benefits are:

- Cleaner discharge of water through FO membrane
- Direct concentration and extraction of nutrients with MF permeate
- Less demand for biological nutrient removal
- More efficient degradation of micropollutants in concentrated MF stream
- Higher biogas potential

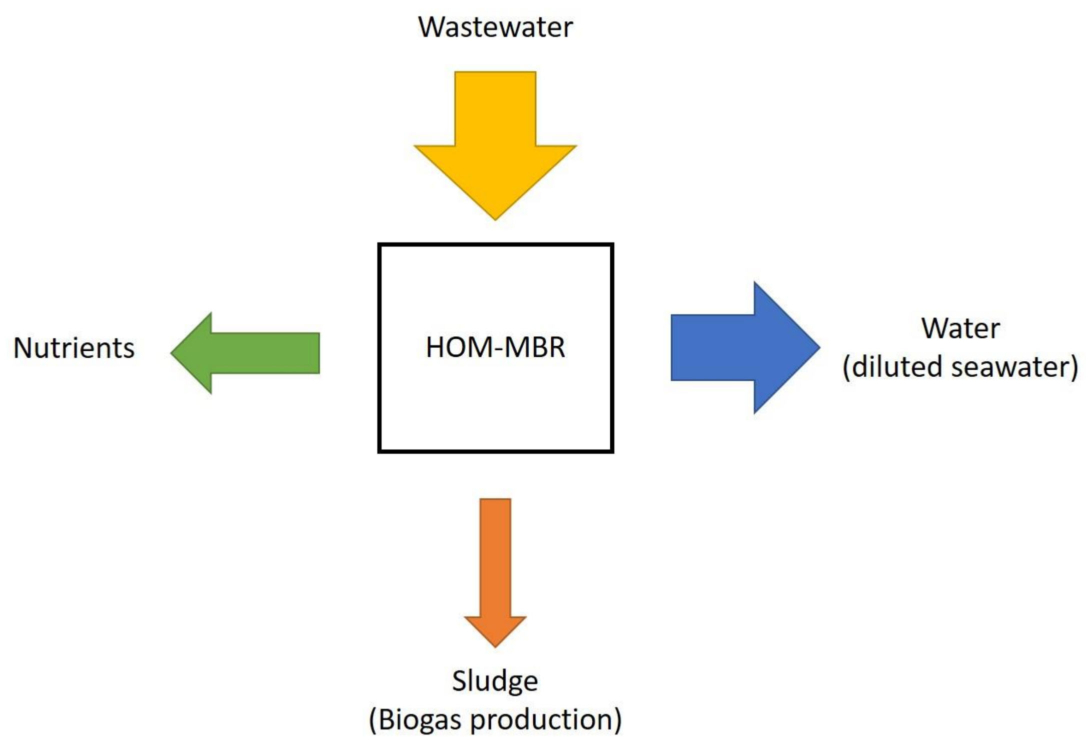

Figure 1 – Illustration of HOM-MBR system

METHODS

- A lab-scale HOM-MBR was operated for 46 days
- The reactor was fed with a synthetic substrate of nutrients, proteins and carbohydrates with a M:F ratio of 0.1 mgBOD/mg suspended solids/d [4]
- The reactor kept a sludge volume of 5L and a SRT of 20d was maintained
- The concentrated substrate was added independently of inlet water flow to keep F:M ratio independent of flow through the reactor
- MF and FO flow varied throughout the period to give HRT ranging from 6-110h and NRT ranging 30-480h
- Samples were collected daily to measure development in MLSS, conductivity, orthophosphate and NH_4-N concentration in sludge
- The degree of flocculation was characterized by the residual turbidity [4]

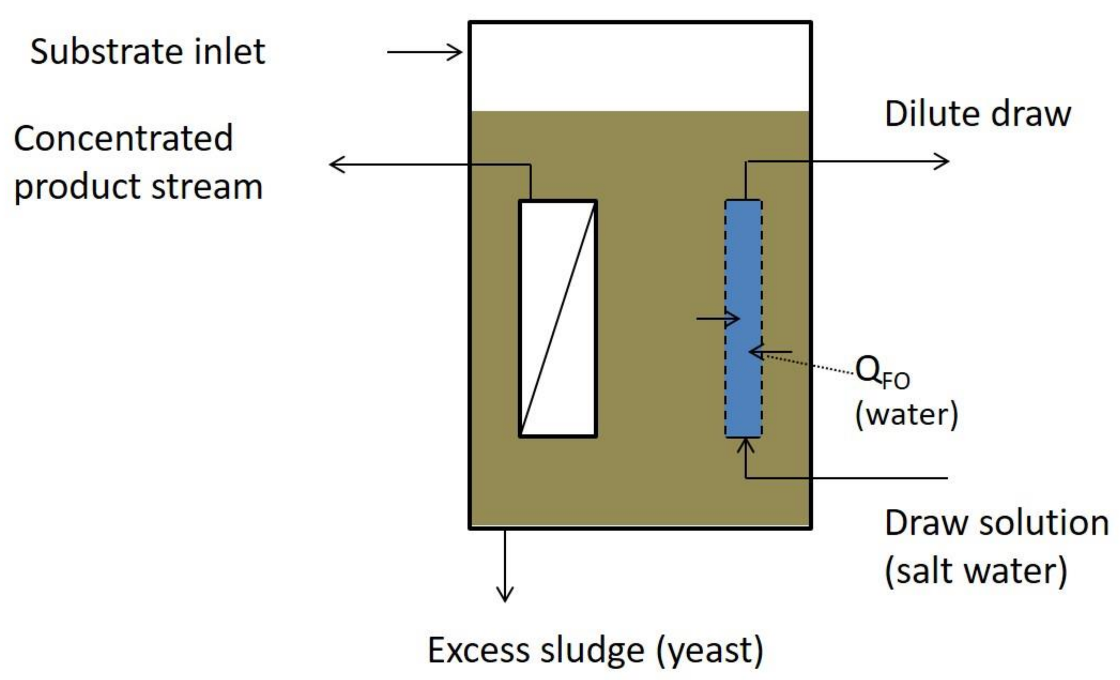

Figure 2 - Operational parameters

RESULTS AND DISCUSSION

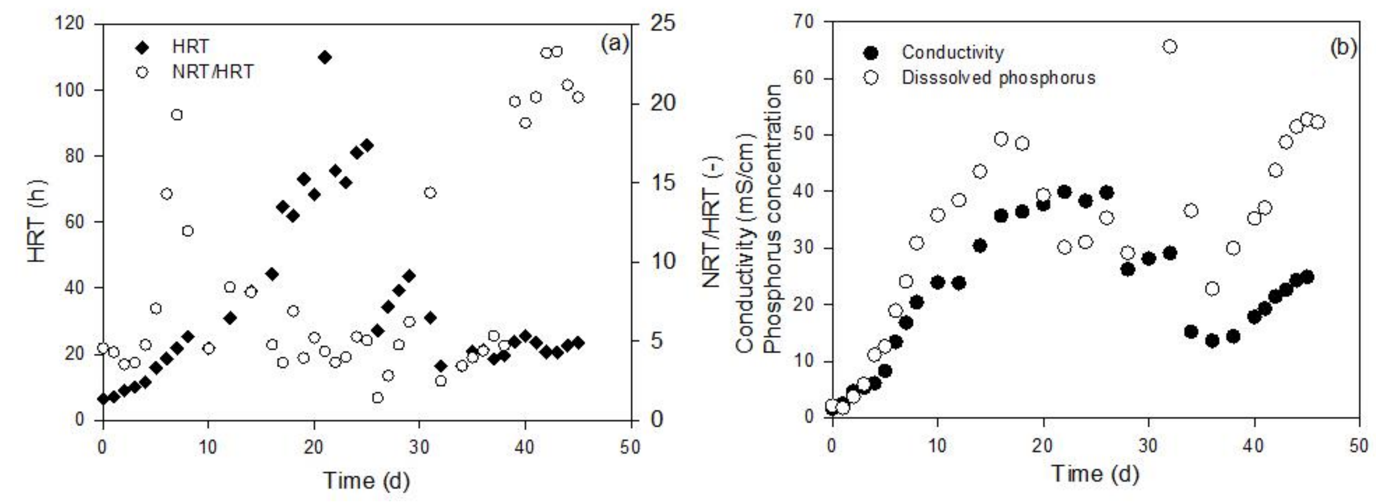

Figure 3 – HRT and NRT/HRT (a) and conductivity and dissolved phosphorus concentration in sludge plotted against time (b)

- HRT increased independently of NRT during day 10-26.
- At day 39-46 NRT was elevated independently of HRT to concentrate solutes.
- Higher HRT and NRT/HRT resulted in accumulation of salts and nutrients reflected by sludge conductivity and orthophosphate concentrations.

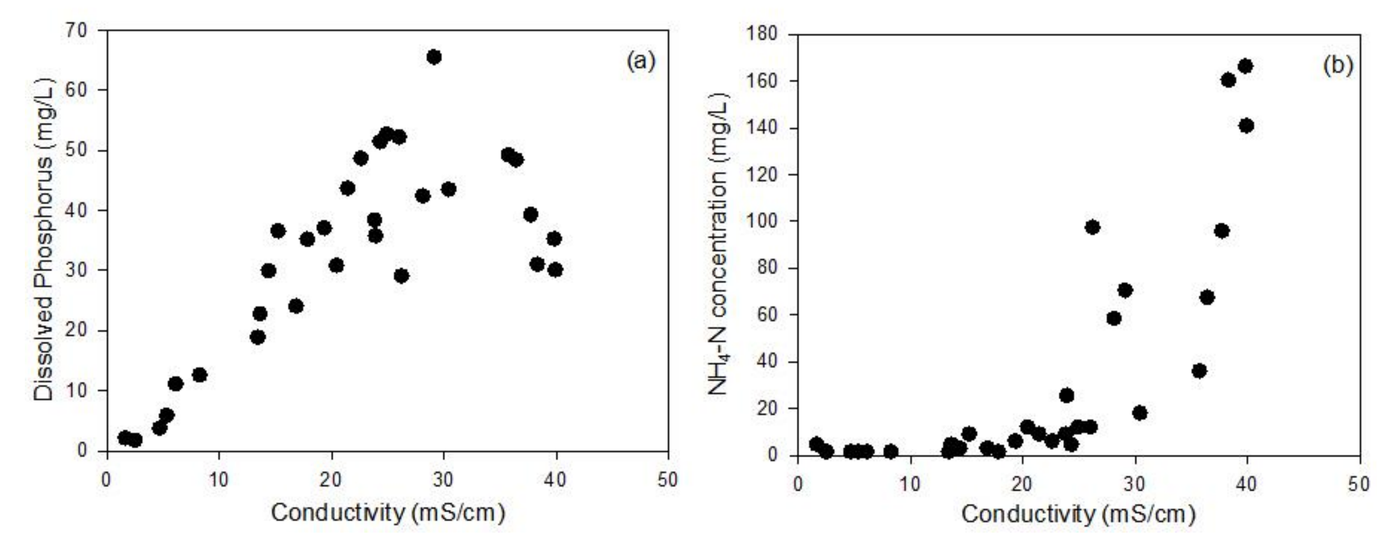

Figure 4 – Dissolved phosphorus concentration (a) and NH_4-N concentration (b) plotted against conductivity

- At high concentration factors, i.e. conductivities exceeding 25 mS/cm, phosphorus precipitation was observed.
- At conductivities above 25 mS/cm high NH_4-N concentrations were observed as a result of inhibition of nitrification.

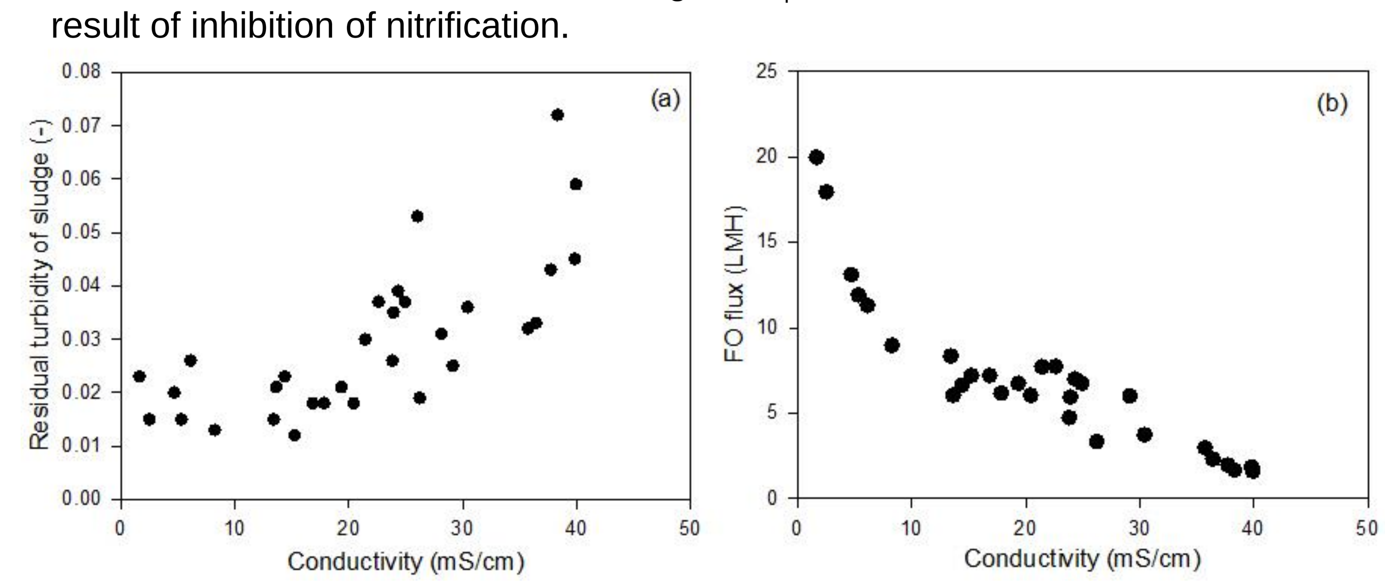

Figure 5 – residual turbidity and FO flux plotted against sludge conductivity

- A higher concentration factor of solutes and conductivity results in sludge deflocculation, which accelerates membrane fouling.
- There is a clear reduction in FO flux with higher sludge conductivity, as this increases osmotic pressure.

CONCLUSIONS

- A HOM-MBR system was developed, where the main part of water leaves through the osmotic membrane
- Increasing the relative amount of water leaving through the osmotic membrane increase the concentrations of dissolved phosphorus in the MF permeate, in this study up to 52 mg/L which potentially can be precipitated and used as a fertilizer.
- Precipitation was observed at orthophosphate concentrations above 30-40 mS/cm. As phosphorus precipitates in the reactor at high concentration factors, it will leave the reactor with the excess sludge outtake.
- Increasing the conductivity above 25 mS/cm leads to lower FO flux, deflocculation, which causes membrane fouling, and reduces microbial activity such as nitrification.

References:
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