Microalgae to recover P from small wastewater treatment plants

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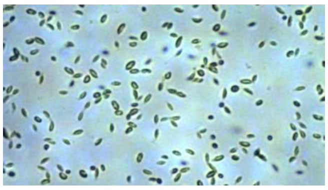
1. Introduction

Recovering P from small and remote wastewater treatment plants (WWTP) presents several challenges as suitable systems require robustness, low maintenance and ability to cope with often high variability of P concentrations in wastewater.

Scotland is considered as 97% rural with around 1600 WWTP of a capacity lower than 500PE, most of them concentrated in the northern part of the country. A large part of eutrophication potential is caused by the insufficient treatment of wastewater in septic tanks and small WWTPs.

The extremophilic microalgae *Chlamydomonas acidophila*, which grows at a pH of 2-3, appears to have potential for P recovery at these sites, as it is able to recover P and N in different wastewaters at high rates and at low light intensities.

Picture 1: Microalgae *Chlamydomonas acidophila*, (© Ania Escudero, GCU)



2. P-recovery process

A proprietary photobioreactor (PBR; Greenskill Environmental Technology Ltd.) was implemented at Scottish Water's Wastewater Development Centre in Bo'ness, Scotland.

The PBR's central unit consisted of a 500L tank fed with settled effluent (after primary treatment) at an HRT of 2.0 - 3.8 days. The microalgae biomass was retained in the PBR by a tangential flow filter utilizing hollow fibre membranes. The tank was continuously illuminated at a low rate equivalent to 0.4 Ampere electrical current.

3.1. P-recovery process results

- Recoveries/removals:
  - 50-75% $[PO_4]^{3-}$
  - 75-100% NH_4^+
  - 50% COD (reaching values close to those reported for final effluent after conventional secondary treatment)
- Robust system → maintained long-term as mono-algal culture
- Reliable biomass separation using tangential flow filtration → no foam or biofilm formation in the PBR.

Picture 2: 500L PBR implemented at Bo'ness (© Ania Escudero, GCU)

3.1. P-product results

- The biomass concentration in the PBR reached values of up to 4g L^{-1}.

Picture 3: Microalgae biomass in the 500L PBR (© Ania Escudero, GCU)

- NaOH was added to the microalgae biomass to increase the pH and favour sedimentation, yielding a microalgae paste of ~6% TS.

Picture 4: Microalgae paste after liquid separation (© Ania Escudero, GCU)

- This paste can be dried to 90% TS and ground into a powder.

Picture 5: Dried microalgae biomass (© Joanne Roberts, GCU)

4. Discussion

Most studies on microalgae use final, aerobically digested effluent to avoid inhibition derived from high concentrations of NH_4^+ and COD in primary effluents and competition with other organisms (bacteria and fungi) present in the wastewater. However, *C. acidophila* have shown to be able to grow and recover nutrients in primary settled effluent. Moreover, it removed around 50% of the COD from the primary effluent, which is close to COD removal reported for conventional secondary treatment. **Therefore, this process appears to be promising as a secondary-tertiary treatment in WWTPs.**

The potential for microalgae biomass recovery ranges from 1.3 to 2.6 Mg/y/plant, based on WWTP capacities of 100 PE - 200 PE, with an average P-content in the dry microalgae biomass of around 1.4% (41-82 kg P_2O_5/y/plant), N-content of 7%, and further main components such as plant hormones, vitamins, fatty acids and antioxidants.

5. Conclusion

Chlamydomonas acidophila microalgae technology seems to be suitable for small WWTPs as it:

- has been shown to be robust (no foaming or biofilm formation);
- can be maintained long term as a mono-algal culture (without being invaded by other species);
- can recover P and N from wastewater with high variability of nutrients;
- requires much lower light intensities to grow and consume nutrients than other microalgae used for wastewater treatment, which leads to a lower energy consumption by the PBR;
- produces microalgae biomass that could be distributed locally to support circular economy.

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