An Innovative Activated Sludge System for Enhanced Nutrient Recovery via Downstream Cultivation of Green Microalgae

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Publication date:
2014

Document Version
Publisher's PDF, also known as Version of record

Technical University of Denmark

An Innovative Activated Sludge System for Enhanced Nutrient Recovery via Downstream Cultivation of Green Microalgae

Borja Valverde-Pérez*, Elham Ramin, Barth F. Smets and Benedek Gy. Plósz**

*bvape@env.dtu.dk **beep@env.dtu.dk DTU Environment, Department of Environmental Engineering, Technical University of Denmark, Miljøvej, Building 113, 2800 Kgs. Lyngby, DENMARK

1. INTRODUCTION

Current resource recovery strategies [1]:

- Metal salt addition for phosphorus precipitation
- Ammonia stripping and recovery as salt
- Ultrafiltration
- Reverse osmosis

Disadvantages:
- High energy demand
- Requires metal salts

Resource recovery through a two-stages bacterial-algal system [2]:

- Enhanced biological phosphorus removal and recovery system (EBP2R) to produce growth media with targeted N-to-P ratios
- Optimal algal cultivation, thereby intracellularly storing both N and P
- Direct application on land for fertigation

Advantages:
- Complete biological process
- Comparably lower environmental impact

Optimal N-to-P ratio

Fertigation

2. OBJECTIVES

The goals of this study are to

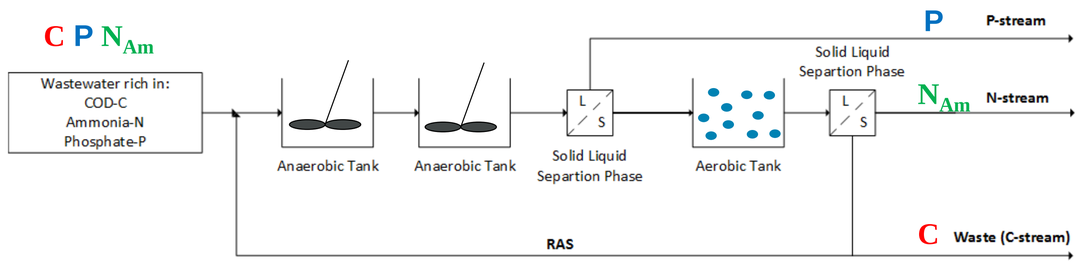
i) provide the **model-based design** of the EBP2R system

ii) **optimize** the nutrient recovery capacity

iii) analyse the sensitivity of the nutrient recovery performance with regard to the influent fractionation and biological processes through **global sensitivity analysis** (GSA)

3. METHODS

- System description:



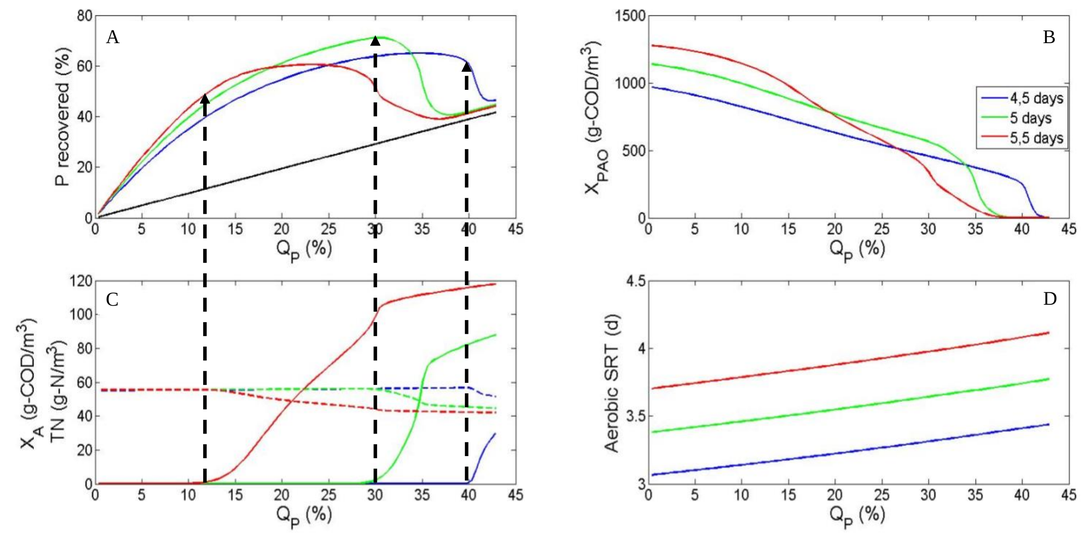
- P-stream: phosphorus rich stream diverted form the anaerobic tanks
- N-stream: ammonia rich stream obtained by keeping a comparably low aerobic SRT
- C-stream: wastage of the sludge to the anaerobic digester

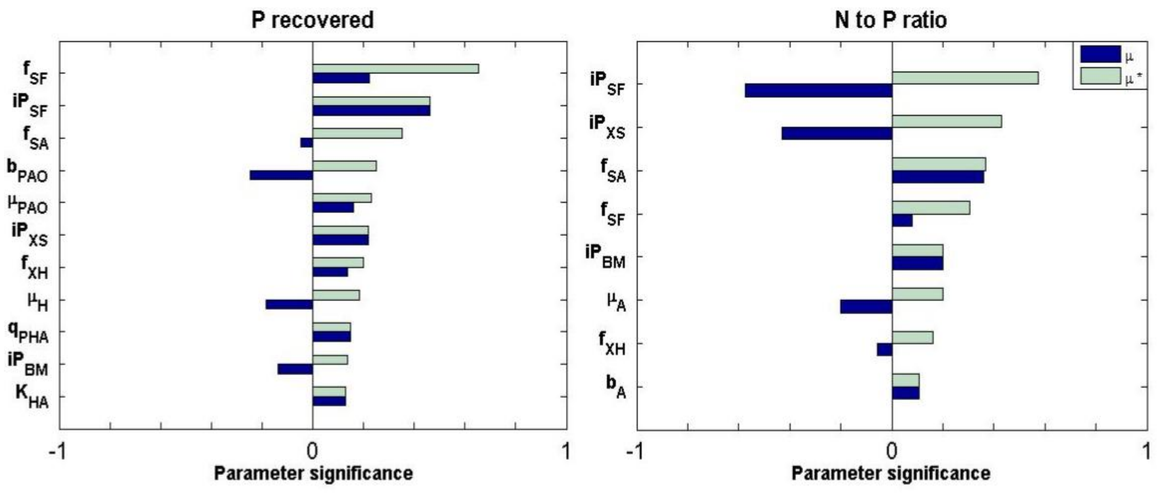
- System is modeled using the activated sludge model 2d (ASM-2d) [3]

- GSA: Morris screening [4]
  - Estimates the distribution of the elementary effects (*EE*) of each input parameter to the model output
  - Ranking is established based on the mean of the absolute values of *EE* (μ^*)

Sampling parameter space → Simulation of the EBP2R using sampled parameters → Calculation of the sensitivity measures

4. RESULTS



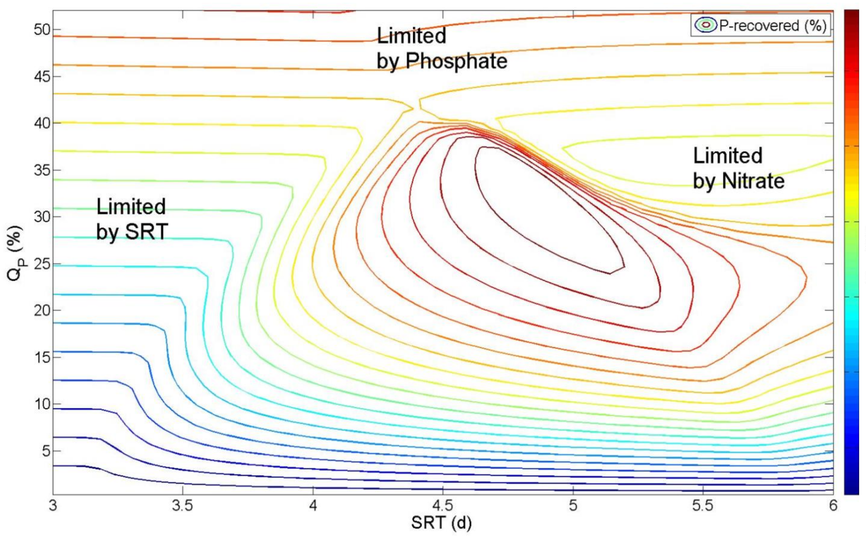


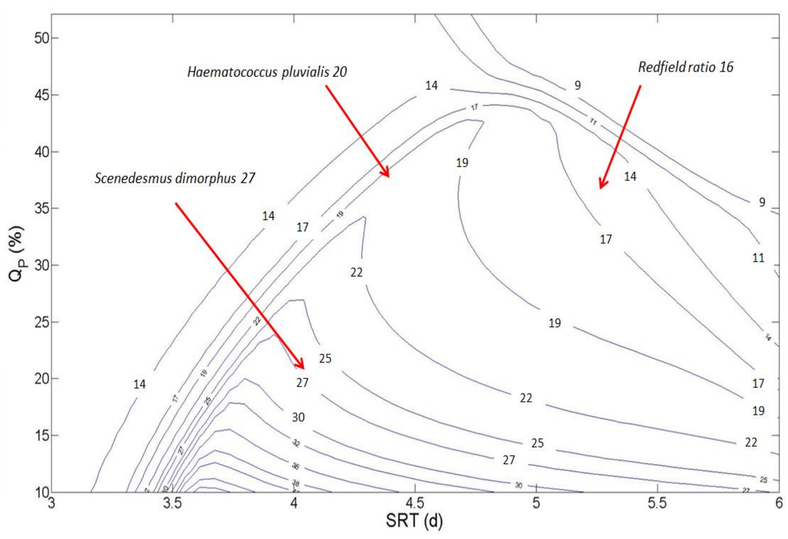
Exploring the system behavior:

A. Increase in P-recovery up to a maximum load as function of the Qp
B. Maximum P-recovery corresponds to the onset of PAOs wash-out
C. PAOs are washed-out due to the nitrifier activity
D. Nitrifiers grow at high P-stream flows because the aerobic SRT increases due to solids up-concentration in the aerobic reactor

Global sensitivity analysis:

- P-recovery is mainly dependent on the influent wastewater fractions:
  - Effect of the COD fractions depends on fate in the system (growth vs storage) and the associated nutrient content (iPSF and iPxs)
- N-to-P ratio mainly dependent on the influent fractionations, as consequence of the effect on the P-recovery
- Nitrifiers only affect the N-to-P ratio by removing nitrogen. Bioavailable COD is sufficient to mitigate the nitrate impact on PAO activity





Process optimization:

- Optimal P-recovery at SRT=5 days and Qp=0.3·Qin. At other conditions PAO activity is limited by:
  - SRT
  - Phosphate starvation in the aerobic reactor
  - Nitrate recirculation to the anaerobic reactors
- The EBP2R is able to yield to N-to-P ratios optimal for cultivation of different green-microalgae :
  - *Scenedesmus dimorphus* N/P=27
  - *Haematococcus pluvialis* N/P=20
  - *Redfield ratio* N/P=16
- Algae chosen to grow in the PhBR have to be able to take up all the incoming phosphorus and nitrogen at high P-recovery rates

5. CONCLUSIONS

- Phosphorus recovery by the **EBP2R is controlled by 3 different factors**: system SRT, phosphorus availability in the aerobic reactor and nitrate recycling to the anaerobic tanks. The **optimal operation conditions** through scenario simulations are an **SRT of 5 days and Q_P of 0.3·Qin**. This results in **70% of the influent P recovered**.
- The EBP2R can be used to construct different N-to-P effluent ratios. Using a typical municipal influent wastewater, the constructed **effluent quality can be optimized in terms of nutrient balance for different green micro-algae,** such as *Scenedesmus dimorphus* or *Haematococcus pluvialis*.
- GSA show that after optimization of the EBP2R, the variability of the **P recovery and the effluent N-to-P ratio** in the EBP2R **primarily depends on the influent wastewater quality** rather than on the kinetics or stoichiometry of the biological processes in the EBP2R system.

References:

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Acknowledgement:

- The research was financially supported by the Danish Council for Strategic Research, as part of the Integrated Water Technology (InWaTech) project, a collaboration between the Technical University of Denmark (DTU) and the Korea Advanced Institute of Science and Technology (KAIST).
- The authors wish to thank Dr. Xavier Flores-Alsina (PROCESS-CAPEC, Technical University of Denmark) for providing the ASM2d Matlab code used to carry out this study.