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

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## 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

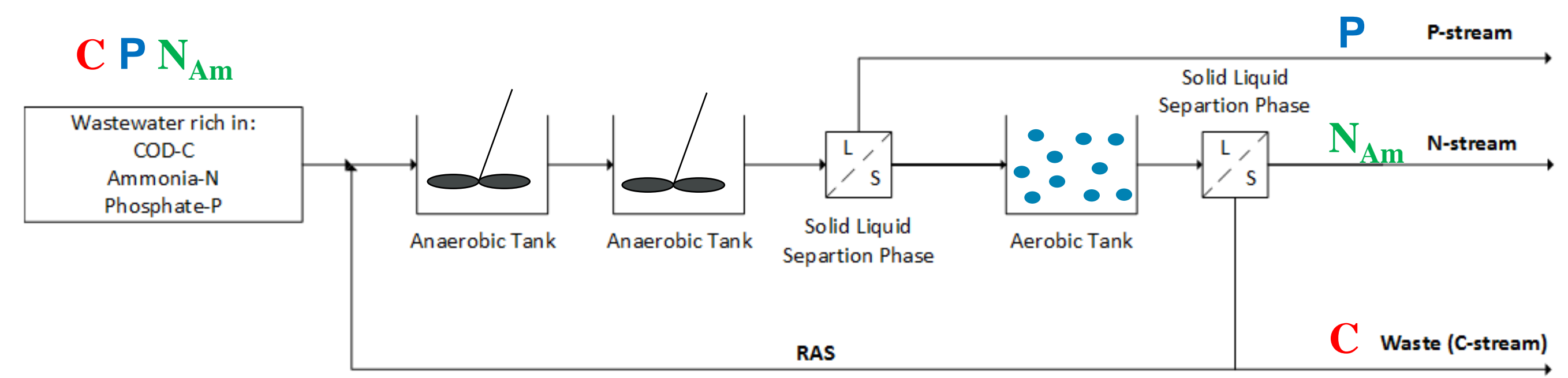
## 2. OBJECTIVES

The goals of this study are to

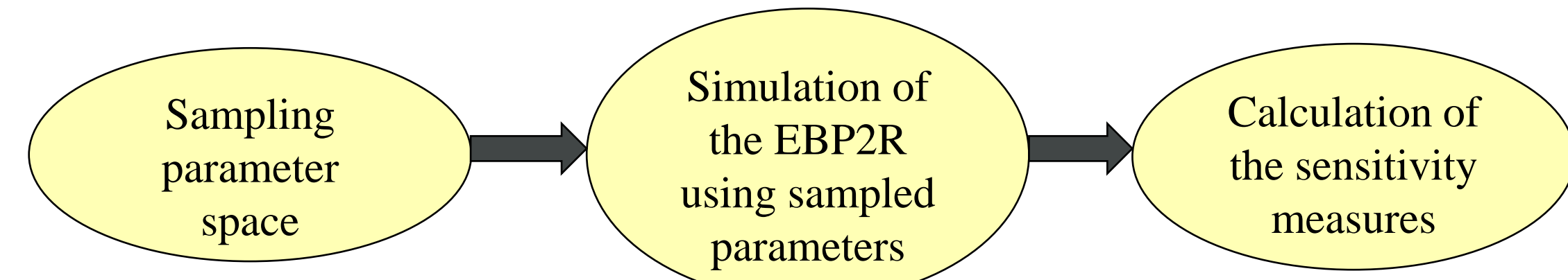
- provide the **model-based design** of the EBP2R system
- optimize** the nutrient recovery capacity
- analyse the sensitivity of the nutrient recovery performance with regard to the influent fractionation and biological processes through **global sensitivity analysis (GSA)**

## 3. METHODS

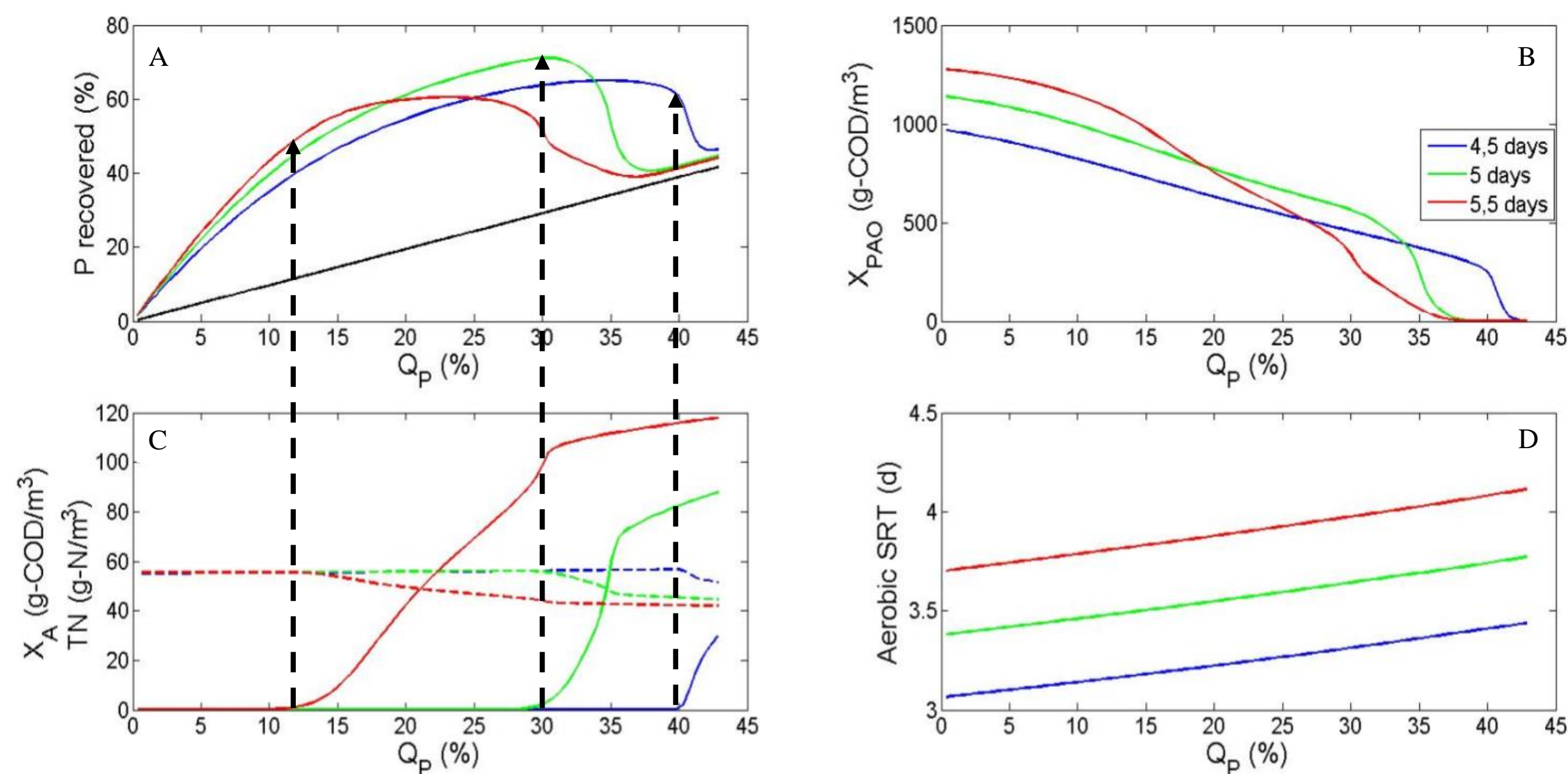
• System description:



- P-stream: phosphorus rich stream diverted from 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* ( $\mu^*$ )

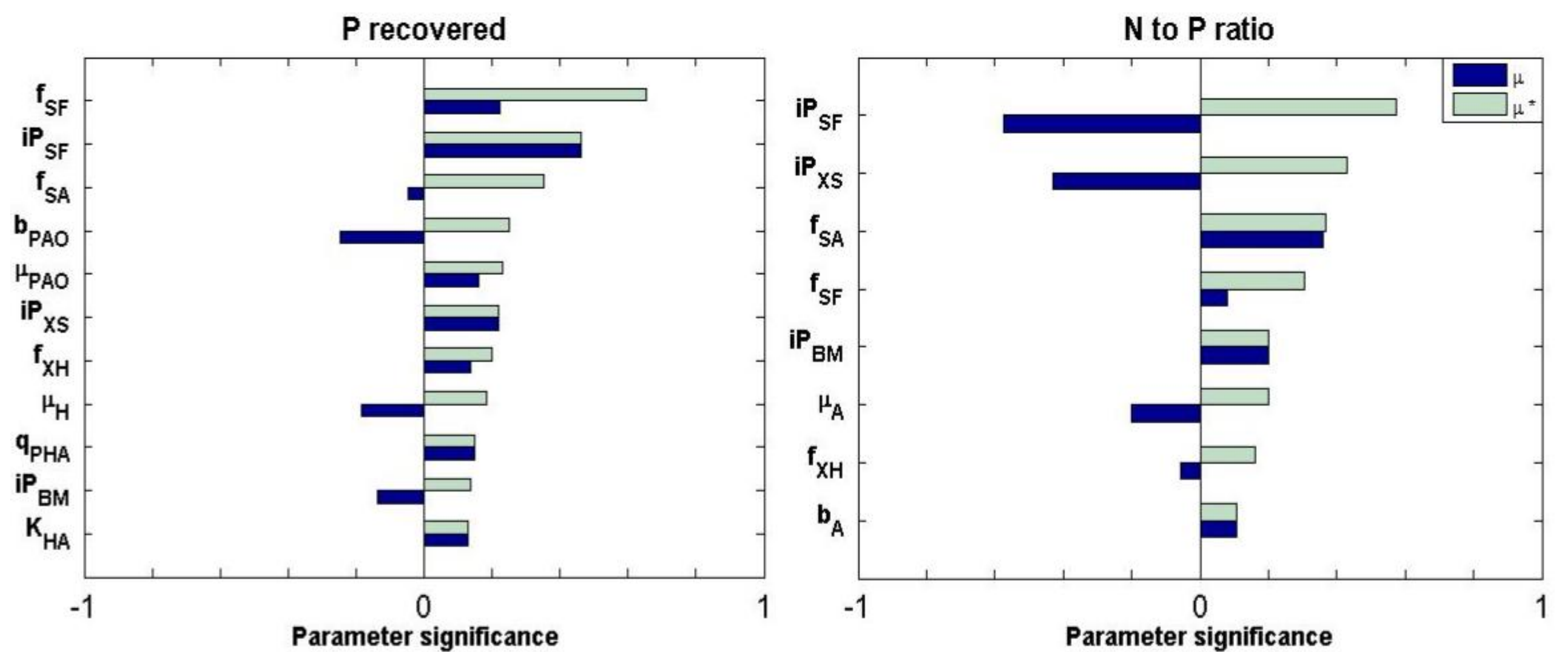


## 4. RESULTS



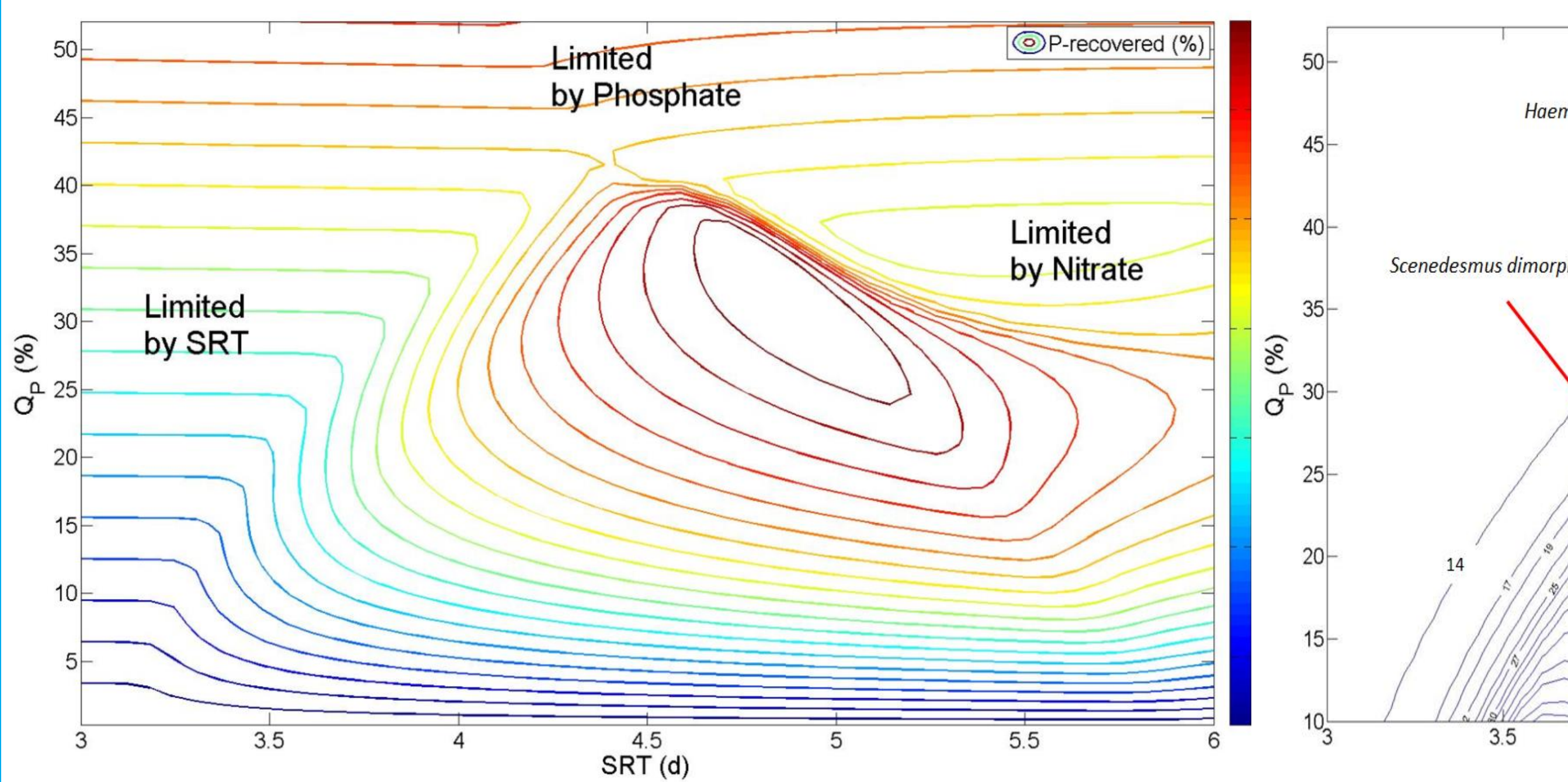
Exploring the system behavior:

- Increase in P-recovery up to a maximum load as function of the  $Q_p$
- Maximum P-recovery corresponds to the onset of PAOs wash-out
- PAOs are washed-out due to the nitrifier activity
- 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  $Q_p=0.3 \cdot Q_{in}$ . 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  $0.3 \cdot Q_{in}$ . 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.

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