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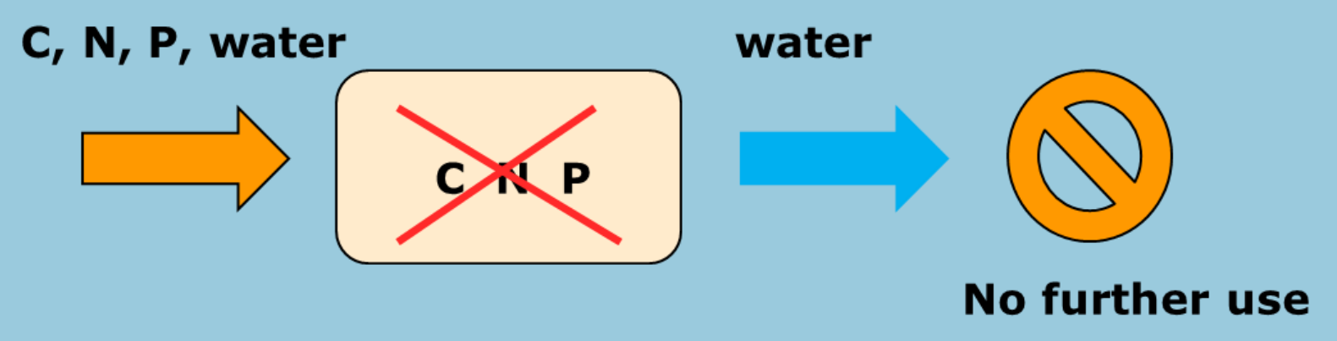
Wastewater resource recovery with green microalgae – modelling the microalgal growth, nutrient uptake and storage using ASM-A

Dorottya S. Wágner*, Borja Valverde-Pérez, Mariann Sæbø, Marta Bregua de la Sotilla, Jonathan Van Wagenen, Barth F. Smets and Benedek Gy. Plósz

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

1. INTRODUCTION

- Conventional wastewater treatment focuses on the destruction of organic chemicals and nutrients.



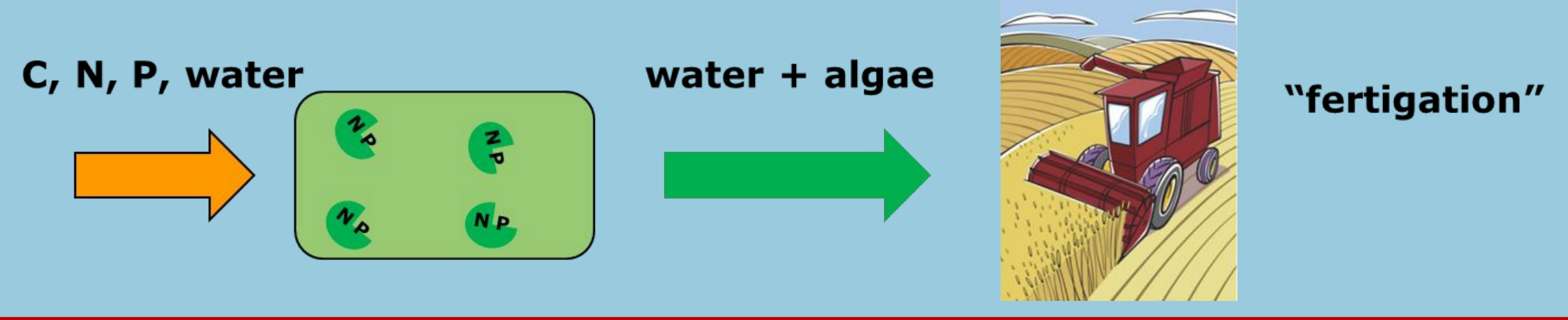
C, N, P, water

C N P

water

No further use

- Domestic wastewater should be considered as a resource of energy, nutrients and fresh water.
- Potential resource recovery using microalgae.
- Microalgal biomass can be used as a slow leaching fertilizer.



C, N, P, water

water + algae

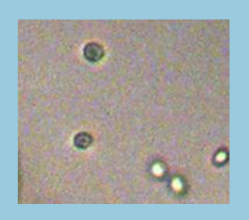
“fertigation”

2. OBJECTIVES

- Development of a **microalgal** process **model** in the **ASM framework** → compatible with activated sludge models
- **Identification** of **biokinetic processes** for **photoautotrophic** and **heterotrophic** microalgal growth including **nutrient uptake and storage**

3. MATERIALS AND METHODS

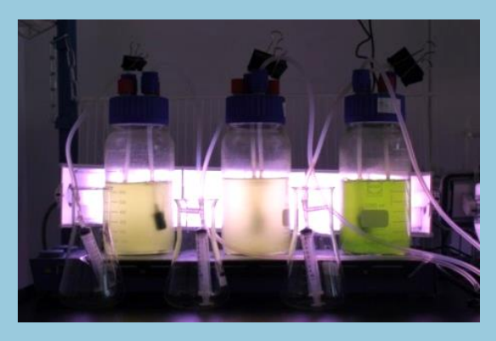
- Mixed green microalgal culture of:
  Chlorella sp. (Sorokiniana)
  and *Scenedesmus sp.*



- Targeted experiments in 3 scales:

2 mL microbatch

- Assessing the specific growth rate under different light intensities



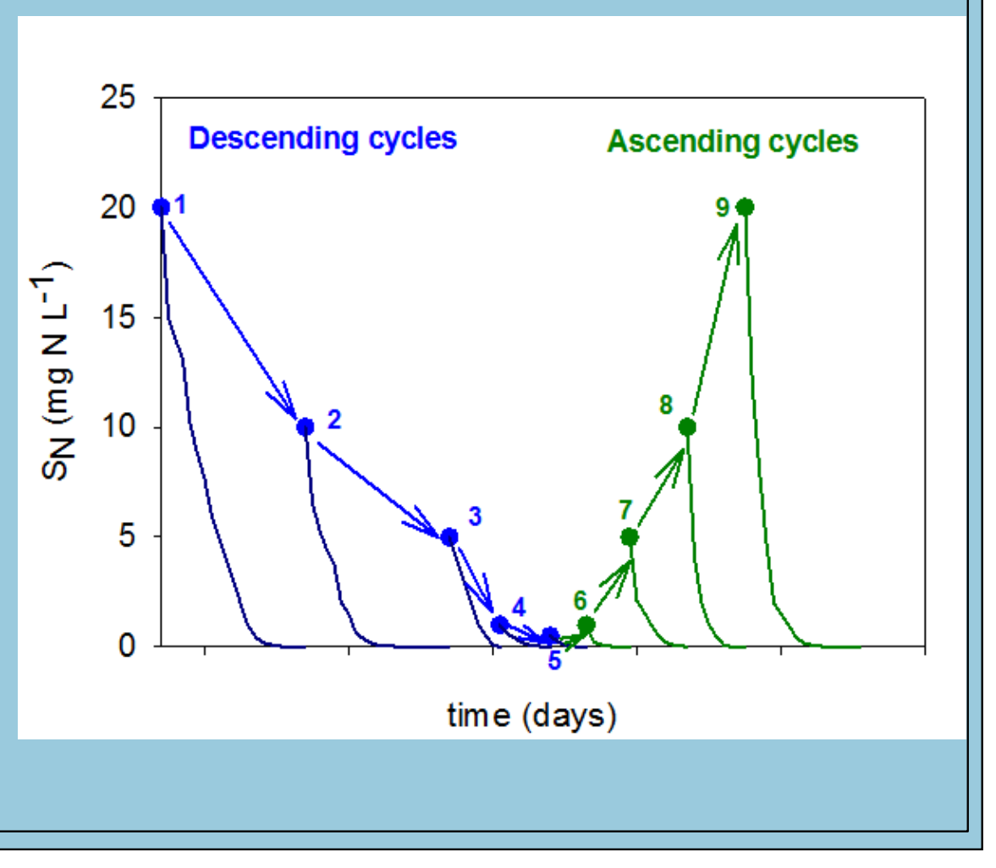
1-L batch

- Assessing the growth and nutrient uptake and storage under nitrogen and phosphorous limited conditions

24-L open airlift PBR

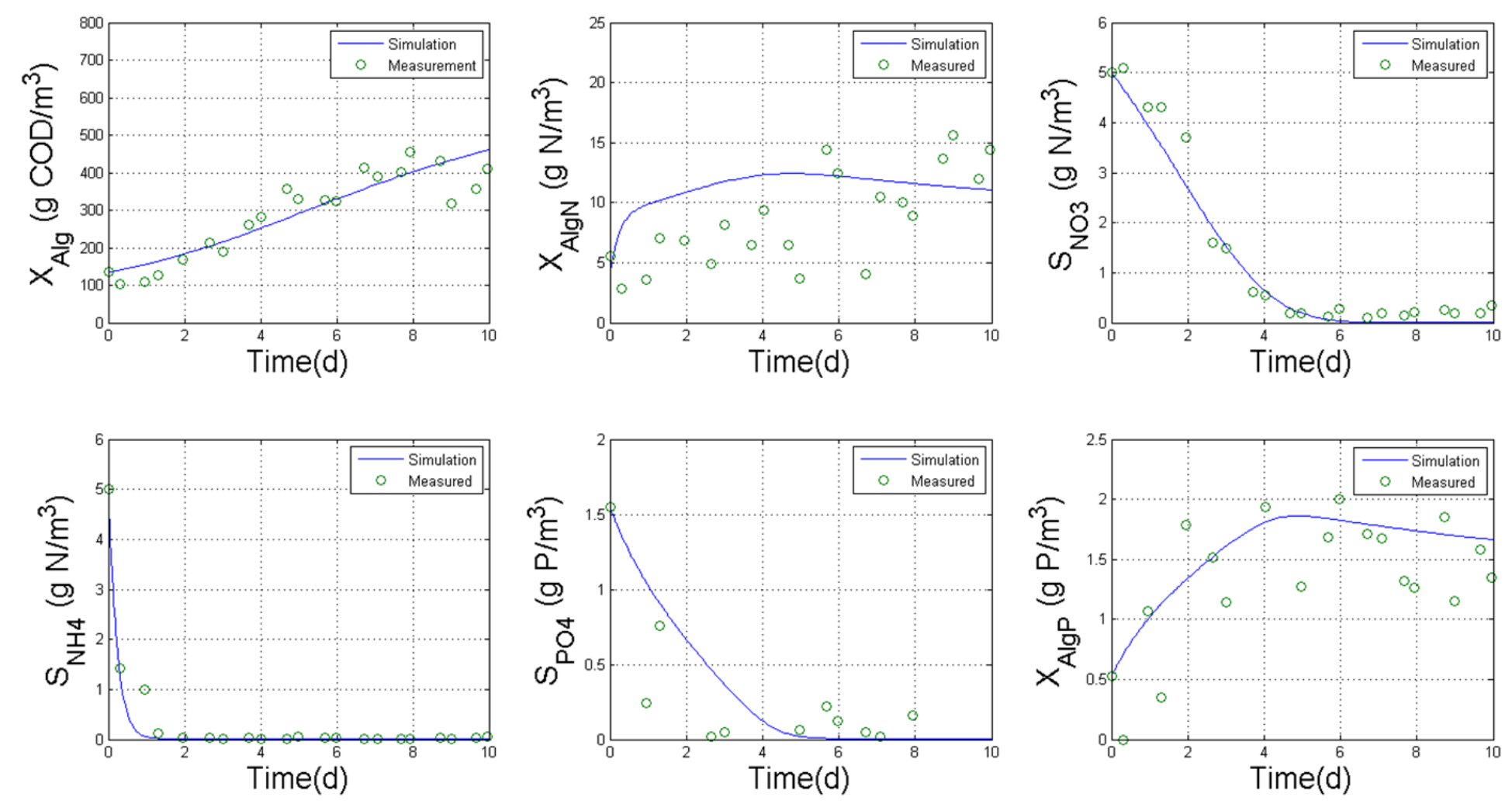
Cycle	Initial N conc. (g N/m³)
1 and 9	20
2 and 8	10
3 and 7	5
4 and 6	1
5	0.5

- **Cycles 1-5:** the initial ammonia and nitrate concentration **decreased** in sequential cycles.
- **Cycles 5-9:** the initial ammonia and nitrate concentration **increased**.
- The different initial substrate to biomass ratio in each cycle allows **decoupling** the culture history from the **substrate availability** impact.



4. RESULTS

Model calibration using descending cycles (cycle 2):



- We calibrate the model for each descending cycle.
- We obtain an average parameter set from the 4 cycles.

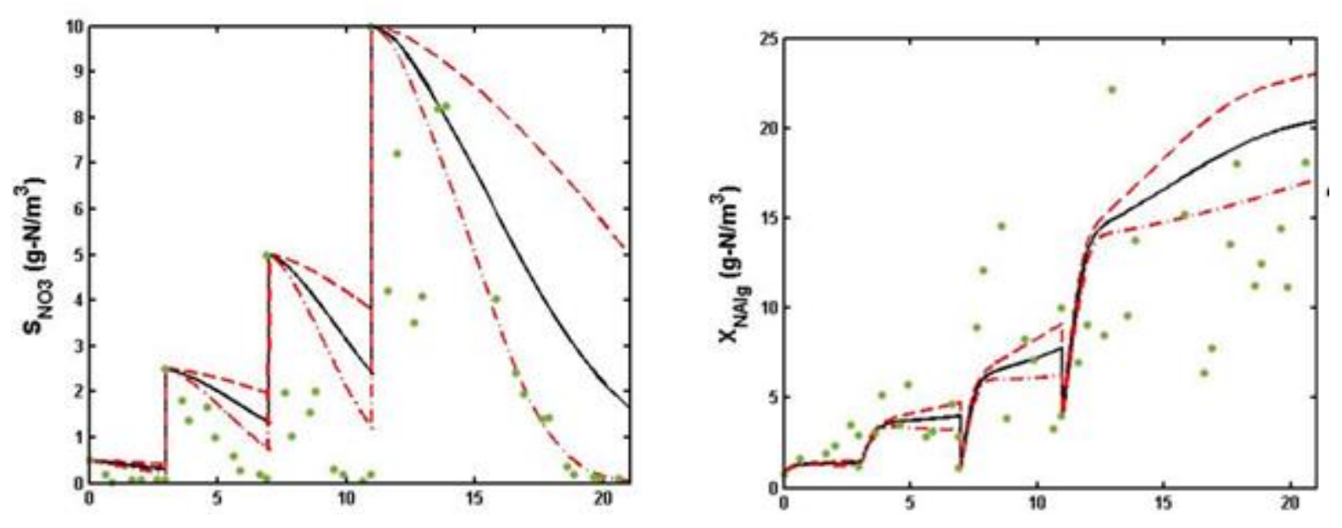
Two-step model evaluation to test the following hypothesis:

- What is the influence of culture history and substrate availability on parameter estimates?
- Can we use a default parameter set?
- Can we explain the discrepancy as a result of parameter variability?

- Step 1 – Janus coefficient
  - **J~1** calibrated model prediction is good
  - **J>>1** calibrated model prediction fails

Cycle 2-8	RMSE calibration	RMSE evaluation	Janus coefficient
Ammonium in bulk liquid (S_{NH4})	0.72	0.44	0.61
Nitrate in bulk liquid (S_{NO3})	0.71	14.00	19.72
Phosphate in bulk liquid (S_{PO4})	0.91	0.51	0.56
Algal biomass (X_{Alg})	0.19	0.1	0.53
Nitrogen quota (X_{AlgN})	1.27	0.70	0.55
Phosphorous quota (X_{AlgP})	0.91	0.14	0.15
Total	4.71	15.9	3.38

- Step 2 – Monte Carlo simulations
  - On the 4 **ascending cycles**
  - Using **average parameter** values estimated from model calibration



- The discrepancy between measured and simulated data is explained by parameter variability for algal biomass, ammonia and phosphate concentrations and the phosphorus storage.
- The prediction of **internal nitrogen quota** is **influenced** by the **substrate availability**.
- The prediction of **soluble nitrate** is compromised by the **culture history**.

The biokinetic processes of ASM-A:

Process rates	
R1 [g N m^{-3} d^{-1}]	$k_{NH4}\cdot\frac{S_{NH4}}{S_{NH4}+K_{NH4,Alg}}\cdot\frac{X_{Alg,Nmax}\cdot X_{Alg}-X_{Alg,N}}{X_{Alg,Nmax}\cdot X_{Alg}}\cdot X_{Alg}$
R2 [g N m^{-3} d^{-1}]	$k_{NO}\cdot\frac{S_{NO}}{S_{NO}+K_{NO,Alg}}\cdot\frac{K_{NH4,Alg}}{K_{NH4,Alg}+S_{NH4}}\cdot\frac{X_{Alg,Nmax}\cdot X_{Alg}-X_{Alg,N}}{X_{Alg,Nmax}\cdot X_{Alg}}\cdot X_{Alg}$
R3 [g P m^{-3} d^{-1}]	$k_{PO4}\cdot\frac{S_{PO4}}{S_{PO4}+K_{PO4,Alg}}\cdot\frac{X_{Alg,PPmax}\cdot X_{Alg}-X_{Alg,PP}}{X_{Alg,PPmax}\cdot X_{Alg}}\cdot X_{Alg}$
R4 [g COD m^{-3} d^{-1}]	$\mu_{A,max}\cdot(1-\frac{X_{Alg,Nmin}X_{Alg}}{X_{Alg,N}})\cdot(1-\frac{X_{Alg,PPmin}X_{Alg}}{X_{Alg,PP}})\cdot\frac{S_{Alk}}{S_{Alk}+K_{Alk}}\cdot\frac{I_{Av}}{I_S}\cdot e^{1-\frac{I_{Av}}{I_S}}\cdot X_{Alg}$
R5 [g COD m^{-3} d^{-1}]	$\mu_{H,max}\cdot(1-\frac{X_{Alg,Nmin}X_{Alg}}{X_{Alg,N}})\cdot(1-\frac{X_{Alg,PPmin}X_{Alg}}{X_{Alg,PP}})\cdot\frac{S_A}{S_A+K_A}\cdot\frac{S_{O2}}{S_{O2}+K_{O2}}\cdot\frac{K_I}{K_I+I_{Av}}\cdot X_{Alg}$
R6 [g COD m^{-3} d^{-1}]	$b_{Xalg}\,.\,X_{Alg}$

5. CONCLUSION

- A **novel** process **model** in the **ASM framework** for predicting **algal behavior** in PBR has been identified, calibrated and critically evaluated
- **Different scale** lab **experiments** have been used to estimate different parameter sets
- The model can **predict algal biomass, ammonia, phosphate** and **internal PP quota** using **a mean parameter set**
- The prediction of **internal nitrogen quota** is influenced by the **substrate availability** and the **soluble nitrate** is compromised by the **culture history**

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