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A Green Micro-Algal Growth Model developed in the Activated Sludge Modeling Framework

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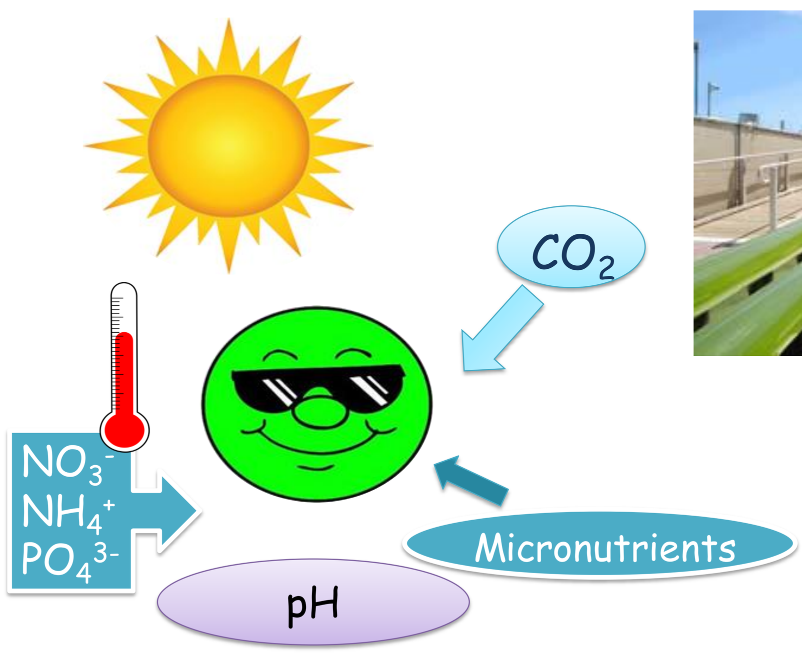
1. INTRODUCTION

Microalgae photobioreactors can be used for wastewater treatment as:
•Tertiary treatment step for nutrient removal
•Nutrient recovery technology due to the phosphorus and nitrogen internal storage

Different reactor designs:
•Open pond reactors
•Closed photobioreactors (e.g. flat panel reactors)

Algal biomass applications:
•Direct use for biofuel production (e.g. biodiesel or biogas)
•Biofertilizer (the indirect use for biofuel production)
•High value products (e.g. pigments)

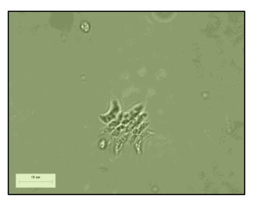


2. OBJECTIVES

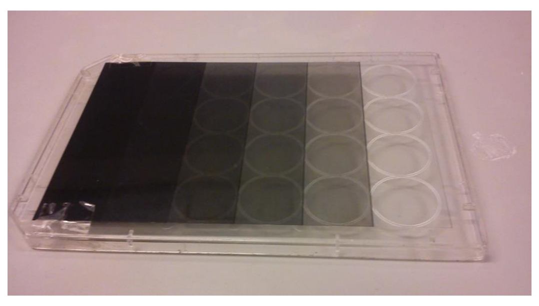
- Development of a process model for the photobioreactor in the Activated Sludge Modelling (ASM) framework:
  - Connecting conventional wastewater treatment plants with photobioreactors
- Simulation of the micro-algal uptake, storage and growth on phosphorus and nitrogen

3. MATERIALS AND METHODS

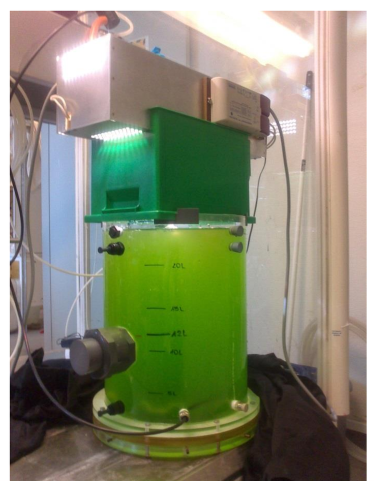
- Microorganisms: mixed green microalgal culture of *Chlorella sp.* and *Scenedesmus sp.*



- Culturing of microalgae:
  - MWC+Se growth medium
  - Constant temperature (20°C)



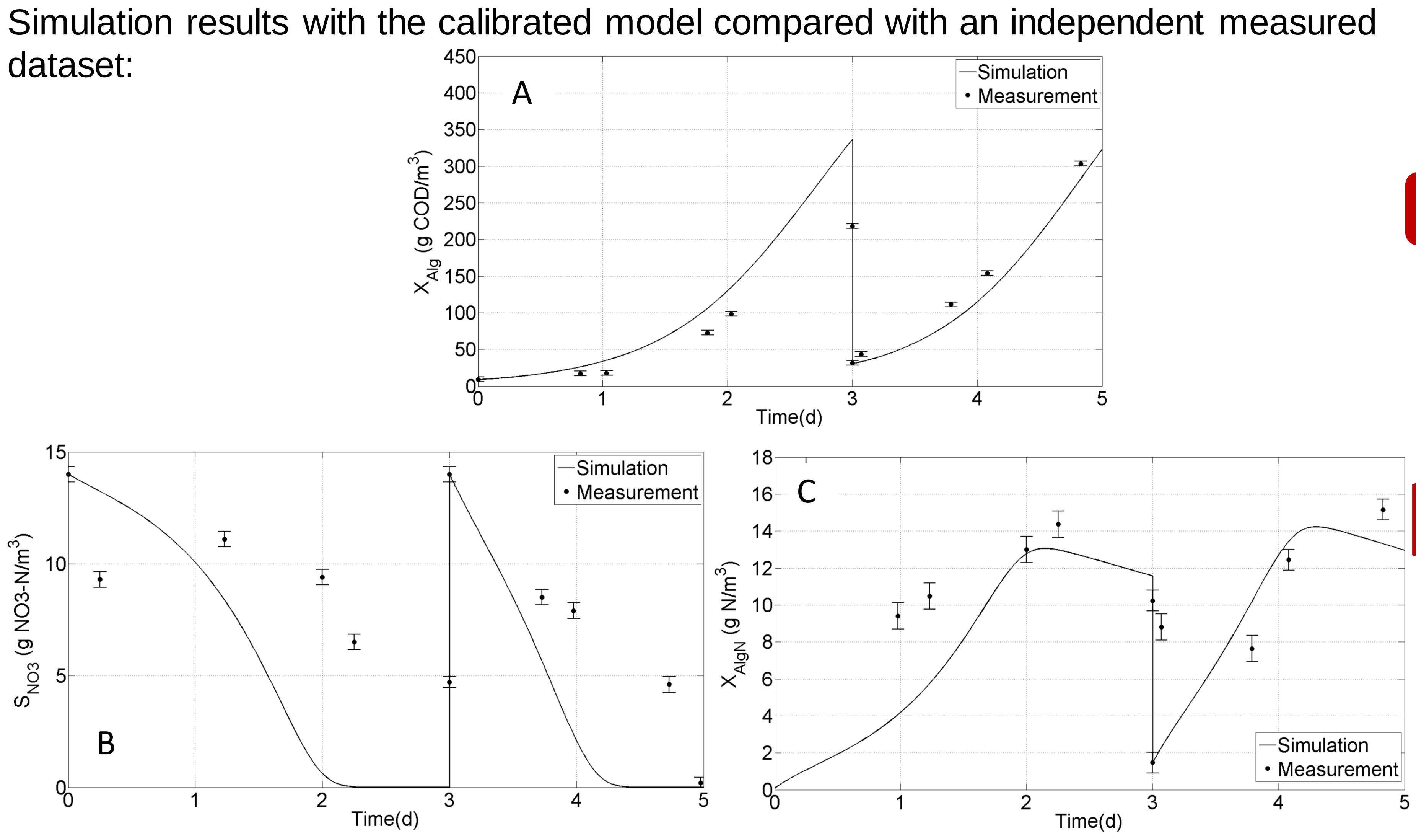
- Parameter estimation through targeted experiments:
  - Micro-batch experiments
    - Assessment of the growth rate under different light intensities
  - Batch experiments
    - Assessment of the growth and nutrients uptake under limitation by different macronutrients (N, P)



4. RESULTS

Process rates	
$k_{NH4}\cdot\frac{S_{NH4}}{S_{NH4}+K_{NH4}}\cdot\frac{X_{Alg,Nmax}\cdot X_{Alg}-X_{Alg,N}}{X_{Alg,Nmax}\cdot X_{Alg}}\cdot X_{Alg}$	**R1 [g N m^{-3} d^{-1}]**
$k_{NO}\cdot\frac{S_{NO}}{S_{NO}+K_{NO}}\cdot\frac{K_{NH4}}{K_{NH4}+S_{NH4}}\cdot\frac{X_{Alg,Nmax}\cdot X_{Alg}-X_{Alg,N}}{X_{Alg,Nmax}\cdot X_{Alg}}\cdot X_{Alg}$	**R2 [g N m^{-3} d^{-1}]**
$k_{PO4}\cdot\frac{S_{PO4}}{S_{PO4}+K_{PO4}}\cdot\frac{X_{Alg,PPmax}\cdot X_{Alg}-X_{Alg,PP}}{X_{Alg,PPmax}\cdot X_{Alg}}\cdot X_{Alg}$	**R3 [g P m^{-3} d^{-1}]**
$\mu_{A,max}\cdot(1-\frac{X_{Alg,Nmin}X_{Alg}}{X_{Alg,N}})\cdot(1-\frac{X_{Alg,PPmin}X_{Alg}}{X_{Alg,PP}})\cdot\frac{S_{DIC}}{S_{DIC}+K_{DIC}}\cdot\frac{I_0\times e^{-k_aX_z}}{I_S}\cdot e^{1+\frac{I_0\times e^{-k_aX_z}}{I_S}}\cdot X_{Alg}$	**R4 [g COD m^{-3} d^{-1}]**
$\mu_{H,max}\cdot(1-\frac{X_{Alg,Nmin}X_{Alg}}{X_{Alg,N}})\cdot(1-\frac{X_{Alg,PPmin}X_{Alg}}{X_{Alg,PP}})\cdot\frac{S_A}{S_A+K_A+\frac{S_A^2}{Ki,S_A}}\cdot\frac{S_{O2}}{S_{O2}+K_{O2}}\cdot\frac{K_I}{K_I+I_0\cdot e^{-k_aX_z}}\cdot X_{Alg}$	**R5 [g COD m^{-3} d^{-1}]**
$b_{Xal}\,.\,X_{Alg}$	**R6 [g COD m^{-3} d^{-1}]**

Simulation results with the calibrated model compared with an independent measured dataset:



A) Algal biomass; B)Nitrate in the bulk liquid; and C) Nitrogen internal quota.

R1&R2 Uptake and storage of nitrogen: described in relation to the availability of external N in the wastewater (S_{NH}/S_{NO}), as well as to the internal cell quota of N ($X_{Alg,N}$), defined as cell internal storage of N per total mass of biomass

R3 Uptake and storage of phosphorus: defined relative to the availability of external soluble PO4 in the wastewater (S_{PO4}), as well as to the internal cell quota of P ($X_{Alg,PP}$), defined as cell internal storage of P per total mass of biomass

R4 Photoautotrophic growth: growth is dependent on the internal cell quota of the different nutrients. The uptake of dissolved inorganic carbon (DIC) is modeled using Monod kinetics. Light dependence is modeled using the Steele equation

R5 Heterotrophic growth: The Haldane model is employed to describe the effect on growth rate as a function of the substrate concentration. Oxygen consumption (S_{O2}) is described using the Monod kinetics. The model also takes into account the inhibition due to light intensity of the heterotrophic growth, as well as the nutrient consumption associated with algal growth

R6 Decay : includes internal resources used for maintenance, biomass loss during dark respiration, death and lysis

5. CONCLUSION

- A process model for green micro-algal growth has been identified and developed using the systematic approach of the activated sludge models.
- The model accurately describes the micro-algal growth under constant light intensities.

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