Microalgae biomass growth and lipid production using primary treated wastewater

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Outline

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- Introduction - Microalgae & Wastewater treatment
- Materials and Methods
- Results - Biomass production
  - Nutrients removal
  - Lipid production
- Conclusions

Aim

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The aim of this study was to evaluate the algal production in a laboratory scale open pond using as a feedstock primary treated wastewater.

To further improve the nutrient removal from wastewater and to investigate the potential production of biomass as as renewable energy source.

Introduction

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Microalgae and wastewater treatment:

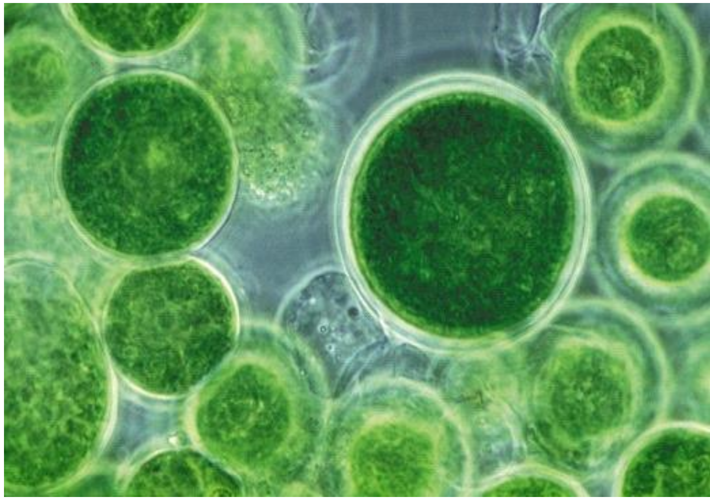
- ✓ Natural treatment systems (sewage lagoons/sewage farms, stabilization ponds, other algal reactors). The first farm for the treatment of sewage with algae was reported in late 1800s in Berlin.

- ✓ Wastewater treatment with algae offers important advantages:
  - low capital and operation cost
  - low energy requirements
  - contribution to reduction of CO_2 emissions
  - use of algal biomass as fertilizer or fuel source
  - great potential for algae to be used as biofuels.

Introduction

- The selection of microalgae for potential biofuel production should take into consideration the:
  - high algal cell density,
  - high lipids content,
  - but also their presence and survival in wastewater.

- What does affect algal growth?
  - Nutrients concentration, especially P and N
  - Aeration rate
  - Light conditions
  - Temperature
  - CO_2
  - pH



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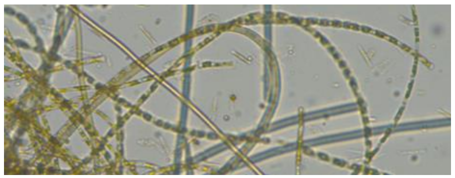
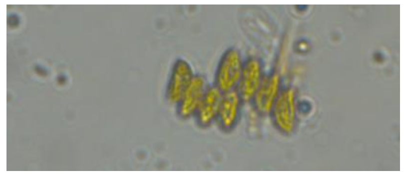
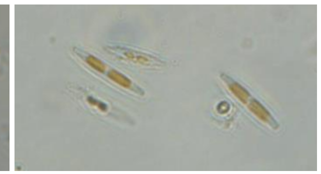
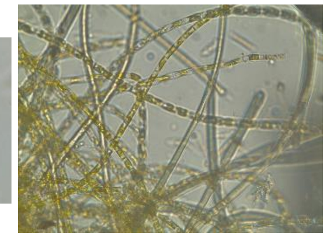
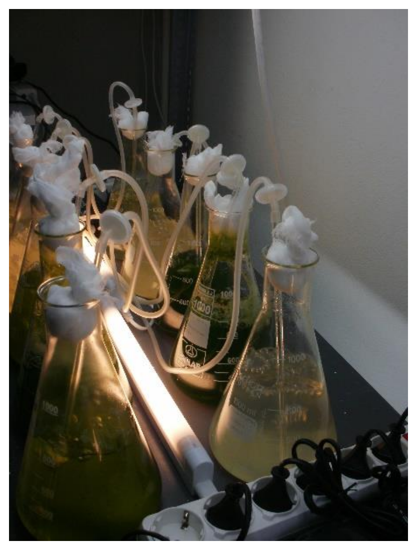
- Identification of suitable species and cultivation system


- Determination of microalgae growth rates


Aravantinou et al. (2013). *Bioresource Technology*, 147 (130-134).

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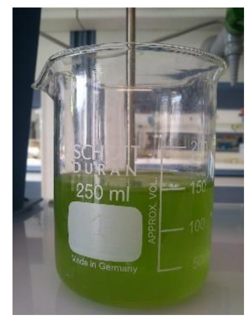
(University of Patras, Environmental Engineering Laboratory)

- Culture optimization

- Short-term toxicity of nanoparticles on microalgae growth Aravantinou *et al*. (2015). Ecotoxicology and Environmental Safety.


- Microalgae harvesting
  Vergini *et al*. (2016)
  Journal of Applied Phycology


- Scale-up
Aravantinou *et al*. (2016)
Environmental Processes


Materials and Methods

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Six sets of experiments were conducted with primary treated wastewater in batch and continuous operating mode. The culture was exposed to artificial light 100 μmol/m^{2}s. In the last set the radiation intensity was set to 200 μmol/m^{2}s.

Phase	Operation mode	Flow rate	HRT (days)
1	Batch	-	-
2	Fill and draw	1 L/d	30
3	Continuous	1 L/d	30
4	Batch	-	-
5*	Batch	-	-
6**	Continuous	1 L/d	30

* Addition of PO_4^{-3}.
**Radiation intensity: 200 μmol/m^{2}s.

Materials and Methods

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Experimental conditions	Investigating parameters
- Laboratory- scale open pond: 50x50x25 cm (LxWxH) - Pre-cultured cells and secondary treated wastewater - Working volume: 30 L - Temperature: 21 ± 2 °C - Photoperiod: 12 h: 12 h (dark: light) - Air supply: 2 L/min - Operation period: 14 to 33 d	- Operation mode: Batch, Fill and Draw Continuous - Flow rate/ Hydraulic Retention Time - Photosynthetic radiation intensity: 100, 200 $\mu mol \cdot m^{-2} \cdot s^{-1}$ - Wastewater: Primary effluent

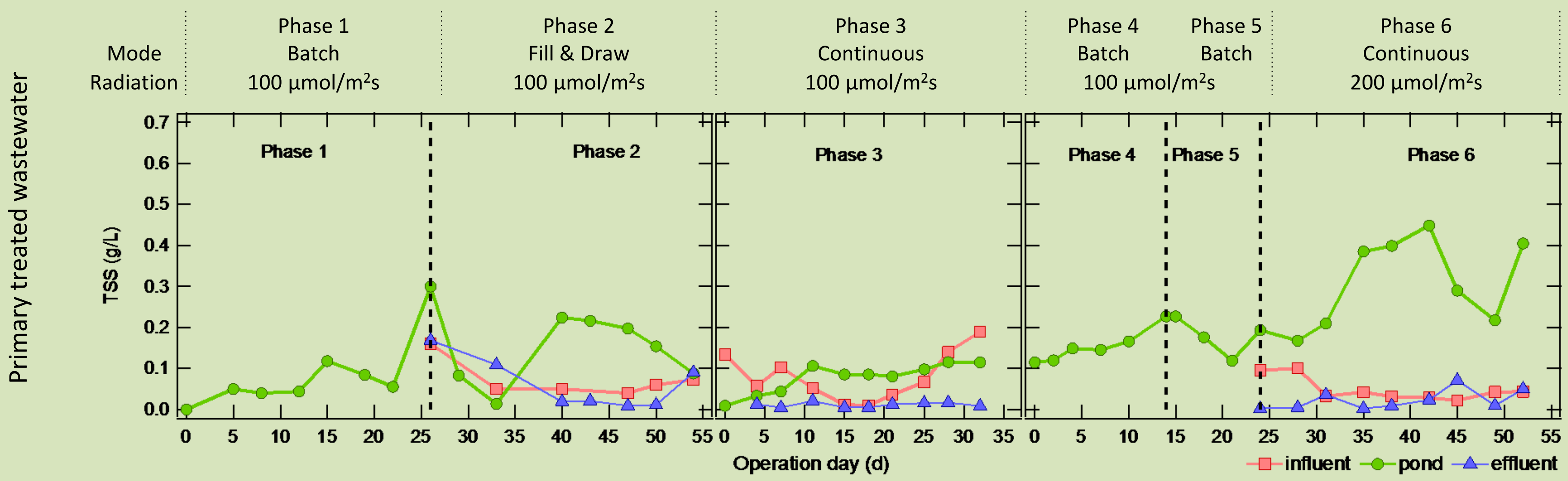
Material and Methods

Parameter	Method
Biomass	- Gravimetric method, Total suspended solids - Absorbance (750 nm) - Chl-a (APHA et al., 1998) - Turbidity (NTU)
Total - N	Method 2,6- dimethylphenol (ISO 7890/1)
Nitrates	Ion Chromatography (APHA et al., 1998)
Total - P	Persulfate digestion and ascorbic acid method (APHA et al., 1998)
Phosphates	Ion Chromatography (APHA et al., 1998)
COD	Method 410.4 (O’ Dell, 1993)
Soluble non-purgeable organic carbon	TOC analyzer (APHA et al., 1998)
pH	pH-meter
Lipid extraction	Method of Folch et al. (1957)

Results

Biomass concentration

- The growth rate of algae was affected by light intensity.
- The maximum biomass concentration of 449 mg/L was observed under continuous mode and high radiation intensity in phase 6.
- Although the light intensity is an important factor in algae growth, the nutrient concentration, which was fed in the pond, is more important for algae growth.

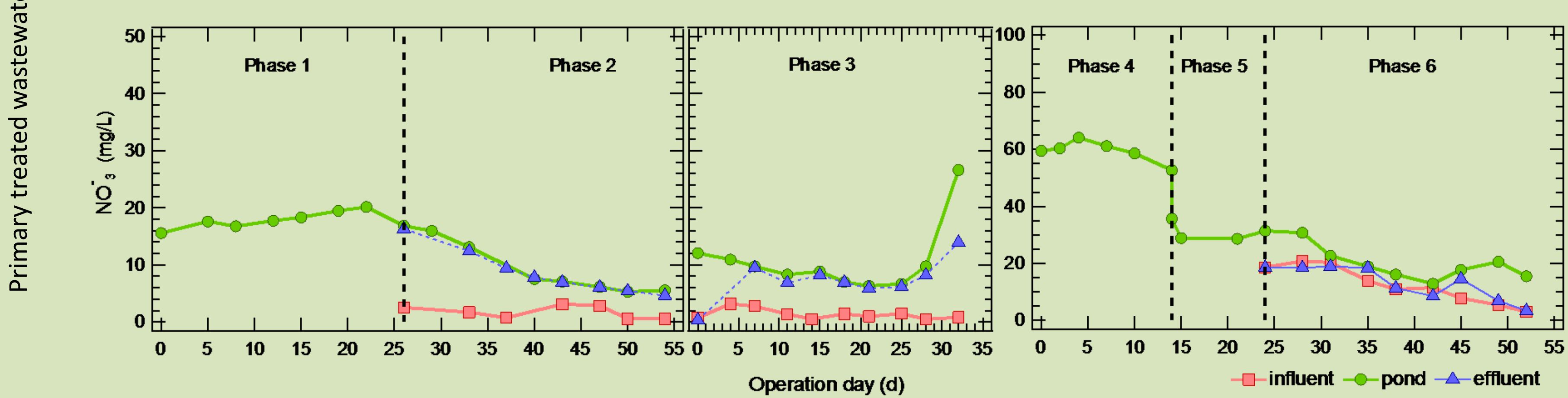


Results

Nitrates

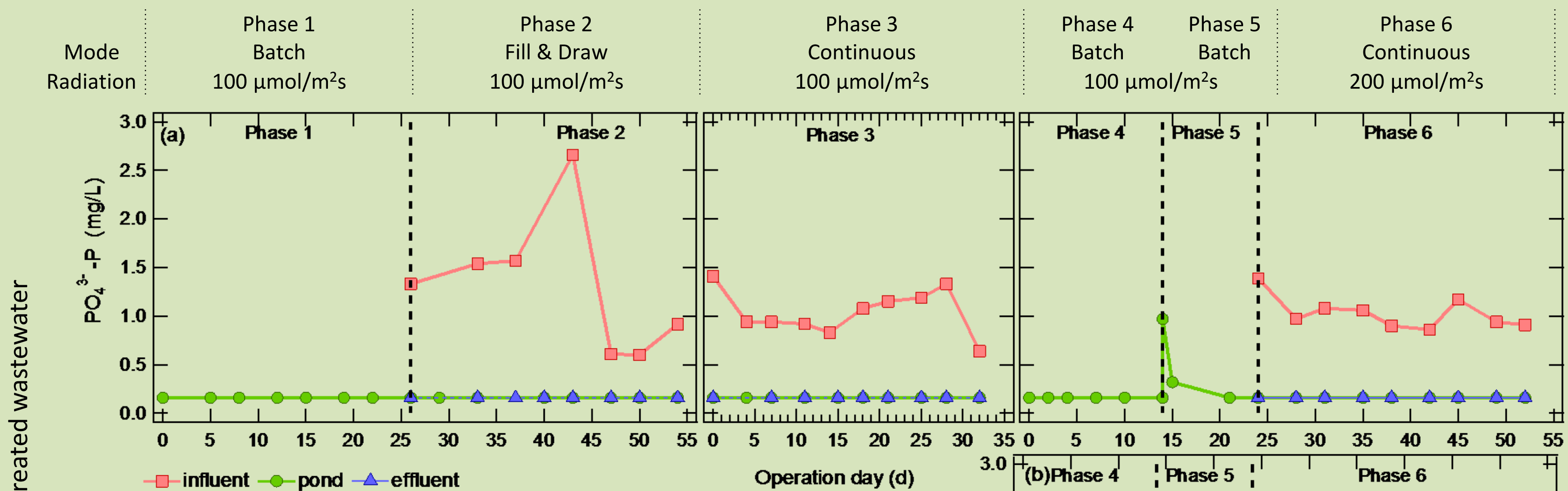
- Microalgae can assimilate a significant amount of nutrients in excess of the immediate metabolic needs.
- The nitrate removal was satisfactory, and the maximum decrease of nitrates concentration (76%) was observed the same day with the external addition of phosphorus on day 14 (Phase 5).

	Phase 1	Phase 2	Phase 3	Phase 4	Phase 5	Phase 6
Mode	Batch	Fill & Draw	Continuous	Batch	Batch	Continuous
Radiation	100 µmol/m^2s	100 µmol/m^2s	100 µmol/m^2s	100 µmol/m^2s		200 µmol/m^2s

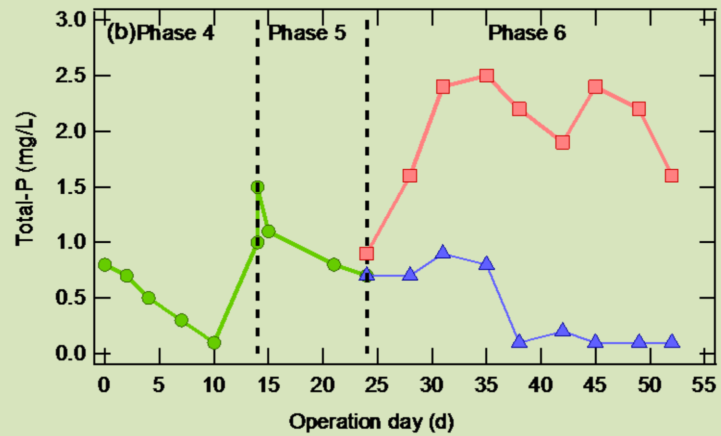


Results

Phosphates



- Phosphates as well as nitrates are essential nutrients for biomass growth.
- Phosphates concentration in the influent ranged from 0.60 to 1.57 mg P/L and in the effluent their concentration was almost zero, implying the complete removal of phosphates.

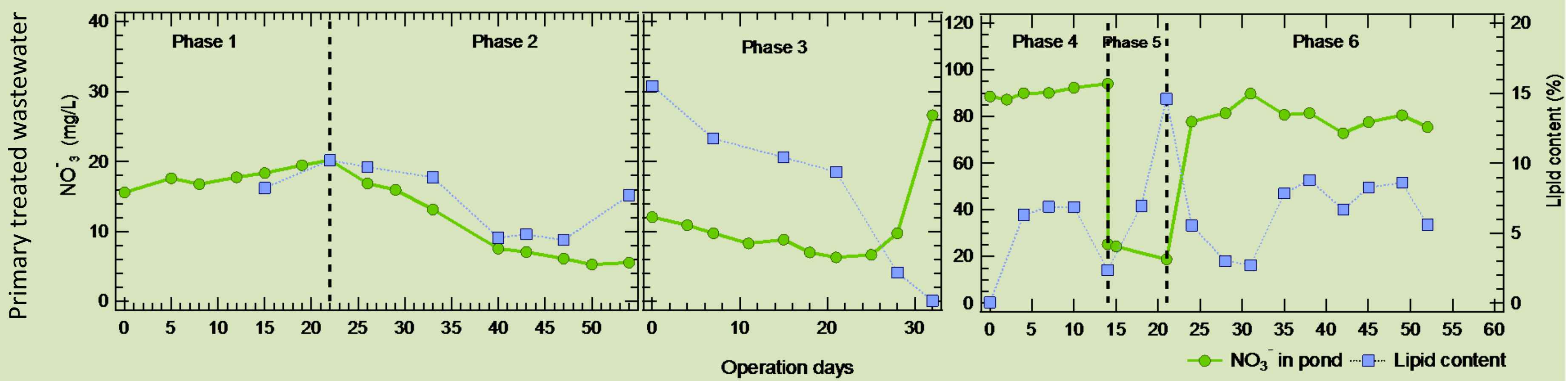


Results

Lipid content

- The lipid content was affected by the influent nutrient concentration, and higher values were observed with low nitrates concentration in the influent.
- Nutrients removal and the impact of nutrients concentration on the lipid content of algal cells is an essential step before the scale-up of biomass and lipid production by microalgae.

Mode	Phase 1 Batch	Phase 2 Fill & Draw	Phase 3 Continuous	Phase 4 Batch	Phase 5 Batch	Phase 6 Continuous
Radiation	100 µmol/m²s	100 µmol/m²s	100 µmol/m²s	100 µmol/m²s		200 µmol/m²s



Conclusions

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- ✓ The algal production was satisfactory in a laboratory open pond, which was fed with primary treated wastewater.
- ✓ Microalgal growth was affected by phosphates concentration and irradiation intensity.
- ✓ The efficiency of microalgae to remove nitrates and phosphates was satisfactory, and reached removals of 76 and almost 100%, respectively.
- ✓ Finally, the highest lipid content was 15% when the microalgae faced starvation conditions.

Next steps

- ✓ Scale-up of ponds with microalgae species with higher lipid content i.e. *Scenedesmus rubescens.*
- ✓ Cultivation of high lipid microalgae in outdoor ponds for wastewater treatment.
- ✓ Investigation of low-cost harvesting method for microalgae biomass (magnetic microparticles, electrocoagulation, flocculation etc.)
- ✓ Long-term impact of nanoparticles on microalgae cultures.

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Thank you for your attention !!!