Urban wastewater from primary treatment followed by microalga cultivation for *chlorella vulgaris* biomass production. pH influence (smallwat21)

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Motivation

Urban wastewaters characteristics

1. High organic load (higher values for COD and TOC).
2. High volumes that can not be reused directly in the process itself nor in irrigation without prior treatment.
3. Presence of different pollutants such as heavy metals, pharmaceutical compounds, etc.
4. High urban sludge volume generation with difficult managements.

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Motivation

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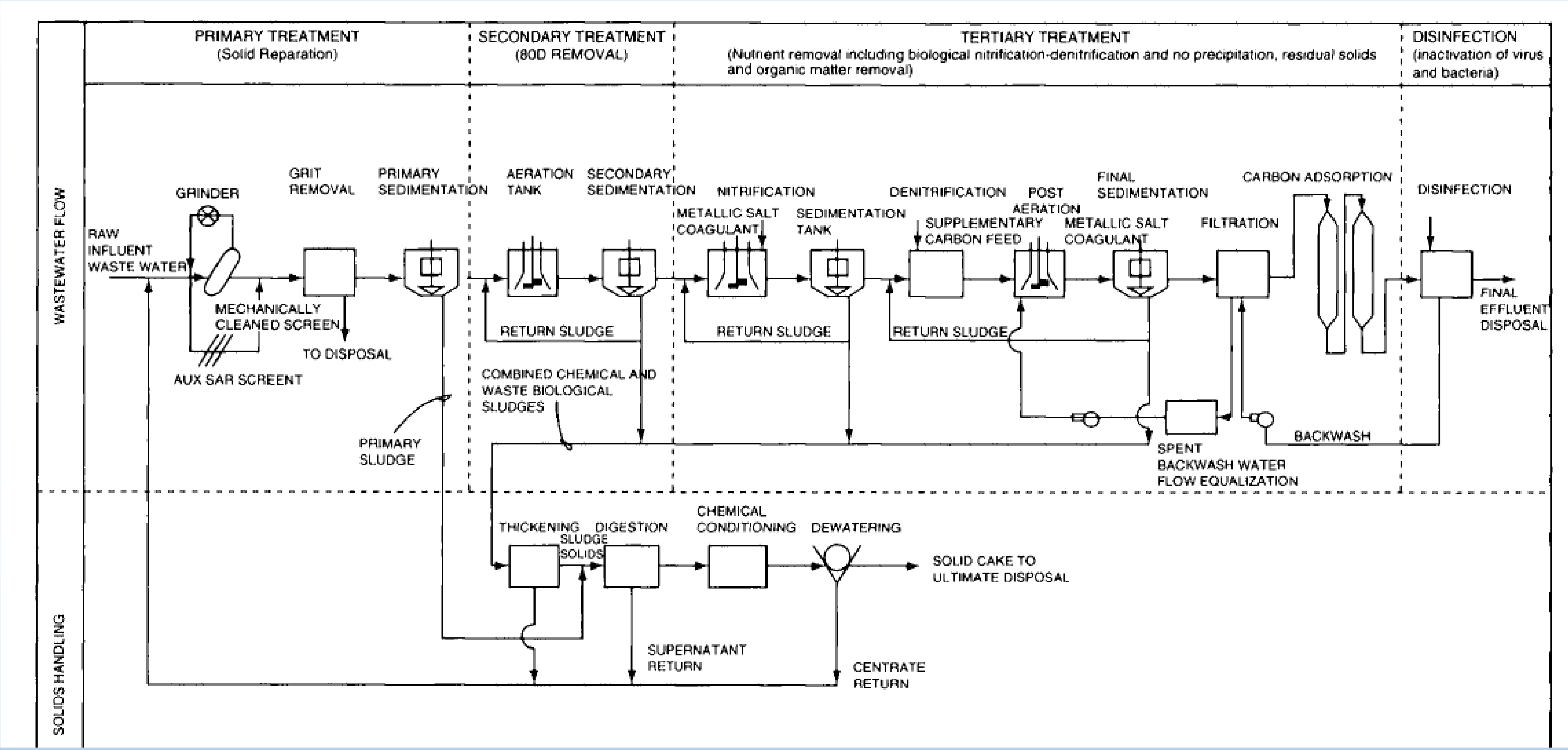
Diagram flow of the urban wastewater treatment plant



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Motivation

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MICROALGAE

- ✓ Simple cellular structure
- ✓ Versatile biochemical composition
  - ✓ **Energetic compounds-rich** composition
  - ✓ Promising **non-food source of biofuels, pigments, bioactive compounds, etc.**
- ✓ **Rapid and high growth rate**
- ✓ Easy culture
- ✓ Environmental applications: **carbon dioxide mitigation, wastewater treatment, etc.**
- ✓ Potential renewable source for **human nutrition, animal feed, cosmetics** and **biomedicine products**, etc.
- ✓ Potential of use in **Aquaculture** (fish feed).

Motivation

Nutrition forms of microalgae

- Autotrophic growth
  - Energy source → Solar light
  - Carbon source → CO_2
- Heterotrophic growth
  - Energy source → Organic substrate (Dark conditions)
  - Carbon source → Organic substrate (Dark conditions)
- Mixotrophic growth
  - Energy source → Solar light
  - Carbon source → Organic S. + CO_2

Motivation

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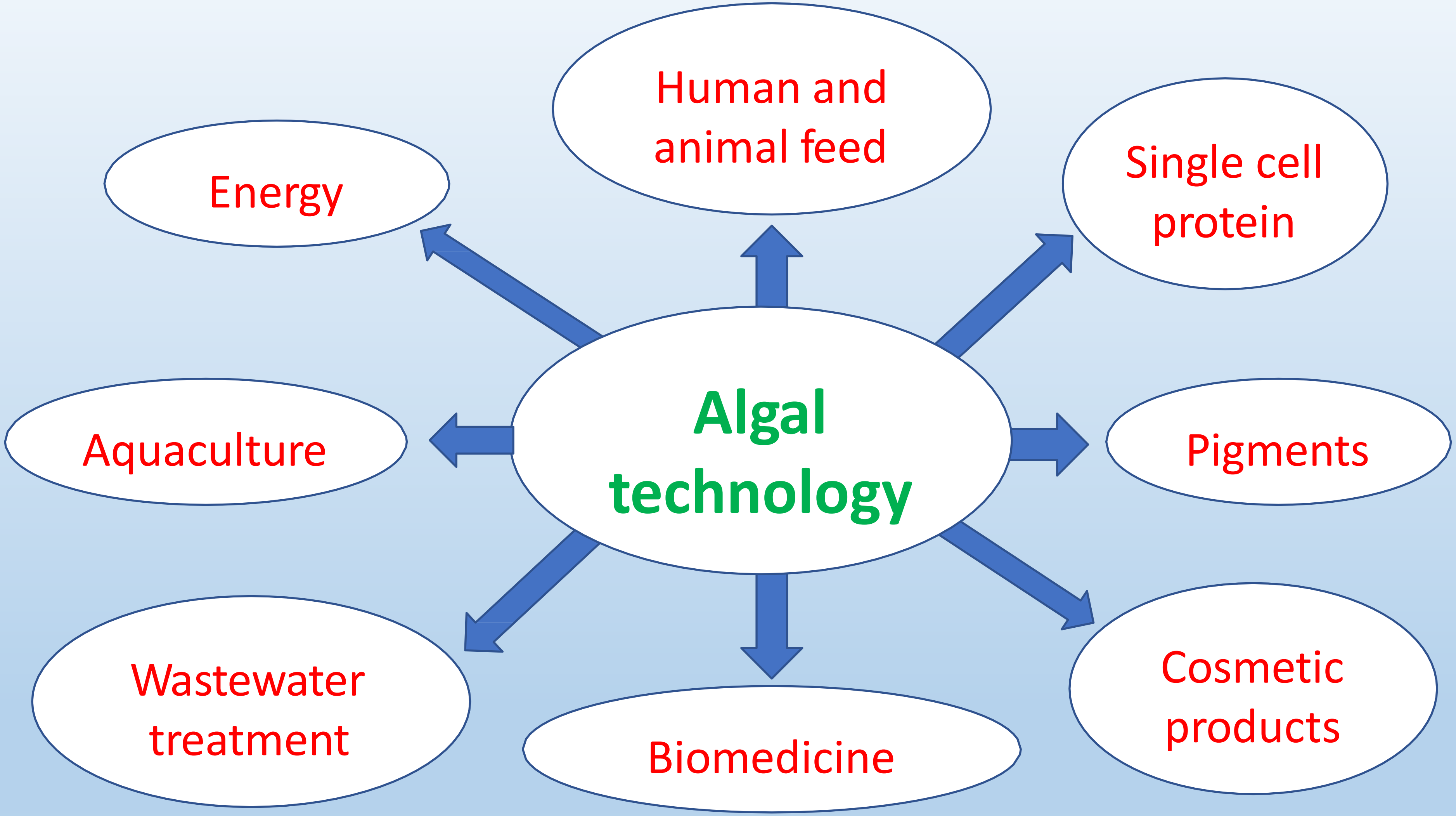

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Motivation

Current problem and solution proposed

Treatment of urban wastewater

Problems

- Treated water generated has not enough quality to use as drinking water or at least for irrigation.
- Higher values of N and P

WWTPs generate large volumes of sludge that are difficult to remove and mange.

Hybrid solution

Include the microalgae in the current urban wastewater treatment plants

Experimental

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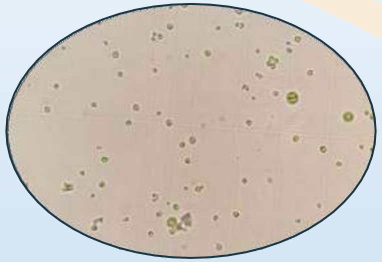
Chlorella Vulgaris



Crude urban wastewater from primary treatment

Photo-bioreactors facility

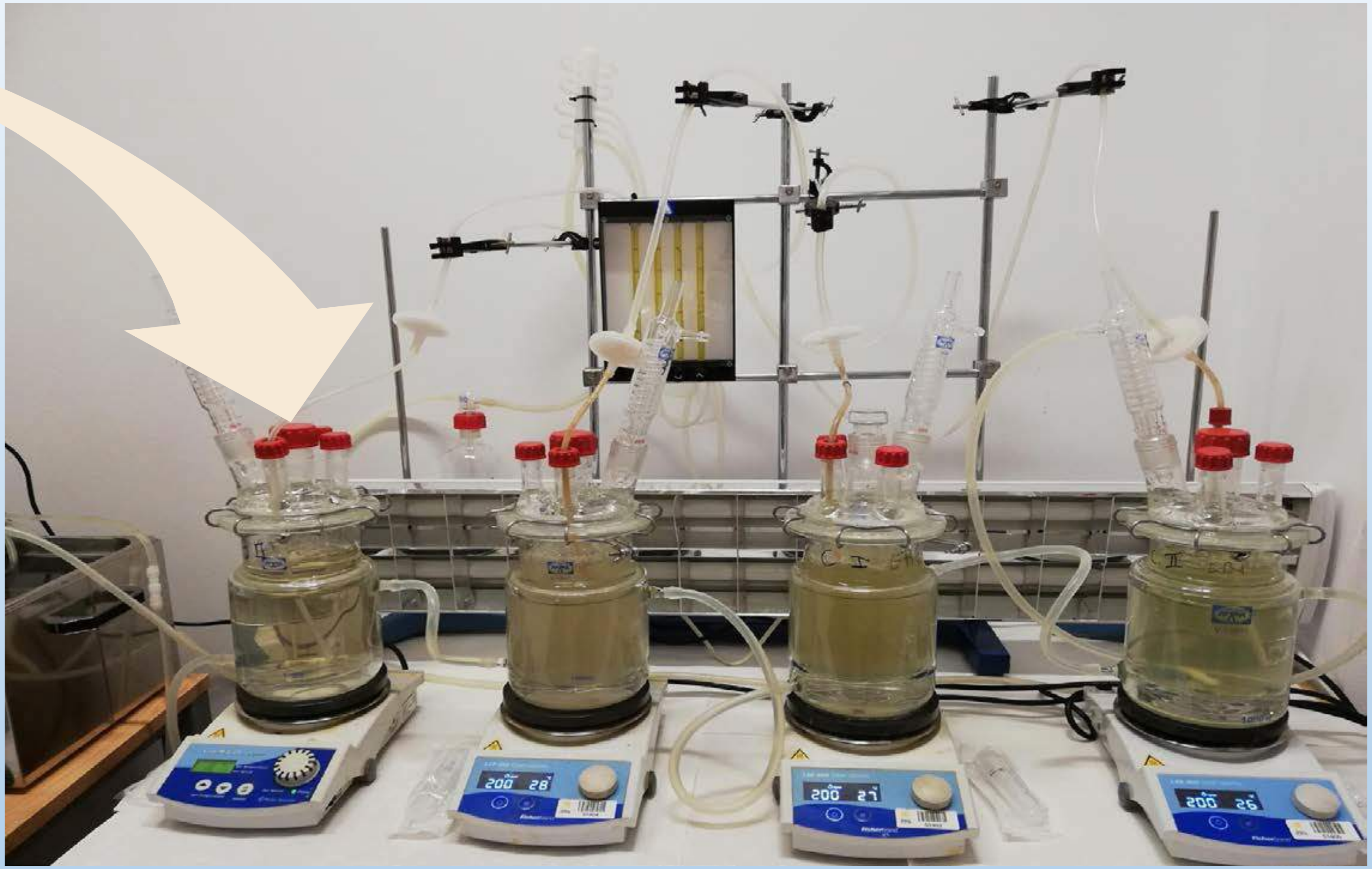


Fig. 1. Experimental facility before culture start-up.

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Experimental

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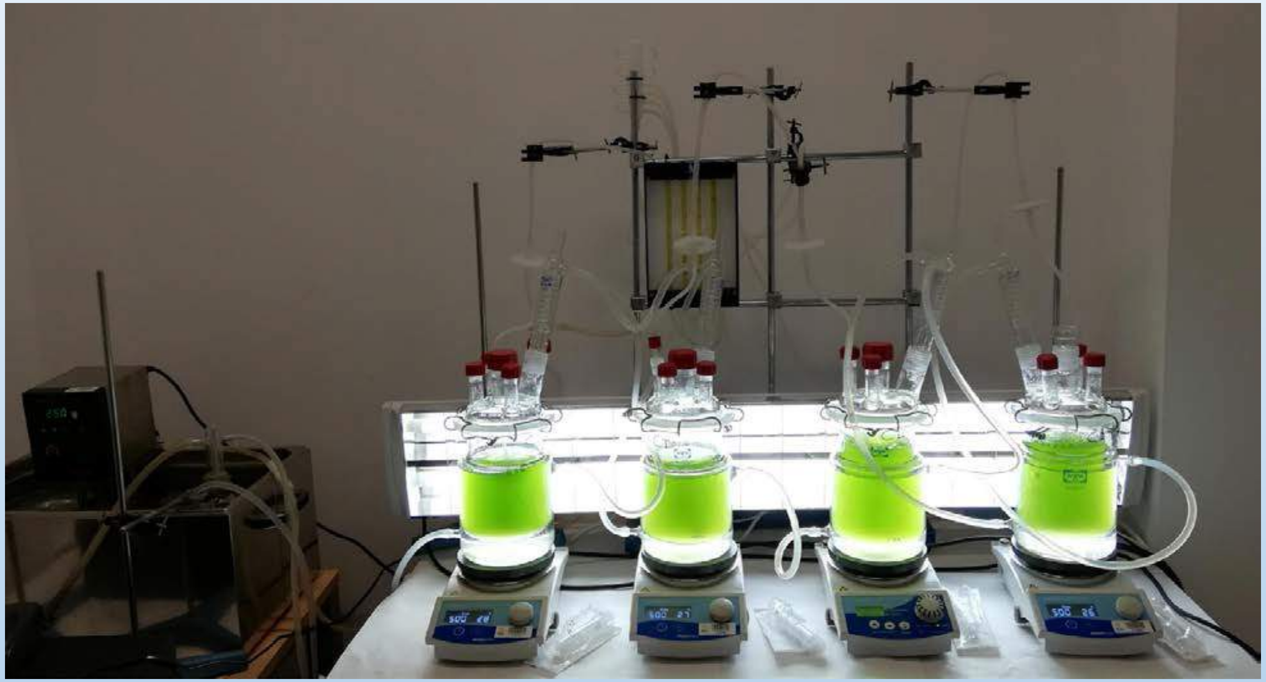


Fig. 2. Cultures at the end of the experiments.

Without sterilization

T = 25 ºC

Stirring rate = 200 rpm

Illumination intensity = 359 µE m^{-2} s^{-1}.

Aeration rate = 0.5 L/min

pH studied
5, 6, 7, 9, 10 and 11

Fig. 3. Experimental common operating conditions.

Results

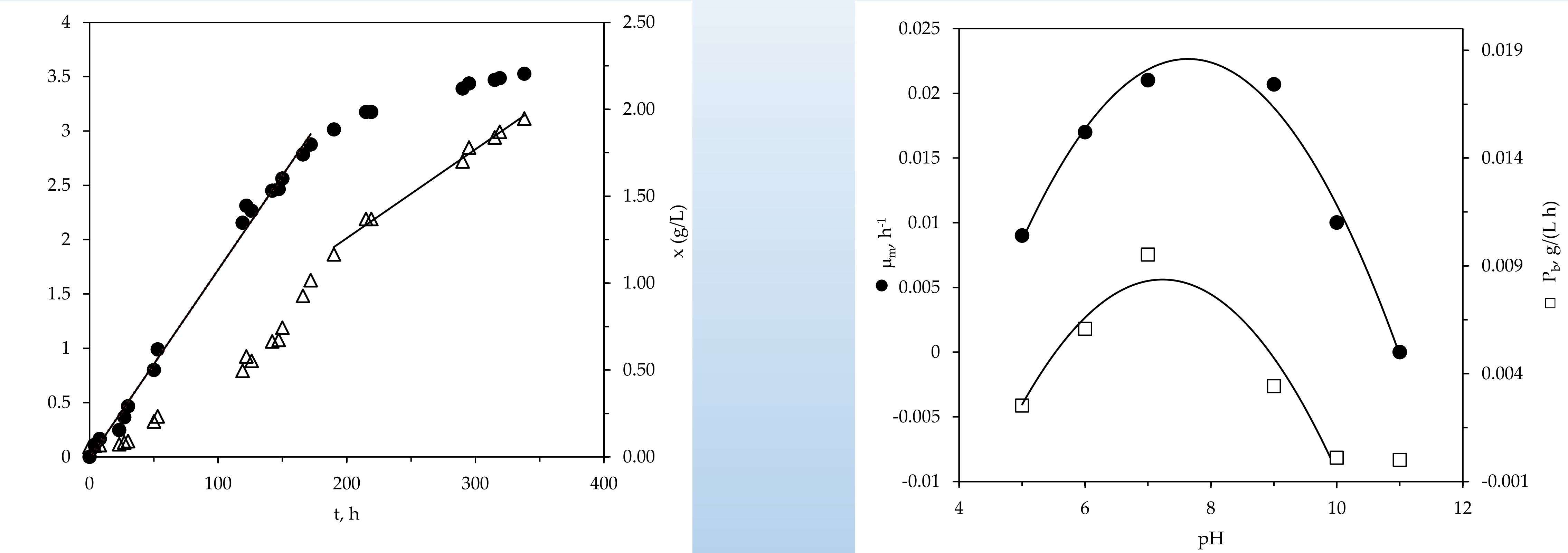


Fig. 1. Growth curves of *C. vulgaris* growth in P-UW at pH = 6 (A) and the variation of the maximum specific growth rates and volumetric biomass productivities versus the pH value of the culture media (B). Common operating conditions: P-UW, aeration rate 0.5 L/min, mechanical stirring 200 rpm, illumination intensity 359 μE/(m^2 s) and temperature 25 ºC.

Results

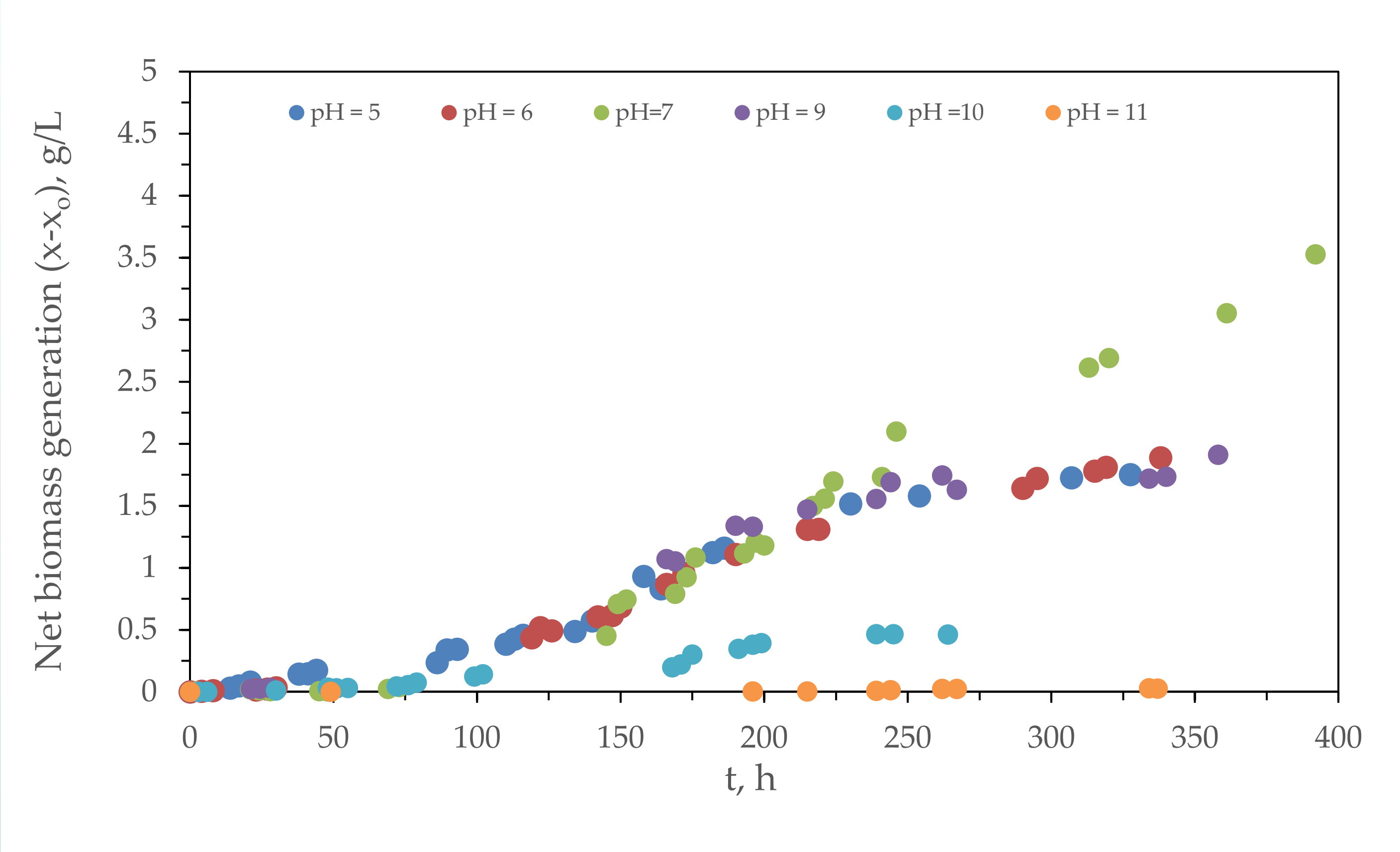
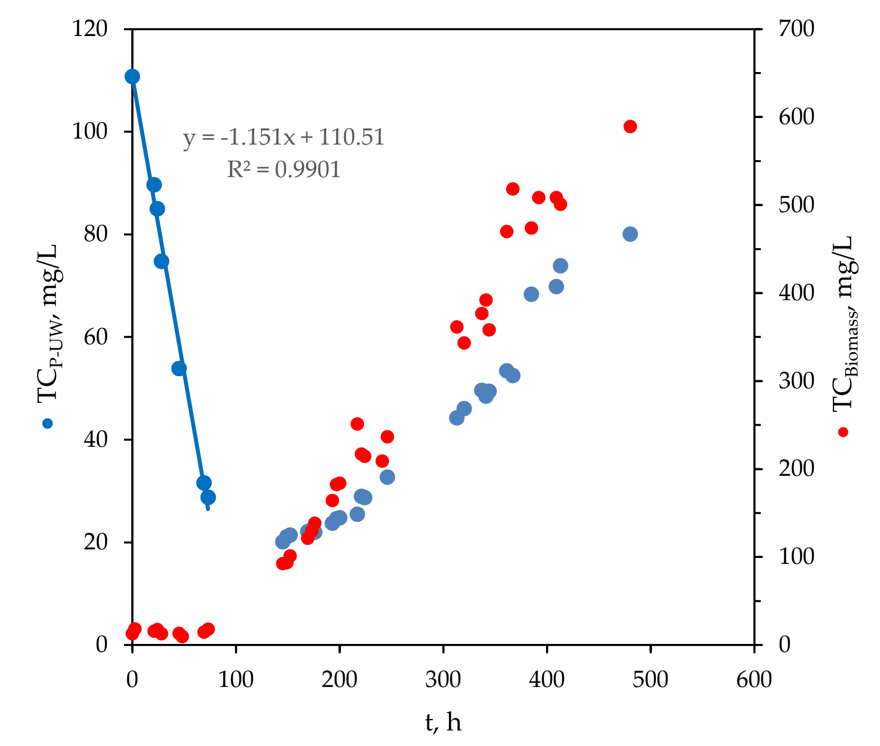
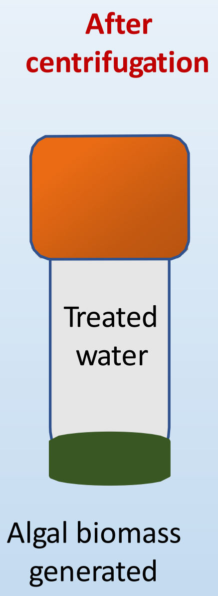


Fig. 2. Net biomass generation ($x-x_o$, g/L) of *C. vulgaris* growth in P-UW at different pH-values. Operating conditions: P-UW (without dilution), mechanical stirring = 200 rpm, aeration rate = 0.5 L/min, T = 25 ºC and artificial illumination at 395 µE/(cm^2 s).

Results





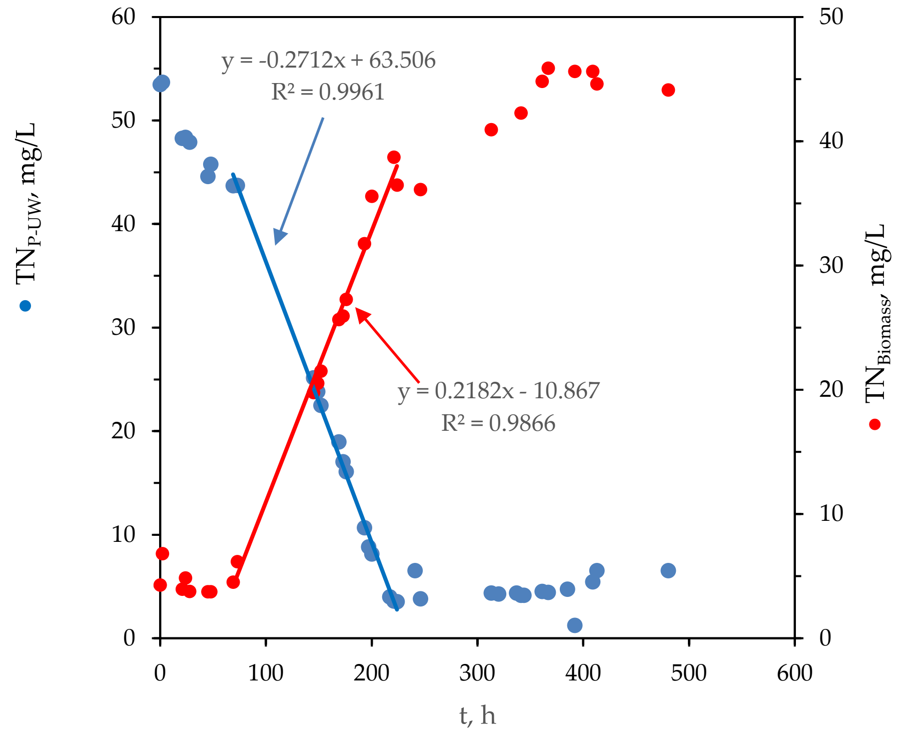


Fig. 3. Carbon and nitrogen species behaviour during *Chlorella vulgaris* growth on P-UW. Operating conditions: P-UW (without dilution), pH = 7, mechanical stirring = 200 rpm, aeration rate = 0.5 L/min, T = 25 ºC and artificial illumination at 395 µE/(cm^2 s).

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Results

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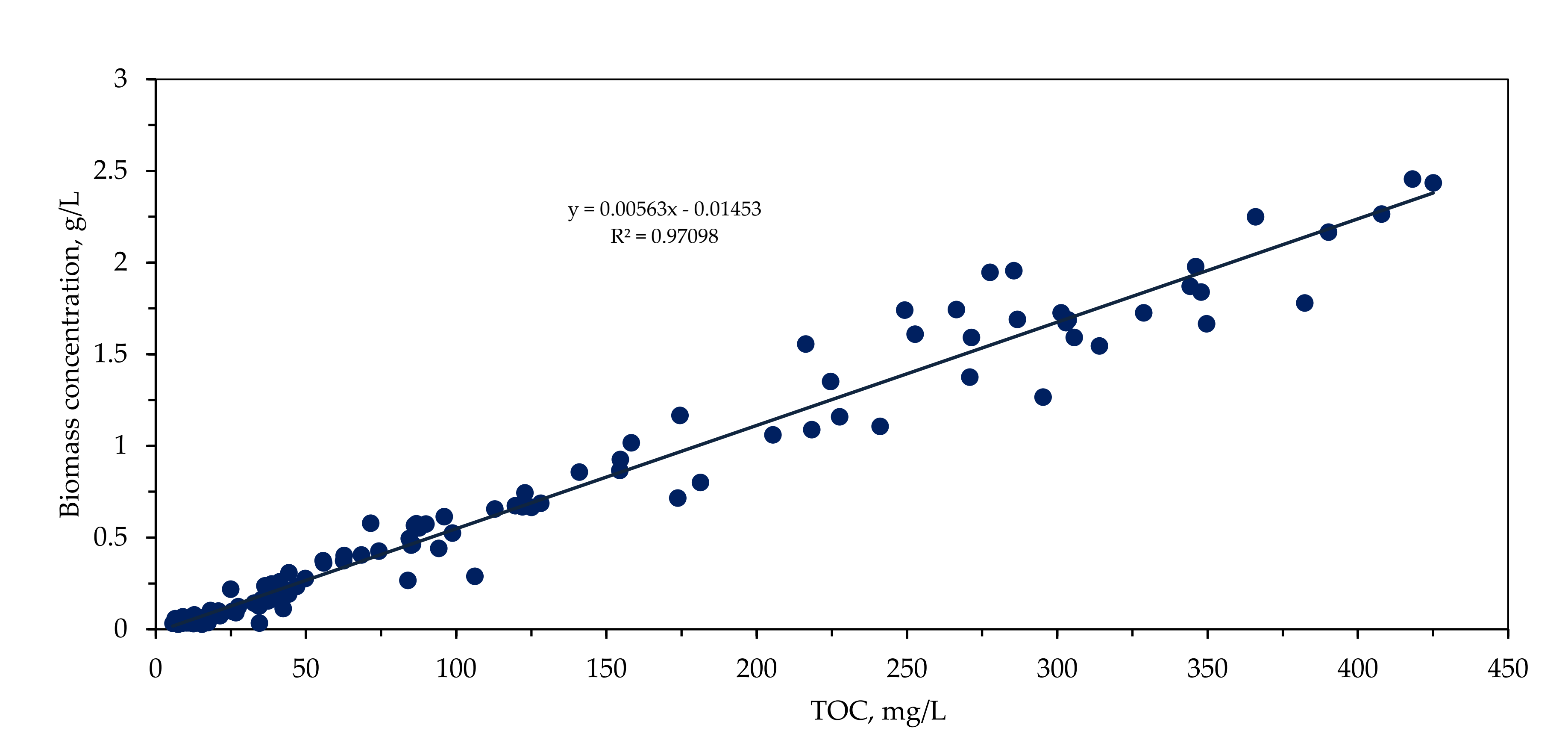

Fig. 4. Linear relationship between biomass concentrations of the microalga *Chlorella vulgaris* versus total organic carbon (TOC) values.

Table 1. Characterization of primary urban wastewater (P-UW) before and after treatment with *Chlorella vulgaris* at different pH-values and control cultures.

Parameter	Tap water	P-UW	UW treated by *Chlorella vulgaris* at different pH values						Control experiment
			5	6	7	9	10	11	UW-aeration[1]
pH	6.85	6.86	4.63	6.03	7.42	9.3	9.99	10.5	9.3
Conductivity, μS/cm	0.00256	1505	1600	1780	1956	2000	1998	1990	2010
Turbidity, FTU	1.19	69	7.7	5.59	5.48	5.57	6.07	5.93	9.71
COD, mg O_2/L	0.00	283.8	192	297	204	104	125	3.57	-[2]
BOD_5 (mgO_2/L)	ND[3]	81.5	5.34	6.84	6	6.42	6.94	0.67	0.01
Disolved O_2, mg O_2/L	8.2	3.07	8.01	8.11	7.32	8.28	8.11	7.65	7.8
Total solid, %	0.020	0.101	-	-	-	-	-	-	-
Organic matter, %	0.006	0.0368	-	-	-	-	-	-	-
Ash (%)	0.013	0.0639	-	-	-	-	-	-	-
TC (mg/L)	24.0	256	64.6	282	80.1	162.4	217	690	70.7
TOC (mg/L)	1.85	135	64.2	278	79.5	69.6	54.9	66.6	25.4
IC (mg/L)	22.1	121	0.47	4.39	0.59	92.8	162	624	45.2
TN (mg/L)	0.51	101	9.48	35.3	6.53	6.41	5.96	4.43	3.5
NN (mg/L)	0.15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0

[1]UW-aeration: This culture simulated the culture with experimental highest microalga growth at pH = 9 but without microalga inoculation and applied the same operating conditions: aeration rate = 0.5 mL/min during 469 h, agitation rate 200 rpm, artificial continuous illumination at intensity = at 395 μE cm^{-2} s^{-1} and temperature = 25 ºC.
[2]-: Data not determined.
[3]ND: not detected.

Results

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Table 2. Biochemical composition of the biomass obtained from Chlorella vulgaris growth in primary urban wastewater at various pH-values and in the control experiment at pH = 9 without microalga.

C. vulgaris biomass	Parameter	Control experiment (only aeration)	C. vulgaris cultures at different pH-values					
			5	6	7	9	10	11
Biochemical composition	Chlorophyll a, %	0.19	0.05	0.06	0.02	0.21	0.20	0.00
	Chlorophyll b, %	0.21	0.01	0.02	0.01	0.06	0.05	0.00
	Total chlorophylls, %	0.40	0.05	0.08	0.03	0.27	0.25	0.00
	Carotenoids, %	0.13	0.02	0.21	0.02	0.10	0.09	0.00
	Crude Proteins, %*	8.39	20.5	13.5	8.13	10.9	21.9	17.8
	Carbohydrates, %	75.8	63.6	70.6	73.4	75.0	67.6	82.8
	Lipids, %	6.56	6.50	7.45	11.5	13.3	6.16	ND
	Total biomass composition, %	91.3	90.7	91.8	93.1	99.6	96.0	100
Biomass in terms of carbon and nitrogen species	TC, mg/L	188	278	282	589	455	187	85.8
	TOC, mg/L	175	276	278	587	426	166	10.2
	IC, mg/L	13.4	1.25	4.39	2.07	28.4	21.2	75.6
	TN, mg/L	11.9	58.7	35.3	44.1	33.4	18.6	1.48

***Crude protein = 6.25 × % total nitrogen in the biomass (Becker, 1994).**

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Conclusions

- Microalgae could play a key function in the treatment of the urban wastewater.
- The feasibility of the *C. vulgaris* in the treatment of primary urban wastewater was demonstrated and verified.
- The incorporation of microalgae to the urban wastewater treatment plant presents a sustainable bioprocess with great benefices for the final treated water quality (reduction on N and P contents), energy and other added values products plus carbon capture to slow down the climatic change.
- Reduction on the production of the secondary sludge.
- The application of hybrid system (conventional-microalgae) in the wastewater treatment is an innovation to achieved the sustainability.

Acknowledgements

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Thank you for your attention