Microalgae
Cultivation in Wastewater

Aguas de Lorca

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INTRODUCTION

Aguas de Lorca is the company that manages the Urban Water Cycle in Lorca (Murcia, Spain), including 6 urban WasteWater Treatment Plant (WWTP) and an industrial WWTP treating water from local tannery industry.

La Hoya WWTP (**Figure 1**) was designed to treat up to 20,000 m³/d of domestic water from Lorca city centre and La Hoya district, and industrial water from Lorca industrial park. The secondary wastewater treatment is carried out in two stages: (i) Stage A composed of two reactors (1,757 m³ total volume), followed by two settling units, and (ii) Stage B, consisting on two aeration tanks with a total volume of 8,969 m³. Finally, to separate biological floc, there are two units for secondary settling and the tertiary treatment is made up of coagulation-flocculation, settling, sand filters and UV lamps/chlorination. The sludge produced is stabilized by anaerobic digestion, generating 35,000 Nm³ biogas/month, that is used to fuel boilers and a Combined Heat and Power (CHP) plant (504 kW).

Curtidos WWTP (**Figure 2**) treats wastewater from 15 tannery companies. This wastewater is characterized by its high content of Chromium III (Cr III). The secondary treatment includes a bioreactor continuously permeating throught tubular ultrafiltration membranes.

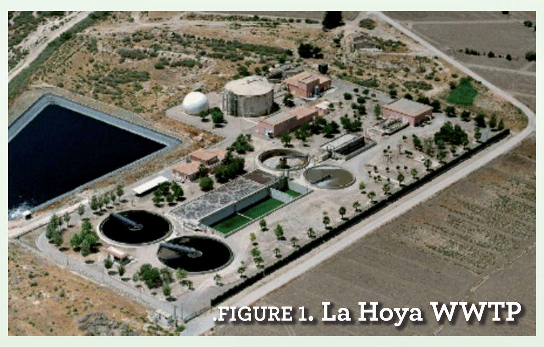


FIGURE 1. La Hoya WWTP

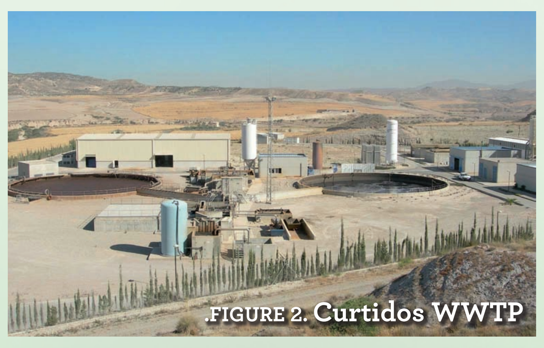


FIGURE 2. Curtidos WWTP

The cultivation of algae has been studied in recent decades due: (i) The capacity to remove Carbon Dioxide (CO_2), (ii) The production of value-added products (nutrition, pharmacy, chemistry fine, etc.) and (iii) algae are an alternative to traditional fossil fuels (biodiesel, biomethane, biohydrogen and bioethanol).

Microalgae are photoautotrophs organism, getting energy from sunlight and inorganic matter, however some species grow using organic matter as a source of energy or carbon. Industrial and municipal wastewaters are potential resources for production of microalgae, being *Chlorella* one of the most interesting species due to its ability to remove nutrients from the water and its rapid growth.

OBJETIVES

Since 2013, Aguas de Lorca has developed several projects aimed to cultivate the microalgae *Chlorella* using as culture medium wastewater. The main objectives of this projects are the following:

1) To cultivate *Chlorella vulgaris* at laboratory scale by using as culture medium water from La Hoya WWTP, assessing its capacity to remove nutrients (Nitrogen (N) and Phosphorus (P)) from wastewater.
2) To cultivate *Chlorella vulgaris* at laboratory scale by using as culture medium water from Curtidos WWTP (tannery wastewater), assessing its capacity to remove nutrients (N and P) and Cr III.
3) To cultivate *Chlorella vulgaris* at laboratory scale over solid supports (carriers).
4) To design and build a photoreactor to cultivate *Chlorella vulgaris* at pilot scale.

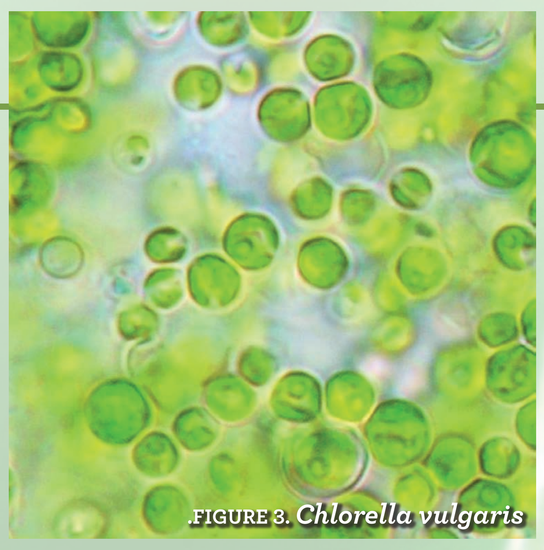


FIGURE 3. *Chlorella vulgaris*

METHODOLOGY AND RESULTS

I. MICROALGAE CULTIVATION IN WASTEWATER FROM LA HOYA WWTP (2013-2014)

TASK 1: Cultivate *Chlorella vulgaris* using as culture medium the output of the first biological stage (primary wastewater) and the effluent under temperature (T) and light controlled conditions. Light/dark cycles were simulated by means of LED lamps, T was constant (20ºC) by mean of a electric heater and CO_2 was supplied by an small blower.

Primary water (Table 1), WWTP effluent (Table 2) and treated water (outpout) were characterized by the determination of Amoniacal Nitrogen (NH_4-N), Nitrates (NO_3-N), Total Nitrogen (N), Phosphorous (P) and Chemical Oxygen Demand (COD).

TABLE 1 Results obtained from algae cultivation in primary water

Parameter	Primary wastewater	Output	Removal efficiency
NH_4-N (mg/l)	90.0	4.9	95%
NO_3-N (mg/l)	0.3	19.2	-
N (mg/l)	120.0	60.0	50%
P (mg/l)	14.0	<1.0	>93%
COD (mg/l)	800	70	91%

TABLE 2 Results obtained from algae cultivation in the WWTP effluent

Parameter	WWTP Effluent	Output	Removal efficiency
NH_4-N (mg/l)	22.0	<1.0	>95%
NO_3-N (mg/l)	4.7	0.2	96%
N (mg/l)	36.0	<5.0	>86%
P (mg/l)	3.3	0.3	91%

TASK 2: Determination of chlorophylla and phaeophytins. Determination of *chlorophylla* allows to know algae biomass and consequently, the algae growth rates (Figure 4 and Figure 5). The *phaeophytins* are products of *chlorophylla* decomposition; that allow to know the phase of algae growth (Figure 6 and Figure 7).

FIGURE 4. Primary wastewater: Chlorophylla evolution.

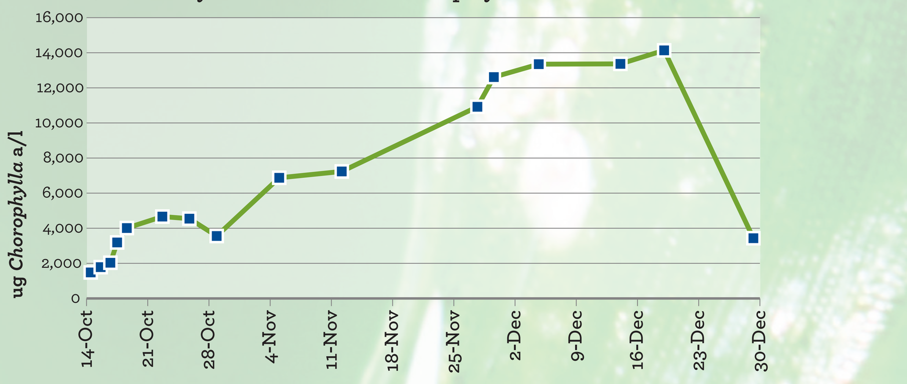


FIGURE 5. WWTP effluent: *Chlorophylla* evolution.

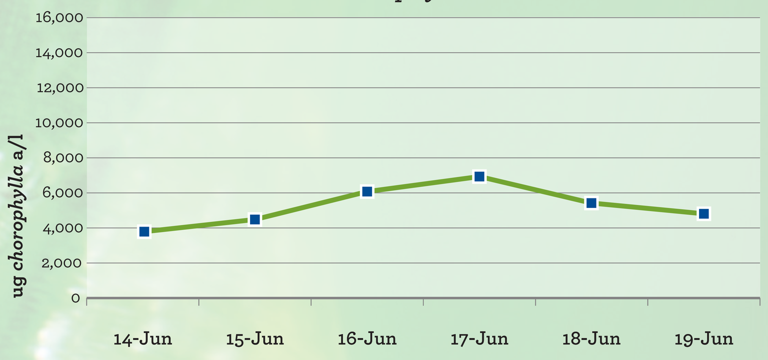


FIGURE 6. Primary wastewater: ratio Phaeophytins/chlorophylla.

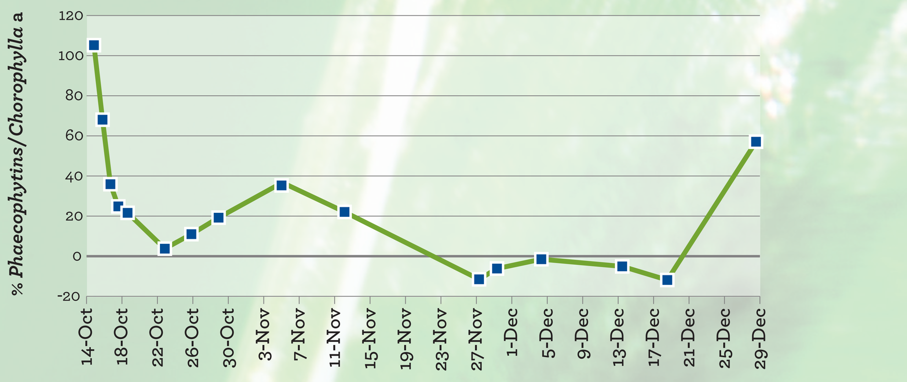
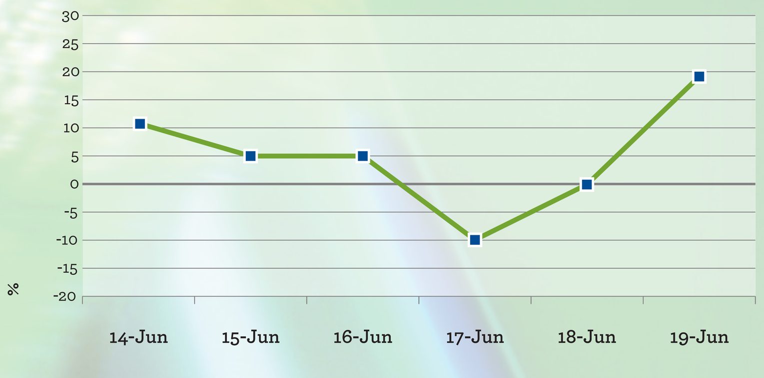


FIGURE 7. WWTP effluent: ratio Phaeophytins/chlorophylla.



II. MICROALGAE CULTIVATION IN WASTEWATER FROM TANNERY WWTP (2013-2014)

TASK 1: Cultivate *Chlorella vulgaris* in tannery wastewater under T and light controlled conditions. Tannery wastewater (Table 3) was characterized by the determination of NH_4-N, NO_3-N, N, P and Cr (III).

TABLE 3 Results obtained from microalgae cultivation in tannery wastewater

Parameter	Tannery wastewater	Output	Removal efficiency
NH_4-N (mg/l)	2.8	0.5	82%
NO_3-N (mg/l)	88.0	16.0	82%
N (mg/l)	96.0	32.0	67%
P (mg/l)	5.7	0.4	93%
Cr (III) (mg/l)	0.33	0.08	76%

TASK 2: Determination of chlorophylla (Figure 8) **and phaeophytins** (Figure 9).

FIGURE 8. Tannery wastewater: Chlorophylla evolution.

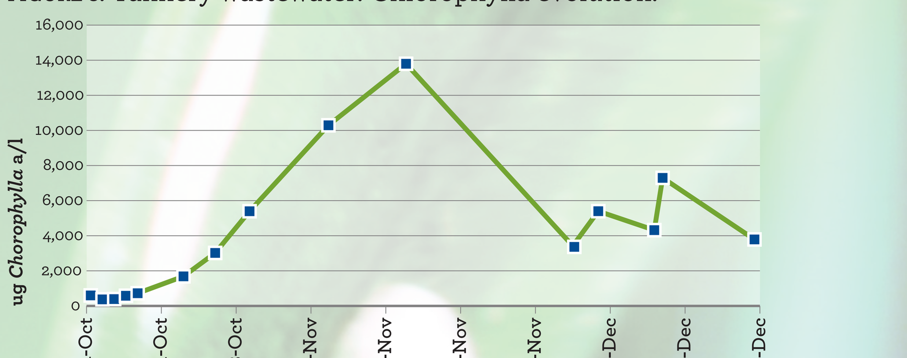
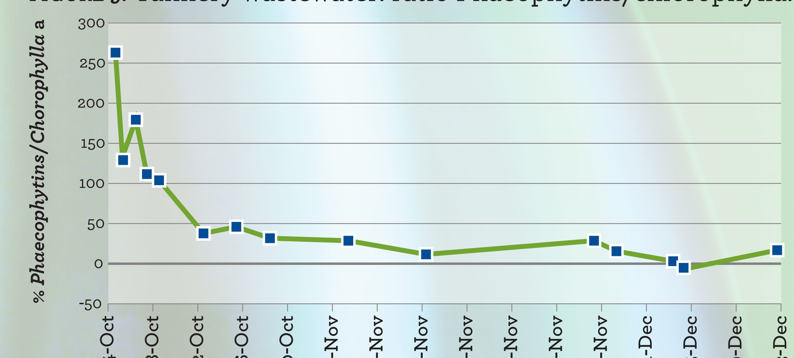


FIGURE 9. Tannery wastewater: ratio Phaeophytins/chlorophylla.



III. MICROALGAE CULTIVATION OVER SOLID SUPPORTS (2014-2015)

The advantage of microalgae cultivation (Figure 10) over solid supports is the easier separation between algae and treated water. Carriers are used as solid supports, encouraging microalgae fixing and growing; each one can contain between 50–100 mg of wet microalgae.

FIGURE 10. Microalgae cultivation over solid supports

Supports with and without fixed microalgae — Wastewater before microalgae treatment — Wastewater treated with microalgae — Microalgae separation detail by settling

IV. DESIGN AND BUILD OF A PILOT PHOTOREACTOR (2015-2016)

Last works has lead to design and build a pilot scale photoreactor for outdoor microalgae cultivation in wastewater from primary treatment of La Hoya WWTP. This photoreactor consists in a glass column of 15 cm diameter by 100 cm high, filled with carriers. The bottom is conically shaped in order to concentrate the detaching microalgae. Air is supplied by a central tube connected to a blower.

TABLE 4 Photoreactor characteristics

Parameter	Value
Column volume (liters)	22
Useful volumen (liters)	15
Volume of carriers (%)	10
Residence time (days)	3-4

FIGURE 11. Photoreactor for outdoor microalgae cultivation.

CONCLUSIONS

- *Chlorella vulgaris* **algae** cultivated in wastewaster from primary treatment and La Hoya WWTP effluent are able to significantly remove nutrients (N and P) from wastewater. So microalgae culture can present a polishing alternative or ,combined with an adequate pretreatment, a system to implement for the treatment of low load wastewater streams.
- *Chlorella vulgaris* **algae** cultivated in tannery wastewater from Curtidos WWTP are able to remove suitable amounts of nutrients, but also to reduce Cr (III) levels.
- Results from the assays aimed at assess the microalgae capacity of growth over fixed supports show that the system is adequate, leading to suitable nutrients removal outputs and an optimal separation of microalgae from water.