Innovative technologies for a cost-effective biogas upgrading in wastewater treatment plants

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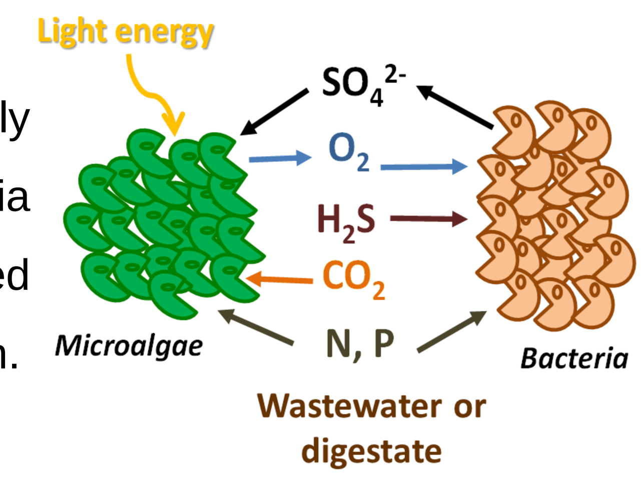
INTRODUCTION

Based on its high CH_4 content (40-75%), **biogas** is considered a renewable energy source for the production of heat and power. **H_2S removal** is mandatory due to its toxicity and hazards associated with the corrosion of metals, while **CO_2 removal** increases the specific calorific value and reduces biogas costs of compression and transportation [1].

Biogas upgrading in algal–bacterial photobioreactors constitutes a cost-effective and environmentally friendly alternative for the removal of both contaminants [2]. These processes are based on the CO_2 consumption by microalgae via photosynthesis and the oxidation of H_2S to sulfate by sulfur-oxidizing bacteria using the oxygen photosynthetically produced [3]. In addition, domestic wastewater or anaerobic effluents can be used as nutrient source to support algal-bacterial growth.



MATERIALS AND METHODS

The experimental set-up consisted of a 9.6 m³ high rate algal pond (HRAP) interconnected to a 7 m³ settler and a 150 L bubble column.

Operating conditions:

HRAP recirculation velocity: 25 cm s⁻¹

HRT-HRAP: 3.5 days

HRT-settler: 7 hours

Domestic wastewater composition

NH_4^+ (mg L^{-1})	41.1±3,9
$N-NO_3$ (mg L^{-1})	0
$N-NO_2$ (mg L^{-1})	0
PO_4^{3-} (mg L^{-1})	6.1±0.2
SO_4^{2-} (mg L^{-1})	79.1±8.2
COD (mg L^{-1})	543.0±35.2
IC (mg L^{-1})	51.4±3.1

Raw biogas composition:

CH_4 (%)	68.4±1.7
CO_2 (%)	34.0±1.8
H_2S (ppm)	2069±991

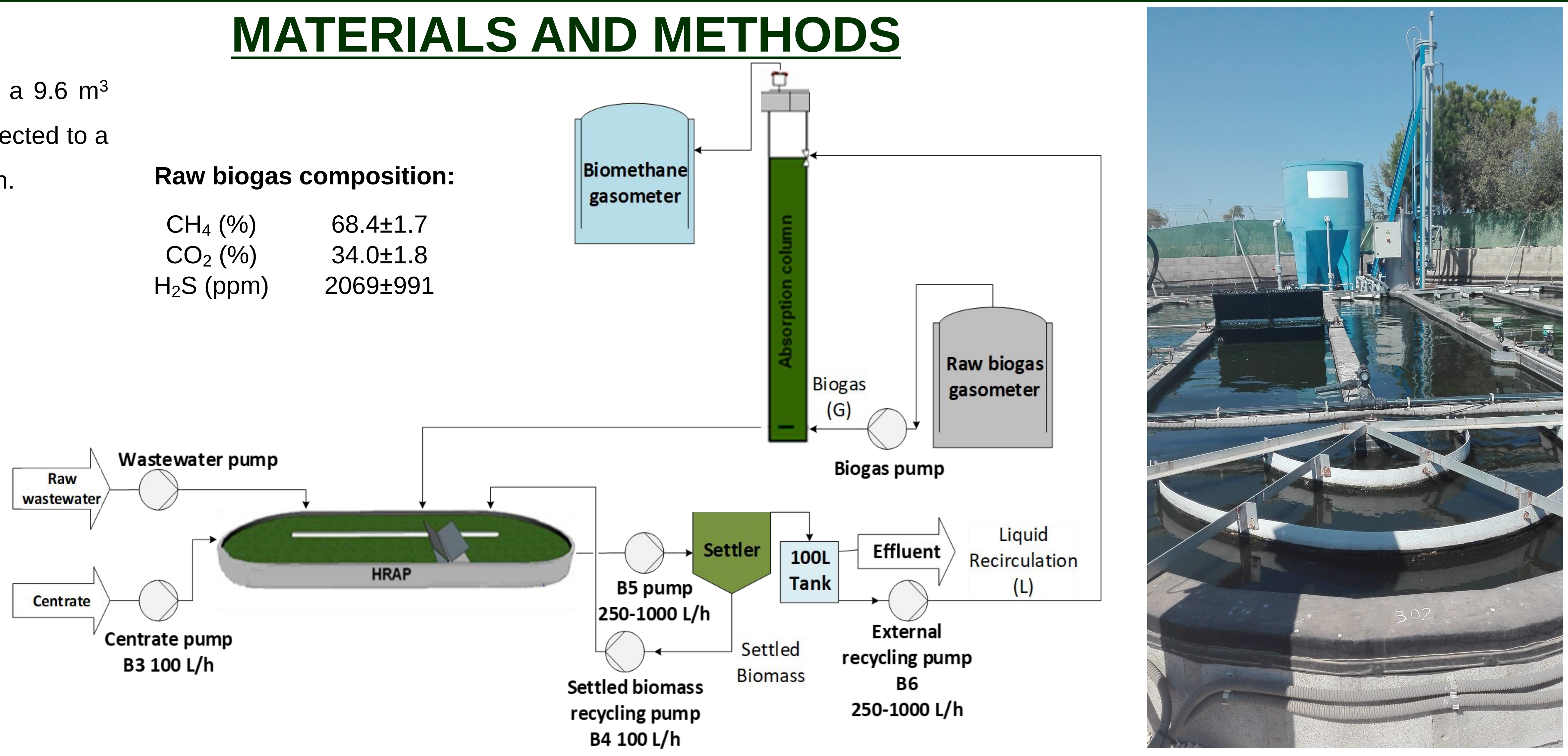


Figure 1. Schematic diagram (left) and photograph (right) of the continuous biogas upgrading experimental plant at Aqualia's facility in Chiclana

RESULTS AND DISCUSSION

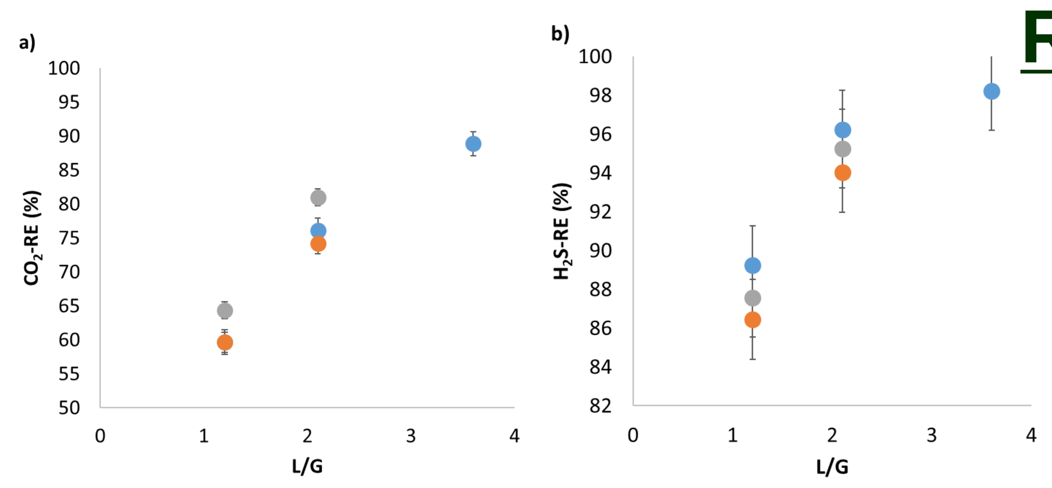


Figure 2. Influence of the L/G on a) CO_2-RE, b) H_2S-RE at a biogas flowrate of 261 (●), 377 (●) and 471 L/h (●).

Enhancements in CO_2 and H_2S removal efficiencies (REs) were observed with the increase in the liquid to biogas ratio (L/G).

The highest CH_4 concentration was 86.8±1.4 % at a L/G of 3.6 as a result of the high O_2 and N_2 content in the upgraded biogas.

A decrease in the pH of the recirculating cultivation broth from 7.95±0.08 to 6.69±0.30 was measured between the bottom and the top of the absorption column due to the acidic nature of CO_2 and H_2S.

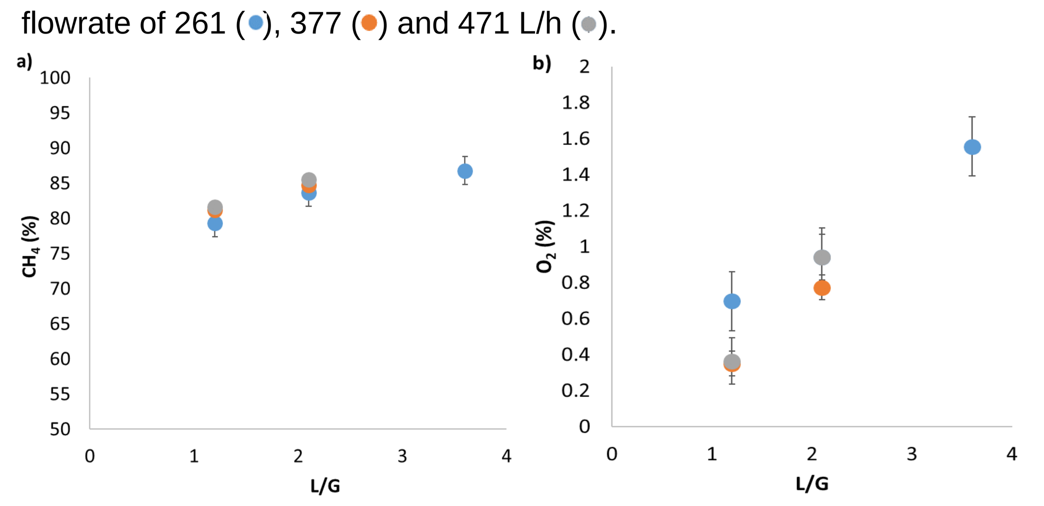


Figure 3. Influence of the L/G on bio-methane composition: a) CH_4, b) O_2 at biogas flowrate of 261 (●), 377 (●) and 471 L/h (●).

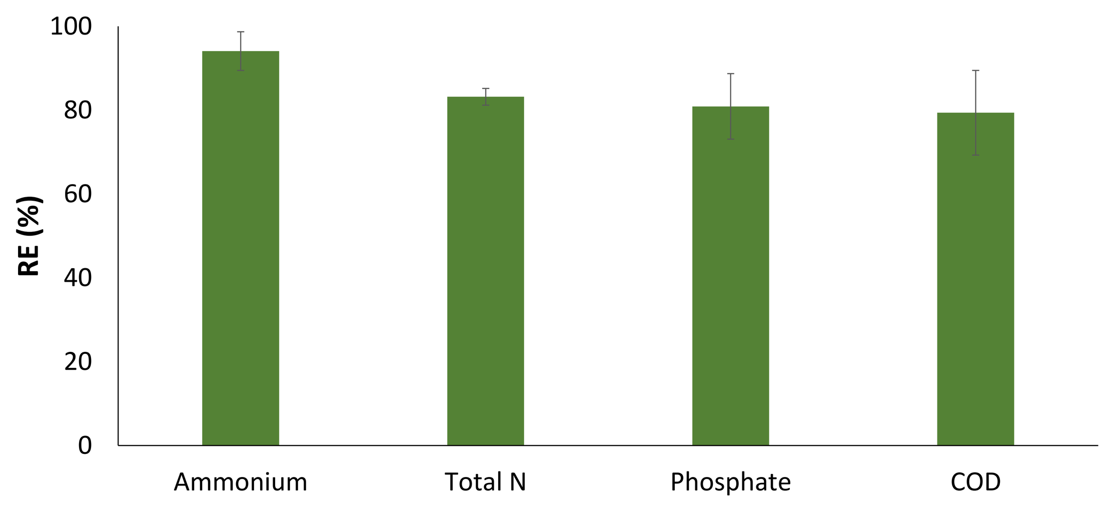


Figure 4. Ammonium, total nitrogen, phosphate and COD removal efficiencies in the system.

Table 1. Effluent composition

COD (mg L^{-1})	99.4±31.3
$N-NH_4^+$ (mg-N L^{-1})	1.9±1.5
$N-NO_2$ (mg-N L^{-1})	0.2±0.1
$N-NO_3$ (mg-N L^{-1})	1.9±1.0
PO_4^{3-} (mg L^{-1})	1.2±0.4
SO_4^{2-} (mg L^{-1})	136.5±13.5
IC (mg L^{-1})	25.6±5.5

COD: Chemical Oxygen Demand

IC: Inorganic Carbon

CONCLUSIONS

- ✓ The influence of L/G ratio on CO_2 and H_2S removal efficiencies was significant with the increase in CO_2-RE and H_2S-RE at higher L/G ratios. However, an increase in the L/G ratio promoted a higher desorption of O_2 and N_2 contained in the recycling liquid, which negatively impacted on the CH_4 concentration in the upgraded biogas.
- ✓ No significant effect of biogas flowrate on biomethane composition was observed.
- ✓ The effluent obtained complies with the EU Directive discharge requirements.
- ✓ An increase in the pH or alkalinity of the cultivation broth could enhance CO_2 and H_2S absorption at lower L/G.

REFERENCES

- [1] Toledo-Cervantes A., Serejo M., Blanco S., Pérez R., Lebrero R., Muñoz R., (2016). Photosynthetic biogas upgrading to bio-methane: Boosting nutrient recovery via biomass productivity control. Algal Res.17, 46-52.
- [2] Bahr M., Díaz I., Domínguez A., González A. and Muñoz R. (2013). Microalgal-Biotechnology as a platform for an integral biogás upgrading and nutrient removal from anaerobic effluents. Environ. Sci. Technol. 2014, 48, 573-581.
- [3] Posadas E., Serejo M.L., Blanco S., Pérez R., García-Encina P.A. and Muñoz R. (2015). Minimization of biomethane oxygen concentration during biogas upgrading in algal-bacterial photobioreactors. Algal Res. 12: 221-229.

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