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# Photosynthetic biogas upgrading in wastewater treatment plants

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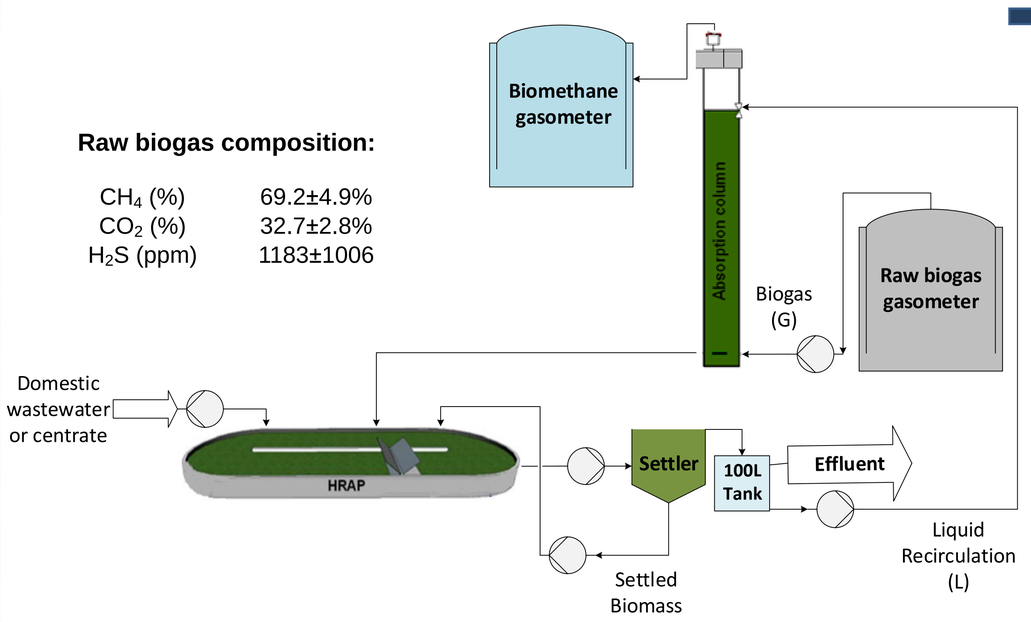
## INTRODUCTION

**Biogas**, which mainly consists of $CH_4$ (40-75%), $CO_2$ (15-60%) and $H_2S$ (0.005-2%), constitutes a valuable renewable energy source able to reduce current dependence on fossil fuels. In this context, **$CO_2$ removal** increases the specific calorific value and reduces biogas costs of compression and transportation, while **$H_2S$ removal** is mandatory due to its toxic and corrosive nature [1].

**Photosynthetic biogas upgrading** represents a cost-effective and environmentally friendly platform for the removal of both pollutants. This process is based on the consumption of $CO_2$ by microalgae via photosynthesis and the concomitant oxidation of $H_2S$ to sulfate by sulfur-oxidizing bacteria using the oxygen photosynthetically produced [2]. Moreover, **domestic wastewater (DWW) or centrate** can be used as nutrient source to support algal-bacterial growth [3].

## MATERIALS AND METHODS




**Raw biogas composition:**

| | |
|---|---|
| $CH_4$ (%) | 69.2±4.9% |
| $CO_2$ (%) | 32.7±2.8% |
| $H_2S$ (ppm) | 1183±1006 |

➡ **Objetive:** To assess the influence on biomethane composition of:

- ❑ **L/G ratio:** 1.2, 2.1 and 3.5
- ❑ **Biogas flow rate (G):** 274, 370 and 459 L $h^{-1}$

**Figure 1.** Photograph (left) and schematic diagram (right) of the biogas upgrading experimental plant at Aqualia's facility in Chiclana de la Frontera (Spain)

**Table 1.** Summary of main operating parameters during the three operational stages

| Parameter | Stage | | |
|---|---|---|---|
| | I | II | III |
| Type of wastewater | DWW | DWW | Centrate |
| HRT (d) | 3.5 | 8 | 73 |
| Average temperature (°C) | 23.5±2.5 | 12.4±2.3 | 18.8±3.0 |
| Average pH in the cultivation broth | 7.3±0.2 | 7.1±0.5 | 8.9±0.3 |

## RESULTS AND DISCUSSION

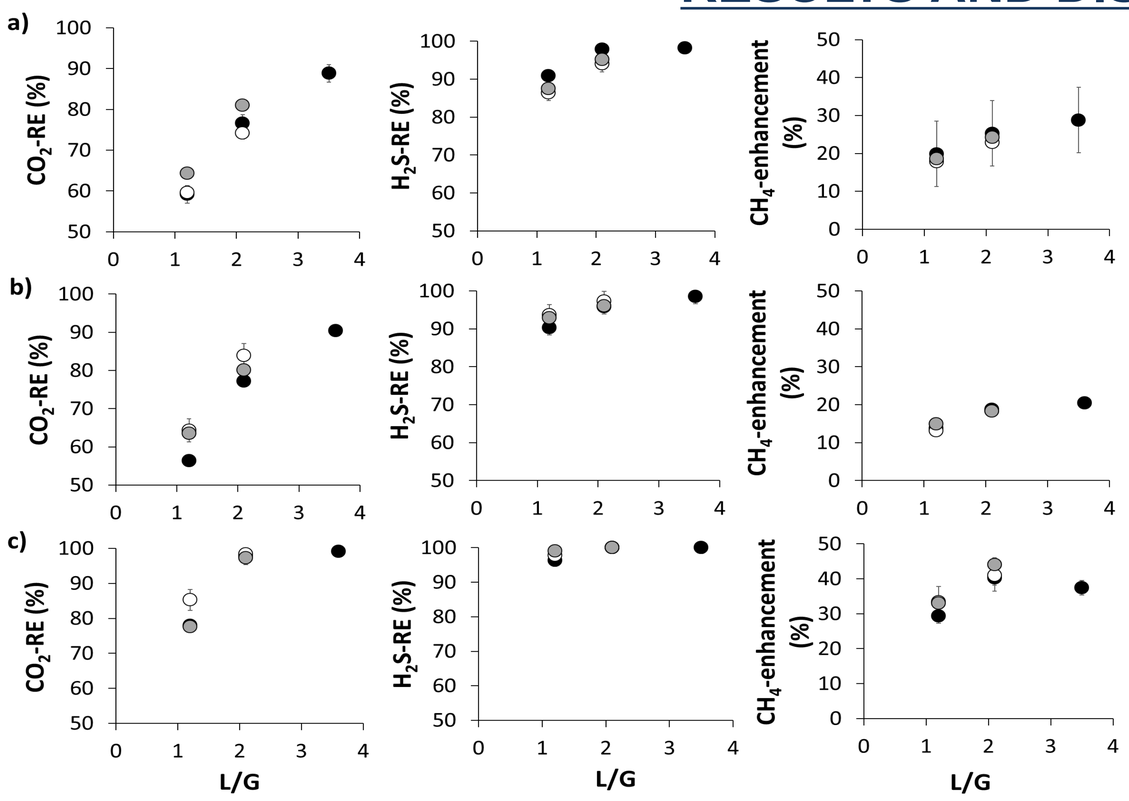



**Figure 2.** Influence of the L/G ratio on biogas upgrading performance at biogas flowrate of 276 (black), 370 (white) and 459 (grey) L $h^{-1}$ during stage I (a), stage II (b) and stage III (c).

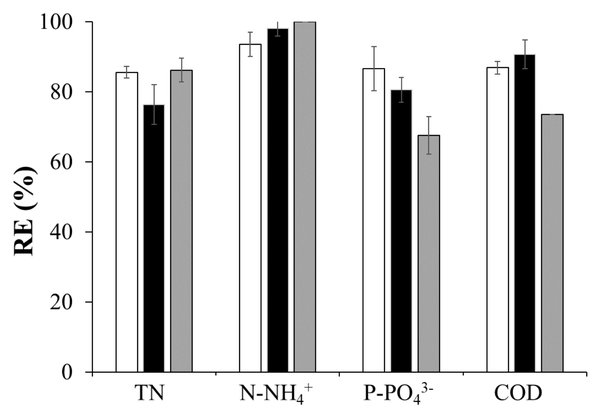



**Figure 3.** Wastewater removal efficiencies in the high rate algal pond during stage I (white), II (black) and III (grey)

**Table 2.** Effluent composition under steady state conditions

| Effluent composition | DWW, HRT= 3.5 days | DWW, HRT = 8 days | Centrate, HRT = 73 days |
|---|---|---|---|
| COD (mg $L^{-1}$) | 99.4±31.3 | 65.0±21.7 | 123.8±0 |
| N-$NH_4^+$ (mg-N $L^{-1}$) | 3.1±1.7 | 1.0±1.1 | 0±0 |
| N-$NO_2$ (mg-N $L^{-1}$) | 0.8±0.5 | 0.4±0.2 | 13.3±11.7 |
| N-$NO_3$ (mg-N $L^{-1}$) | 2.0±1.2 | 9.6±0.5 | 38.1±7.4 |
| P-$PO_4^{3-}$ (mg $L^{-1}$) | 1.0±0.5 | 1.3±0.3 | 19.9±5.4 |

## CONCLUSIONS

- ✓ Negligible influence of the hydraulic retention time (HRT) in the HRAP and the biogas flowrate (G) in the absorption column on the biogas upgrading performance.
- ✓ Despite higher L/G ratios supported higher $CO_2$ and $H_2S$ removals, an increase of $N_2$ and $O_2$ stripping was observed, which negatively impacted $CH_4$ concentration in the upgraded biogas.
- ✓ An increase in $CO_2$ and $H_2S$ removals was obtained using centrate instead of domestic wastewater due to the higher alkalinity and pH of the influent.
- ✓ To the best of our knowledge, this work demonstrated for the first time the capacity of algal-bacterial systems for the simultaneous biogas upgrading and wastewater treatment at semi-industrial scale.

## References:

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[2] Marín D., Posadas E., Cano P., Pérez V., Blanco S., Lebrero R. and Muñoz R. (2018). Seasonal variation of biogas upgrading coupled with digestate treatment in an outdoors pilot scale algal-bacterial photobioreactor. Bioresour. Technol. 263, 58-66

[3] Serejo M.L., Posadas E., Boncz M.A., Blanco S., García-Encina P., Muñoz R. (2015) Influence of biogas flow rate on biomass composition during the optimization of biogas upgrading in microalgal-bacterial processes. Environ. Sci. Technol. 49,3228–3236

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